Friedrich-Alexander-Universität
Erlangen-Nürnberg

Module description

for the degree programme

Master of Science Data Science

(Version of examination regulation: 20212)

for the winter term 2025/2026

flat version (only modules, no levels (Konten)), in alphabetical order

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1	**Module name** 65985	**Advanced Business Analytics Seminar** Advanced business analytics seminar	**5 ECTS**
2	Courses / lectures	Seminar: Advanced Business Analytics Seminar (2 SWS)	5 ECTS
3	Lehrende	Yannick Rank Prof. Dr. Freimut Bodendorf	

4	**Module coordinator**	Dr. Pavlina Kröckel
5	**Contents**	The problems faced by decision makers in today's competitive business environment are complex and multi-faceted, and often require skills that go beyond theoretical data science knowledge. Solving such problems effectively requires the employment of a structured approach to business problem-solving. **Advanced Analytics** is defined by Gartner as *"the autonomous or semi-autonomous examination of data or content using sophisticated techniques and tools, typically beyond those of traditional business intelligence (BI), to discover deeper insights, make predictions, or generate recommendations*." Advanced Analytics refers to the fields of Machine Learning, Predictive Analytics, Process Mining, Text Mining, and Social Network Analysis, to name a few. It is presumed that participants are familiar with the theoretical concepts from one or more of the mentioned data science areas. The focus of the seminar is on the application of those concepts on given use cases from industry. This course is mostly organized as a self-study. Work will be done in groups of three to five students. All topics are presented and explained in the kick-off session, as well as organizational issues and other relevant information. Teams will have to present their progress on the chosen topic.
6	**Learning objectives and skills**	Students gain practical skills in extracting and manipulating structured and unstructured data, executing methods for descriptive, predictive, or prescriptive analysis, and effectively interpreting and presenting analytic results. Thus, students do not only get hands-on technical experience but also gain domain knowledge and learn soft-skills relevant for data scientist (e.g., teamwork, critical thinking, storytelling). For **students without technical knowledge**, we will also offer topics requiring literature review, case study analysis or conceptual design. Whenever possible, we assign topics that are currently important for our cooperation partners.
7	**Prerequisites**	For the technical topics: • Students should have at least introductory level data mining and machine learning knowledge. • Preference is given to students who have taken the Business Intelligence lecture offered in the summer semester. For non-technical topics: no pre-requisits. **Registration** via StudOn is **required**. The registration period is announced for each seemster and all students who register in this

		timeframe have **equal chances** to be admitted. Thus, an early registration does not guarantee a place in the seminar.
8	**Integration in curriculum**	semester: 2
9	**Module compatibility**	International Information Systems Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung • The seminar is mostly organized online. Presence (online) is expected during the kick-off lecture in the beginning of the semester, the mid-term presentations and other appointments individually arranged with the topic supervisor. • Participation in the mid-term presentation is mandatory. If this condition is not fullfilled, further participation in the seminar will not be allowed. *
11	**Grading procedure**	Seminarleistung (100%) The grade is based on the final presentation and participation and engagement during the semester.
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Relevant literature will be given during the seminar.

1	**Module name** 46110	**Advanced Methods: Microwave Remote Sensing** Advanced methods: Microwave remote sensing	**5 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt!	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	Prof. Dr. Matthias Braun
5	**Contents**	Selected methods related to microwave remote sensing
6	**Learning objectives and skills**	The students • understand the principles of microwave remote sensing; • are able to process microwave remote sensing data; • know to customize and adopt scripts for data processing. A series of practical exercises builds on each other throughout the course. Results of these exercises will develop from individual contributions and small-group work, and from a discussion with the whole group. Course attendance is therefore compulsory.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Geographie Master of Science Data Science 20212
10	**Method of examination**	schriftlich Weekly assignment (Problem-solving issues within the broader context of Microwave Remote Sensing, max. 3 pages) or written paper (max. 15 pages) *
11	**Grading procedure**	schriftlich (100%) Weekly assigments (100 %)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Will be provided at the beginning of the course

1	**Module name** 46120	**Advanced Methods: Remote Sensing: Spectroscopy and Analysis of Spectral Data** Advanced methods: Remote sensing: Spectroscopy and analysis of spectral data	**5 ECTS**
2	Courses / lectures	PG Masterseminar: Advanced Methods MSc: Remote Sensing: Spectroscopy and Analysis of Spectral Data (2 SWS)	5 ECTS
3	Lehrende	Dakota Robin Pyles	

4	**Module coordinator**	Prof. Dr. Matthias Braun
5	**Contents**	Selected methods related to the advanced analysis of spectroscopy data
6	**Learning objectives and skills**	The students • understand the major principles of spectroscopy for remote sensing; • practice different state-of-the-art methods for an analysis of spectroscopy data; • understand the applicability, limitations, and pitfalls of these methods; • know potential applications of spectral analyses to topics in physical geography. A series of practical exercises builds on each other throughout the course. Results of these exercises will develop from individual contributions and small-group work, and from a discussion with the whole group. Course attendance is therefore compulsory.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Geographie Master of Science Data Science 20212
10	**Method of examination**	schriftlich Weekly assignment (Problem-solving issues within the broader context of Spectroscopy and Analysis of Spectral Data, max. 3 pages) or written paper (max. 15 pages) *
11	**Grading procedure**	schriftlich (100%) Weekly assigments (100 %)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Will be provided at the beginning of the course

1	**Module name** 46115	**Advanced Methods: Scripting for GIS analysis** Advanced methods: Scripting for GIS analysis	**5 ECTS**
2	Courses / lectures	PG Masterseminar: Advanced Methods MSc: Scripting for GIS Analysis (2 SWS)	5 ECTS
3	Lehrende	Dr. Sebastian Feick	

4	**Module coordinator**	Prof. Dr. Matthias Braun
5	**Contents**	Automating Geographic Information System (GIS) workflows using a script language.
6	**Learning objectives and skills**	The students • have a deeper insight into GI-Systems. • are familiar with a free & open source programming language. • are able to use a script language to automate GIS workflows. A series of practical exercises builds on each other throughout the course. Results of these exercises will develop from individual contributions and small-group work, and from a discussion with the whole group. Course attendance is therefore compulsory.
7	**Prerequisites**	n/s
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Geographie Master of Science Data Science 20212
10	**Method of examination**	schriftlich Weekly assignment (Problem-solving issues within the broader context of Scripting for GIS, max. 3 pages) or written paper (max. 15 pages) *
11	**Grading procedure**	schriftlich (100%) Weekly assigments (100 %)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Will be provided at the beginning of the course.

1	**Module name** 46090	**Advanced Methods: Scripting for Remote Sensing of the Environment** Advanced methods: Scripting for remote sensing of the environment	**5 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt!	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	Prof. Dr. Matthias Braun
5	**Contents**	Selected methods related to the processing of Earth observation data
6	**Learning objectives and skills**	The students • understand the major principles of data availability and processing chains; • are able to prepare scripts towards an automated processing of Earth observation data; • know to customize and adopt existing algorithms for data processing; • understand advanced methods of data processing. A series of practical exercises builds on each other throughout the course. Results of these exercises will develop from individual contributions and small-group work, and from a discussion with the whole group. Course attendance is therefore compulsory.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Geographie Master of Science Data Science 20212
10	**Method of examination**	schriftlich Weekly assignment (Problem-solving issues within the broader context of Scripting for Remote Sensing of the Environment, max. 3 pages) or written paper (max. 15 pages) *
11	**Grading procedure**	schriftlich (100%) Weekly assignmemts (100 %)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Will be provided at the beginning of the course

1	**Module name** 46257	**Advanced Semiconductor Technologies Photovoltaic Systems I - Fundamentals** Advanced semiconductor technologies - Photovoltaic systems I - Fundamentals	**5 ECTS**
2	Courses / lectures	Tutorium: Questionaire PV Systems 1	-
3	Lehrende		
4	**Module coordinator**	Prof. Dr. Christoph Brabec Prof. Dr. Wolfgang Heiß	
5	**Contents**	**Lecture / Exercise / Lab work** The lecture will introduce into the fundamentals of photovoltaic energy conversion. The conversion of light into electricity is one of the most efficient power technologies by today and is expected to transform our energy system towards a renewable scenario. The limits of photovoltaic energy conversion, the materials and architectures of major PV technologies and advanced characterization methods for modules as well as solar fields will be introduced theoretically and experimentally during the lecture, a seminar and the lab works.	
6	**Learning objectives and skills**	• The students will learn the concept of black body radiation and the radiation laws and the limits of light energy conversion. The fundamental semiconductor junctions (p-n, M-i-M, Shottky and Hetero Junction are repeated. The one diode and two diodes replacement circuits are explained . Electrical, optical, recombination and extraction loss mechanisms are discussed separately and demonstrated at the hand of numerical drift-diffusion equation solvers. The most important solar cell concepts (Si, CIGS, CdTe, GaAs, Perovksites, Organics) are introduced, and the strengths and weaknesses of each technology are analysed. • Characterization of Photovoltaic Modules will trained by flashed measurements in the lab. Defect imaging methods like DLIT, EL or PL imaging will be trained at the hand of module installations in Erlangen.	
7	**Prerequisites**	Bachelor in Material Science, Nanotechnology, Energy Technology, Electronic Engineering, Computer Science, Physics, Chemistry, Chemical Engineering , or comparable	
8	**Integration in curriculum**	no Integration in curriculum available!	
9	**Module compatibility**	Material Science Master of Science Data Science 20212	
10	**Method of examination**	Variabel Advanced Semiconductor Technologies – Photovoltaic Systems I - Fundamentals (Prüfungsnummer: 62571) Examination performance, oral examination, duration (in minutes): 15, graded, 5 ECTS Share in the calculation of the module grade: 100.0%	

		Alternative examination forms: written exam (90 min). Choice of the examination form is done on the basis of the didactic character of the module. The decision for the examination form will be communicated: • in semesters where the lecture takes place: no more than two weeks after lecture start in the lecture and in the StudOn group • in semesters without lecture: at least two weeks before the repetition exam in the StudOn group *
11	**Grading procedure**	Variabel (100%) Advanced Semiconductor Technologies – Photovoltaic Systems I - Fundamentals (examination number: 62571) Share in the calculation of the module grade: 100.0 %
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 40 h Independent study: 110 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 42800	**Advanced Topics in Deep Learning** Advanced topics in deep learning	**5 ECTS**
2	Courses / lectures	Vorlesung: Advanced Topics in Deep Learning (4 SWS) (SoSe 2025) Übung: Supplements for Advanced Topics in Deep Learning (SoSe 2025)	5 ECTS -
3	Lehrende	Prof. Dr. Vasileios Belagiannis Marc Hölle	

4	**Module coordinator**	Prof. Dr. Vasileios Belagiannis
5	**Contents**	The students will learn advanced deep learning topics, including recent network architectures, generative models, self-supervision, interpretability and explainability. In the exercises, the students will implement advanced models and techniques for classification or regression tasks. The lecture topics include: • Geometric deep learning • Attention and transformers • Unsupervised and self-supervised learning • Generative models • Interpretability • Explainability • Efficient Inference • Uncertainty estimation • Transfer learning and domain adaptation • Few-shot learning
6	**Learning objectives and skills**	The students will learn: • State-of-the-art topics in Deep Learning • Recent Neural network architectures • Generative modelling • Lifelong learning approaches • Robustness and reliability in Deep Learning.
7	**Prerequisites**	Basic knowledge of machine learning, deep learning, and programming.
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten) Written exam of 90 min duration
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english

16	**Bibliography**	• Goodfellow, I., Bengio, Y., Courville, A., & Bengio, Y. (2016). Deep learning. • Deisenroth, M. P., Faisal, A. A., & Ong, C. S. (2020). Mathematics for machine learning. Cambridge University Press. • Molnar, C. (2020). Interpretable machine learning. Lulu. com.

1	**Module name** 93116	**AI-1 Systems Project** AI-1 Systems project	**10 ECTS**
2	Courses / lectures	Projektseminar: AI-1 Systems Project (4 SWS)	10 ECTS
3	Lehrende	Prof. Dr. Michael Kohlhase Jan Frederik Schaefer	

4	**Module coordinator**	Prof. Dr. Michael Kohlhase
5	**Contents**	This project complements the symbolic AI methods covered in the AI-1 Lecture with practical experience in implementing the algorithms or applying existing state-of-the-art libraries and systems. Practical areas of covered in this project include • Logic Programming • Rational Agents • Search (classical/adversarial) • Constraint Satisfaction/Propagation • Propositional/First-Order Reasoning • Knowledge Representation • Planning Project participants will work on multiple concrete problems/applications in small project teams. The results will be • evaluated using benchmark/problems and/or competitions between project teams. • documented in (short) project reports and be presented to the group.
6	**Learning objectives and skills**	Students will • develop and implement algorithms or apply existing systems/ libraries to multiple symbolic AI Problems, • acquire hands-on experience in an established research field, • learn best practices in software development and documentation, • gain first experience in academic writing.
7	**Prerequisites**	Strong programming skills in any programming language.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212
10	**Method of examination**	Praktikumsleistung The project consists of several large tasks (≈6). The first task is solved individually, the other tasks are solved in teams of 2 students. A presentation is given on one of the tasks (typically as a group presentation where each student gets a ≈10 minute segment that is individually graded). A written report (no restrictions on page number, 10–15 pages is typical) is submitted on one task. Three reviews for other students' reports have to be written. The reviewed students can use the reviews to improve their report. The review process is double-blind and students can choose not to get reviews for their report. *
11	**Grading procedure**	Praktikumsleistung (100%)

		The final grade is composed from the quality of the deliverables, namely the practical part (65% of the grade), the presentation (10% of the grade), the written report and reviews (25% of the grade).
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 40 h Independent study: 260 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 93117	**AI-2 Systems Project** AI-2 Systems project	**10 ECTS**
2	Courses / lectures	Projekt: AI-2 Systems Project (4 SWS) (WiSe 2025)	10 ECTS
3	Lehrende	Jan Frederik Schaefer Prof. Dr. Michael Kohlhase	

4	**Module coordinator**	Prof. Dr. Michael Kohlhase
5	**Contents**	This project complements the statistical AI and Machine Learning methods covered in the AI-2 Lecture with practical experience in implementing the algorithms or applying existing state-of-the-art libraries and systems. Practical areas of covered in this project include • Probabilistic Reasoning • Bayesian/Decision Networks • Temporal Probability Models • MDP/POMDPs • Inductive Learning • Neural Networks • Statistical Learning • Natural Language Processing Project participants will work on multiple concrete problems/applications in small project teams. The results will be • evaluated using benchmark/problems and/or competitions between project teams. • documented in (short) project reports and be presented to the group.
6	**Learning objectives and skills**	Students will • develop and implement algorithms or apply existing systems/ libraries to multiple symbolic AI Problems, • acquire hands-on experience in an established research field, • learn best practices in software development and documentation, • gain first experience in academic writing.
7	**Prerequisites**	Strong programming skills in any programming language.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212
10	**Method of examination**	Praktikumsleistung The project consists of several large tasks (≈6). The first task is solved individually, the other tasks are solved in teams of 2 students. A presentation is given on one of the tasks (typically as a group presentation where each student gets a ≈10 minute segment that is individually graded). A written report (no restrictions on page number, 10–15 pages is typical) is submitted on one task. Three reviews for other students' reports have to be written. The reviewed students can use the reviews to improve their report. The review process is double-blind and students can choose not to get reviews for their report. *

11	**Grading procedure**	Praktikumsleistung (100%) The final grade is composed from the quality of the deliverables, namely the practical part (65% of the grade), the presentation (10% of the grade), the written report and reviews (25% of the grade).
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 40 h Independent study: 260 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 93101	**AI in medical robotics**	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: AI in Medical Robotics (4 SWS)	5 ECTS
3	Lehrende	Prof. Dr. Franziska Mathis-Ullrich Dr.-Ing. Christian-Peter Kunz	

4	**Module coordinator**	Prof. Dr. Franziska Mathis-Ullrich
5	**Contents**	This module is concerned with artificial intelligence technologies in medical robotics and with methods that establish different forms of intelligence in medical robotic systems. Participants will become familiar with the design and application of AI methods and algorithms for perception, motor control, planning, cognition and learning and with their application in biorobotic systems and robotic solutions for diagnosis and treatment. Application domains include minimally invasive surgery, motor rehabilitation, exoskeletons and assistive devices, as well as medical service robotics. The taught methods will be applied to application data during designated computer exercises that are integrated into the course. Topics include, but are not limited to: • Basic principles and classification of artificial intelligence • Overview of AI methods and technologies in medical imaging • Implications of surgical workflow planning using AI methods • Motion planning in robotic surgery, rehabilitation robots and medical service robots • Perception in robotic surgery, rehabilitation robots and assistive robots • Motion planning in robotic surgery, rehabilitation robots and assistive robots • Adaptation and Learning in Human-Robot Interaction • Design criteria and regulations for AI-based medical systems
6	**Learning objectives and skills**	• Students are able to employ artificial intelligence technologies and methods for applications in medical robotics. • They are capable of understanding and handling the complexity of biorobotic AI systems and have command of a versatile set of methods for analyzing and further advancing such systems. • They are able to combine different tools and methods to achieve intelligent perception, planning, control, learning and cognition in robotic solutions for minimally invasive surgery, motor rehabilitation robotics, and medical service robotics.
7	**Prerequisites**	Participants should be familiar with fundamentals of linear algebra. It is advantageous but not required to be have some prior knowledge on robotics, basic methodologies of AI, and basic probability theory.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212

10	**Method of examination**	Klausur Written examination (60 min) *
11	**Grading procedure**	Klausur (100%) Written examination (100 %)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 93054	**Algorithmen und Datenstrukturen für MT - Übung** Algorithms and data structures	**5 ECTS**
2	Courses / lectures	Übung: AuD-MT-TUE (2 SWS) Übung: AuD-MT-RUE (2 SWS)	2,5 ECTS 2,5 ECTS
3	Lehrende	Jasmin Riegel Constantin Jehn	

4	**Module coordinator**	Prof. Dr. Tobias Reichenbach
5	**Contents**	Die Tafel- und Rechnerübungen zu AuD-MT richten sich an Studierende des Studiengangs Medizintechnik und zählen dort zu den Grundlagenvorlesungen im Bereich Informatik. Neben einer Einführung in die (objektorientierte) Programmierung in Java werden verschiedene Datenstrukturen wie verkettete Listen, Bäume und Graphen behandelt. Ein weiterer Schwerpunkt liegt auf dem Entwurf von Algorithmen. Dazu zählen Rekursion, Sortierverfahren und Graphalgorithmen, sowie Aufwandsabschätzung von Algorithmen.
6	**Learning objectives and skills**	Die Studierenden • lösen objektorientierte Programmieraufgaben in der Programmiersprache Java • veranschaulichen Programmstrukturen mit Hilfe einer Untermenge der Unified Modelling Language • vergleichen die Aufwände verschiedener Algorithmen hinsichtlich der Laufzeit und des Speicherbedarfs • implementieren grundlegende kombinatorische Algorithmen, insbesondere Such- und Sortierverfahren, binäre Bäume und grundlegende Graphalgorithmen • verstehen und benutzen Rekursion als Bindeglied zwischen mathematischen Problembeschreibungen und programmiertechnischer Umsetzung • übersetzen rekursive Problembeschreibungen in iterative • planen und bearbeiten Programmieraufgaben so, dass sie zeitgerecht fertig gestellt werden
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	
10	**Method of examination**	Übungsleistung Übungsleistung: 10 Übungsblätter/Programmieraufgaben *
11	**Grading procedure**	Übungsleistung (bestanden/nicht bestanden)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german

16	**Bibliography**	In der Vorlesung und den Übungen werden zu den einzelnen Kapiteln passende Lehrbücher vorgeschlagen.

1	**Module name** 93055	**Algorithmen und Datenstrukturen für MT - Vorlesung** Algorithms and data structures	**5 ECTS**
2	Courses / lectures	Vorlesung: Algorithmen und Datenstrukturen (für Medizintechnik) (GOP) (4 SWS)	5 ECTS
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Tobias Reichenbach
5	**Contents**	Die Vorlesung AuD-MT richtet sich an Studierende des Studiengangs Medizintechnik und zählt dort zu den Grundlagenvorlesungen im Bereich Informatik. Neben einer Einführung in die (objektorientierte) Programmierung in Java werden verschiedene Datenstrukturen wie verkettete Listen, Bäume und Graphen behandelt. Ein weiterer Schwerpunkt liegt auf dem Entwurf von Algorithmen. Dazu zählen Rekursion, Sortierverfahren und Graphalgorithmen, sowie Aufwandsabschätzung von Algorithmen.
6	**Learning objectives and skills**	Die Studierenden • lösen objektorientierte Programmieraufgaben in der Programmiersprache Java • veranschaulichen Programmstrukturen mit Hilfe einer Untermenge der Unified Modelling Language • vergleichen die Aufwände verschiedener Algorithmen hinsichtlich der Laufzeit und des Speicherbedarfs • implementieren grundlegende kombinatorische Algorithmen, insbesondere Such- und Sortierverfahren, binäre Bäume und grundlegende Graphalgorithmen • verstehen und benutzen Rekursion als Bindeglied zwischen mathematischen Problembeschreibungen und programmiererischer Umsetzung • übersetzen rekursive Problembeschreibungen in iterative • planen und bearbeiten Programmieraufgaben so, dass sie zeitgerecht fertig gestellt werden
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	
10	**Method of examination**	Klausur (60 Minuten) Elektronische Prüfung, 60 min. *
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german

16	**Bibliography**	In der Vorlesung werden zu den einzelnen Kapiteln passende Lehrbücher vorgeschlagen.

1	**Module name** 47678	**Algorithmische Bioinformatik** Algorithmic Bioinformatics	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Algorithmic Bioinformatics (4 SWS)	5 ECTS
3	Lehrende	Dr. Anne Hartebrodt Prof. Dr. David Blumenthal	

4	**Module coordinator**	Prof. Dr. David Blumenthal
5	**Contents**	With the growing amount of readily available molecular profiling data, algorithms for analyzing these data are getting more and more important. This lecture provides a close-up view on a selection of these algorithms and introduces the biomedical problems which are addressed by them. In particular, the lecture will cover the following topics: • A very brief introduction to molecular biology. • Algorithms for global and local sequence alignment. • Algorithms for de novo sequence assembly. • Algorithms for secondary RNA structure prediction. • Algorithms for exploratory omics data analysis. • Algorithms for network alignment. • Algorithms for disease mechanism mining in biological networks.
6	**Learning objectives and skills**	Students will • be able to explain the basics of molecular biology, • be able to explain fundamental algorithms used in the field, • be able to use paradigms of algorithm design such as dynamic programming, local search, and ant colony optimization in concrete application scenarios, • be able to reimplement the covered algorithms, • be able to provide detailed, technical explanations of the covered algorithms.
7	**Prerequisites**	Since the lecture will be accompanied by programming exercises in Python, prior knowledge of this programming language is recommended. For students without prior experience, a very brief introduction to Python will be provided in the first two exercise sessions.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Variabel Oral exam 30 min. *
11	**Grading procedure**	Variabel (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	english
16	**Bibliography**	Pointers to relevant papers will be provided throughout the lecture and be made available on StudOn. As optional accompanying literature, the following textbooks are recommended: • Phillip Compeau & Pavel Pevzner: Bioinformatics Algorithms: An Active Learning Approach, Active Learning Publishers, 2018. • Patrick Siarry (Ed.): Metaheuristics, Springer International Publishing, 2016.

1	**Module name** 352989	**Algorithms of Numerical Linear Algebra** Algorithms of numerical linear algebra	**7,5 ECTS**
2	Courses / lectures	Übung: Board Exercise 2 ANLA (2 SWS)	2,5 ECTS
		Übung: Computer Exercises ANLA (2 SWS)	2,5 ECTS
		Übung: Board Exercise 1 ANLA (2 SWS)	2,5 ECTS
		Vorlesung mit Übung: Algorithms of Numerical Linear Algebra (ANLA) (4 SWS)	5 ECTS
3	Lehrende	Benjamin Mann apl. Prof. Dr. Harald Köstler	

4	**Module coordinator**	Prof. Dr. Ulrich Rüde
5	**Contents**	• Vectors • Matrices • Vector Spaces • Matrix Factorizations • Orthogonalisation • Singular Value Decomposition • Eigenvalues • Krylov Space Methods • Arnoldi Method • Lanczos Method • Multigrid
6	**Learning objectives and skills**	Students apply solid theoretical knowledge for the foundations of modern solution techniques in Computational Engineering.
7	**Prerequisites**	• Elementary Numerical Mathematics • Engineering Mathematics or Equivalent,
8	**Integration in curriculum**	semester: 3;1
9	**Module compatibility**	Studienrichtung Simulation and Numerics Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 165 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Trefethen, Bau: Numerical Linear Algebra, SIAM 1997

1	**Module name** 96837	**A look inside the human body - gait analysis and simulation**	**2,5 ECTS**
2	Courses / lectures	Vorlesung: A look inside the human body - gait analysis and simulation (2 SWS)	2,5 ECTS
3	Lehrende	Prof. Dr. Anne Koelewijn	

4	**Module coordinator**	Prof. Dr. Anne Koelewijn
5	**Contents**	The aim of this lecture is to teach methods of gait analysis and simulation. Gait analysis experiments will be covered, as well as more modern approaches to gather walking data. Techniques to process gait analysis experiments are discussed, as well as dynamic models that can be used to create gait simulations. This lecture addresses the following topics: • Measurement systems for gait analysis • Methods to calculate joint kinetics and kinematics from experimental data • Muscle biology, specific to force generation, and modelling of muscles • Methods to calculate muscle activation from experimental data • Energetics of walking • Multibody dynamics • Creating simulations of gait
6	**Learning objectives and skills**	Learning objectives: • Be familiar with the existing measurement options for gait analysis • Know state-of-the art techniques to process gait analysis experiments • Select an appropriate processing technique for a specific experiment • Understand how gait could be simulated and where these simulations could be applied • Know the function of the different components of the human body that are involved in locomotion
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Variabel
11	**Grading procedure**	Variabel (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 45 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english

16	**Bibliography**	• Winter, David A. Biomechanics and motor control of human movement. John Wiley & Sons, 2009. • Kelly, Matthew. "An introduction to trajectory optimization: How to do your own direct collocation." SIAM Review 59.4 (2017): 849-904.

1	**Module name** 47544	**Applied Data Science in Medicine & Psychology** Applied data science in medicine & psychology	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Applied Data Science in Medicine & Psychology (4 SWS) (SoSe 2025)	5 ECTS
3	Lehrende	Prof. Dr. Björn Eskofier Luca Abel Prof. Dr. Nicolas Rohleder Veronika Ringgold	

4	**Module coordinator**	Luca Abel Prof. Dr. Björn Eskofier Veronika Ringgold Prof. Dr. Nicolas Rohleder
5	**Contents**	The interdisciplinary module „Applied Data Science in Medicine & Psychology“ covers basic statistical knowledge and hands-on Python exercises. We will start with relevant knowledge from both disciplines (statistics and programming), which will allow you to analyze your data more efficiently. Since this is a course for students from many different disciplines (life sciences, psychology, medical engineering, etc.) we will gradually build up your knowledge which will allow you to cover more complex ideas as we move through the course. Our goal is to provide you with the necessary knowledge, skills, and tools for future projects, such as theses, and to prepare those of you who wish to pursue a career in science. This course will also complement the seminars „Digital Health Psychology“ and „Digitalization in Clinical Psychology“, as prior knowledge of Python and data analysis will enhance the benefit of both seminars for you.
6	**Learning objectives and skills**	Students: • Develop a programming mindset • Gain an understanding of research data management • Acquire basic python coding skills • Gain a basic understanding of inference statistic • Can load, manipulate, analyze, and visualize data • Understand basics of machine learning
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 5
9	**Module compatibility**	Medical Data Science Master of Science Data Science 20212
10	**Method of examination**	Variabel Written e-Exam (60 min) *
11	**Grading procedure**	Variabel (100%) Exam (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h

14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 965820	**Approximate Computing** Approximate computing	**5 ECTS**
2	Courses / lectures	Übung: Exercises to Approximate Computing (2 SWS) (SoSe 2025) Vorlesung: Approximate Computing (2 SWS) (SoSe 2025)	- 5 ECTS
3	Lehrende	Khalil Esper Jose Juan Hernandez Morales Pierre-Louis Sixdenier Prof. Dr.-Ing. Jürgen Teich	

4	**Module coordinator**	Joachim Falk Prof. Dr.-Ing. Jürgen Teich
5	**Contents**	Approximate Computing denotes a quite young research area that exploits the fact and capability of many applications and systems to tolerate imprecision and/or inexactness of computed results. Prominent areas of applications and novel techniques of computing approximate rather than exact results have brought up new implementations either at hardware and/or software levels for important emergent workloads such as searching, mining, image processing, and data retrieval. Although hardware technology is improving at a fast pace, energy and power are becoming more and more important constraints apart from exactly computing results in an acceptable amount of time. The main goals of approximate computing techniques are therefore to exploit the possible trade-off between power/energy consumption, accuracy, performance, and/or cost, e.g., utilized hardware resources. The purpose of the course approximate computing is to instruct students about the main ideas and concepts of approximate computing. This includes analyzing the trade-off between energy consumption, accuracy, run-time and hardware costs, concrete approximating techniques (e.g. approximate hardware synthesis, approximating algorithms) as well as theoretical background (determining the computational error and its complexity).
6	**Learning objectives and skills**	Fachkompetenz - Wissen • The students know the principles and benefits of Approximate Computing and when it is applicable. • The students know multiple error metrics and their semantic meaning. Fachkompetenz - Verstehen • The students understand the difference between the error metrics. • The students understand the principle of function falsification. • The students can apply the presented approximation techniques. Fachkompetenz - Anwenden • The students are capable of choosing the appropriate approximation technique based on given requirements.

7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Variabel Oral exam in case of less than 20 participants (duration 30 mins). Otherwise, written exam (duration 90 mins). *
11	**Grading procedure**	Variabel (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Weitere Informationen: https://www.cs12.tf.fau.de/lehre/lehrveranstaltungen/vorlesungen/approximate-computing

1	**Module name** 44460	**Architekturen von Superrechnern** Architectures of supercomputers	**5 ECTS**
2	Courses / lectures	Übung: Exercises Architectures of Supercomputers / Übungen Architekturen von Superrechnern (2 SWS) Vorlesung: ArchSup (2 SWS)	2,5 ECTS 2,5 ECTS
3	Lehrende	Farhad Ebrahimiazandaryani Prof. Dr.-Ing. Dietmar Fey	

4	**Module coordinator**	
5	**Contents**	• Principles of computer and processor architectures • Modern processor architectures • Homogeneous and heterogeneous multi/many-core processors • Parallel computer architectures • Classification and principles of coupling parallel computers • High speed networks in supercomputers • Examples of supercomputers • Programming of supercomputers
6	**Learning objectives and skills**	Fachkompetenz Wissen Lernende können die Funktionsweise moderner in Superrechnern eingesetzter Prozessoren wiedergeben. Sie erkennen die besonderen Probleme im Zusammenahng mit dem Ernergieverbrauch und der Programmierung von Superrechnern. Verstehen Lernende können die Unterschiede bei der Kopplung paralleler Prozesse darstellen. Sie können Parallelrechner hinsichtlich ihrer Speicheranbindung und den grundlegenden Verarbeitungsprinzipien klassifizieren. Anwenden Lernenden sind in der Lage ein eigenes technisches oder mathematisches Problem zur Lösung auf einem Supercomputer umzusetzen und auszuführen. Anhand der in der Vorlesung gezeigten Beispiele sind sie in der Lage, Herausforderungen beim Auffinden von Flaschenhälsen zu verallgemeinern und für ihr konkretes Problem anzuwenden. Analysieren Lernende sind in der Lage, ihre Problemstellungen, z.B. naturwissenschaftliche oder technische Simulationsexperimente, hinsichtlich der Rechen- und Speicheranforderungen für einen Supercomputer geeignet für die Architekur zu charakterisieren. Evaluieren (Beurteilen) Lernende können mithilfe der aufgezeigten Methodiken zur Leistungsmesung von Parallerechnern unterschiedliche Rechnerarchitekturen bewerten und für ihre Problemstellung die passende Architektur auswählen.
7	**Prerequisites**	None

8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	schriftlich (30 Minuten)
11	**Grading procedure**	schriftlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 120 h Independent study: 30 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 44522	**Audio Processing for the Internet of Things** Audio processing for the Internet of Things	**2,5 ECTS**
2	Courses / lectures	Vorlesung: Audio Processing for the Internet of Things (2 SWS) (SoSe 2025)	2,5 ECTS
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Nils Peters
5	**Contents**	The course focuses on audio and speech processing algorithms within the context of the Internet of Things (IoT). • Foundation (history, components, current challenges) • Overview of relevant wireless protocols (bandwidth, range, latency, spectrum) • Audio device synchronization (NTP, PTP, device orchestration, acoustic wireless sensor networks, asynchronous and event-driven audio sampling) • Acoustic Sensing for Voice User Interfaces (keyword spotting, speech recognition, speaker verification, anti-spoofing) • Acoustic Scene Detection (event detection, scene classification, anomaly detection, sound tagging, blind reverb estimation) • Sound Creation (text-to-speech, sound generative networks) • Data-over-sound (sound-beacon, watermarking, acoustic fingerprint) • Privacy in IoT (edge vs. cloud processing, secure signal processing, federated learning, differential privacy, audio encryption)
6	**Learning objectives and skills**	The students will be able to • understand the principles, key components, and current in IoT • know the differences between various wireless transmission protocols and can give recommendations based on the IoT use case • understand the differences of edge- and cloud-based audio signal processing • understand algorithmic strategies to enhance privacy in IoT use cases • understand the algorithmic components in a voice user interface • understand state-of-the art methods for detection and classification of acoustic scenes and events • learn and apply algorithms to transmit data via acoustic signals • quantify the impact of latency in audio networks and apply strategies for acoustic device synchronization
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	mündlich (30 Minuten)

11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 45 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Recommendations for each topic are given during the lectures

1	**Module name** 96875	**Ausgewählte Kapitel der Audiodatenreduktion** Advanced topics in perceptual audio coding	**2,5 ECTS**
2	Courses / lectures	Vorlesung: Advanced Topics in Perceptual Audio Coding (2 SWS)	2,5 ECTS
3	Lehrende	Prof. Dr.-Ing. Jürgen Herre	

4	**Module coordinator**	Prof. Dr.-Ing. Jürgen Herre
5	**Contents**	Perceptual audio coding is ubiquitous in modern life (mp3 players, mobile phones, DVD players, computers, ...) Based on related classes (esp. Speech and Audio Processing"), this lecture aims at deepening the understanding of modern algorithms for perceptual source coding of audio. It includes an overview of the most relevant standardized coders, starting with MPEG-1 (incl. mp3) via MPEG-4 all the way to the most recent MPEG Audio standard. The significant algorithms are discussed and new approaches are described. The selected topics include: Efficient coding of several audio channels / parametric multi- channel coding Typical coding artifacts; subjective and objective quality assessment Scalable audio coding Bandwidth extension Semi-parametric audio coding Low-delay audio coding The lecture includes a number of demonstrations and audio examples to illustrate the discussed algorithms.
6	**Learning objectives and skills**	• Wissen - Die Studenten kennen die Hauptkomponenten eines gehörangepassten Audiocodecs, sowie die wichtigsten Algorithmen, Codierstrategien und Bewertungsmethoden. Weiterhin kennen sie die Terminologie und gängige Abkürzungen aus diesem Kontext. • Verstehen - Die Studenten verstehen, wie Designentscheidungen in Audiocodecs die letztendlich erreichte Audioqualität beeinflussen, verstehen die gebräuchlichsten Tools aus dem Bereich der gehörangepasste Audiocodierung und wie verschiedene Anwendungsszenarien das Coderdesign bestimmen. • Anwenden - Die Studenten können übliche mathematische Analysemethoden verwenden, um einfache Coder-Componenten zu beschreiben und gegebenenfalls zu modifizieren. • Analysieren - Die Studenten können Audiocodierungs-Standards und wahrnehmungsbasierte Messwerkzeuge dazu analysieren um die zugrundeliegenden Konzepte und Anforderungen zu erfassen. • Evaluieren (Beurteilen) - Die Studenten können Audiocodierungs-Standards und wahrnehmungsbasierte Messwerkzeuge evaluieren um zu beurteilen, welcher

		Standard bzw. welches Messwerkzeug das passendste ist für einen bestimmten Anwendungsfall. • Synthese - Die Studenten können eine Liste von Anforderungen und Bewertungskriterien für Audiocodecs zusammenstellen für gewünschte Anwendungsfälle. • Lern- bzw. Methodenkompetenz - Die Studenten hinterfragen bestehende Ansätze hinsichtlich ihrer Anwendbarkeit in der Praxis.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	schriftlich oder mündlich Prüfung: Mündlich, 30min. *
11	**Grading procedure**	schriftlich oder mündlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 45 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 47666	**Bewegungsanalyse und biomechanische Grenzgebiete** Motion analysis and biomechanical boundary areas	**2,5 ECTS**
2	Courses / lectures	Vorlesung: Bewegungsanalyse und biomechanische Grenzgebiete (2 SWS)	2,5 ECTS
3	Lehrende	Ilias Masmoudi	

4	**Module coordinator**	Prof. Dr. Anne Koelewijn
5	**Contents**	Anatomie des menschlichen Bewegungsapparates |Muskeln, Sehnen, Bänder, Knochen, Knorpel| Gelenkmechanik Kinematik |Bewegungsanalyse und Motion-Capturing-Systeme| Kinetik |Kraft- & Druckmessplatten, Bodenreaktionskräfte| Elektromyographie 3D-Modellierung in der Biomechanik |Segmentierung, 3D-Modelle| Simulation |FEM, MKS|
6	**Learning objectives and skills**	Nach dem erfolgreichen Absolvieren des Moduls verfügen die Studierenden über die folgenden fachlichen, methodischen und persönlichen Kompetenzen: Die Studierenden verstehen die in der Biomechanik verwendete Technik und angewandte Methoden. Die Studierenden bestimmen die anatomischen Strukturen, die den aktiven bzw. passiven Bewegungsapparat aufbauen und somit Kraftentwicklung und Bewegungen ermöglichen. Die Studierenden sind in der Lage die in der technischen Mechanik erlernten Größen wie Kräfte und Momente auf anatomische Strukturen anzuwenden. Die Studierenden können die Funktion der im Rahmen der Kinematik verwendeten Systeme zum Motion-Capturing beschreiben und gegenüberstellen. Sie sind in der Lage, die in der Kinetik verwendeten Messsysteme wie Kraft- und Druckmessplatten in Aufbau und Funktion zu unterscheiden. Sie können die gemessenen Bodenreaktionskräfte und Kraft-Zeit-Verläufe interpretieren und in Zusammenhang mit Bewegungen und Kraftübertragung setzen. Die Studierenden sind in der Lage ein Vorgehen zur Messung von Muskelaktivitäten bei einer spezifischen Bewegung durch Elektromyographie zu entwerfen. Sie beschreiben die Funktion von EMG-Sensoren, unterschiedliche Filtertechniken, Arten der Ableitung wie auch Einflussfaktoren und erläutern diese. Die Studierenden beschreiben die Vorzüge der 3D-Modellierung im biomechanischen und orthopädischen Umfeld und können die unterschiedlichen Arten der Segmentierung gegenüberstellen.

		Die Studierenden sind in der Lage, Simulation im Maschinenbau und in der Biomechanik gegenüberzustellen und die Unterschiede zu konkretisieren. Sie beschreiben den grundsätzlichen Aufbau von Finiter-Elemente-Analyse (FEM) und Mehrkörpersimulation (MKS) und begründen die Funktion in biomechanischem Kontext.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	elektronische Prüfung 1 Stunde - Digitale Prüfung vor Ort *
11	**Grading procedure**	elektronische Prüfung (100%)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 0 h Independent study: 75 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	Relevante Literatur ist im online-Kurs zu den jeweiligen Kapiteln angegeben.

1	**Module name** 93138	**Big Data Seminar** Big Data seminar	**5 ECTS**
2	Courses / lectures	Hauptseminar: Big Data Seminar (2 SWS)	5 ECTS
3	Lehrende	Dominik Probst	

4	**Module coordinator**	Prof. Dr.-Ing. Richard Lenz
5	**Contents**	• Spannende Inhalte des Forschungsfeldes Big Data • Selbstständige Einarbeitung in führende Technologien • Industriegetriebene wissenschaftliche Fragestellungen • Eigene Themenvorschläge ebenfalls gerne willkommen!
6	**Learning objectives and skills**	Die Studierenden: • arbeiten mit wissenschaftlicher Literatur; • vereinheitlichen unterschiedliche Begriffbildungen; • fassen ihre Exzerpte in einem Vortrag zusammen; • formulieren eine kurze Zusammenfassung des Vortrags (Extended Abstract); • vertreten ihre Auffassung in einer Diskussion.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung • Seminarausarbeitung (ca. 10 Seiten) • Vortrag (ca. 30 Min. Präsentation, zzgl. 15 Minuten Fragen/ Diskussion) *
11	**Grading procedure**	Seminarleistung (100%) Die Bewertung der Prüfungsleistung setzt sich zu je 50% aus der Seminarausarbeitung und dem Vortrag zusammen.
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english
16	**Bibliography**	

1	**Module name** 96312	**Bild-, Video- und mehrdimensionale Signalverarbeitung** Image, video and multidimensional signal processing	**5 ECTS**
2	Courses / lectures	Vorlesung: Image, Video, and Multidimensional Signal Processing (2 SWS)	5 ECTS
3	Lehrende	Prof. Dr.-Ing. Andre Kaup	

4	**Module coordinator**	Prof. Dr.-Ing. Andre Kaup

5	**Contents**	•
		  ◦ Histogram equalization, gamma correction
		•
		  ◦ Morphological filters, erosion, dilation, opening, closing
		•
		  ◦ Trichromacy, red-green-blue color spaces, color representation using hue, saturation and value of intensity
		•
		  ◦ Theory of multidimensional signals and systems, impulse response, linear image filtering, power spectrum, Wiener filtering
		•
		  ◦ Bi-linear interpolation, bi-cubic interpolation, spline interpolation
		  ◦ Image feature detection
		• Image features, edge detection, Hough transform, Harris corner detector, texture features, co-occurrence matrix
		•
		  ◦ Laplacian of Gaussian, difference of Gaussian, scale invariant feature transform, speeded-up robust feature transform
		  ◦ Image matching
		• Projective transforms, block matching, optical flow, feature-based matching using SIFT and SURF, random sample consensus algorithm
		•
		  ◦ Amplitude thresholding, k-means clustering, Bayes classification, region-based segmentation, combined segmentation and motion estimation, temporal segmentation of video
		•
		  ◦ Unitary transform, Karhunen-Loeve transform, separable transform, Haar and Hadamard transform, DFT, DCT

6	**Learning objectives and skills**	The students • understand point operations for image data and gamma correction • test the effects of rank order and median filters for image data • evaluate and differentiate between different color spaces for image data

		• explain the principle of two-dimensional linear filtering for image signals • calculate and evaluate the two-dimensional discrete Fourier transform of an image signal • determine enlarged discrete image signals by bi-linear and spline interpolation • verify image data for selected texture, edge and motion features • analyze image and video data for features in different scale spaces • explain and evaluate methods for the matching of image data • segment image data by implementing basic classification and clustering methods • understand the principle of transformations on image data and apply them exemplarily
7	**Prerequisites**	Course on Signals und Systems I and II recommended
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten) Written exam of 90 min duration
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• J.-R. Ohm: |Multimedia Content Analysis|, Springer, 2016 • J. W. Woods: |Multidimensional Signal, Image, and Video Processing and Coding|, Academic Press, second edition, 2012

1	**Module name** 43932	**Computational Imaging Project** Computational imaging project	**10 ECTS**
2	Courses / lectures	Projekt: Computational Imaging Project (8 SWS) (SoSe 2025)	10 ECTS
3	Lehrende	Prof. Dr. Florian Knoll	

4	**Module coordinator**	Prof. Dr. Florian Knoll
5	**Contents**	Individual or group projects in the area of computational methods in biomedical imaging. The projects range from theoretical analysis to practical implementations of approaches that have recently been published in the literature. Students can either propose their own topics or contact the lecturer for a list of available topics. The project can be done either as 10 ECTS or a 5 ECTS depending on the scope of the work and the study program. If you want to do a project in this semester, please write an email to Prof. Knoll at the beginning of the semester to discuss possible topics.
6	**Learning objectives and skills**	Students acquire and practice the skills to: • Read and discuss literature from the field of biomedical imaging • Implement approaches that are proposed in the literature • Run computational experiments and interpret and communicate their findings in lab meetings
7	**Prerequisites**	Recommended: Computational Magnetic Resonance Imaging Lecture and Medical Engineering II
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Praktikumsleistung The grade is determined by: 50% Software development of approaches from the literature. 25% Presentation of the software and the results in the lab group meeting. 25% Written documentation of the development in form of a project report (max 10 pages). *
11	**Grading procedure**	Praktikumsleistung (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 240 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english
16	**Bibliography**	An individual reading list will be established at the beginning of each project.

1	**Module name** 93109	**Computational Magnetic Resonance Imaging** Computational magnetic resonance imaging	**5 ECTS**
2	Courses / lectures	Vorlesung: Computational Magnetic Resonance Imaging Vorlesung (2 SWS) Übung: Computational Magnetic Resonance Imaging Uebung (2 SWS)	2,5 ECTS 2,5 ECTS
3	Lehrende	Prof. Dr. Florian Knoll Jinho Kim	

4	**Module coordinator**	Prof. Dr. Florian Knoll
5	**Contents**	Computational Magnetic Resonance Imaging provides a deeper look into computational and machine learning methods for the inverse problem of MRI data acquisition and image reconstruction. It is organized as a series of lectures with accompanying programming exercises. In the exercises, students will use Matlab or Python and PyTorch to implement and test the different methods discussed in class. Topics covered will include but are not limited to: • Recap of MR signal and encoding, Fourier imaging • Introduction to the inverse problem of imaging • Partial Fourier imaging • Parallel imaging • Compressed sensing • Machine Learning in MRI
6	**Learning objectives and skills**	After completing this course, students will be able to: • Understand the theory and algorithms of MR data acquisition and image reconstruction • Apply them themselves in real-world MR imaging tasks
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Übungsleistung Variabel Participants have to solve weekly graded exercises. The final exam is a 60-minutes written exam. *
11	**Grading procedure**	Übungsleistung (bestanden/nicht bestanden) Variabel (100%) The grade is determined by the final exam. The grade can be improved by up to 0.7 with bonus points that are awarded for successful completion of the exercises.
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	english
16	**Bibliography**	Z.P. Liang. Constrained Reconstruction Methods in MR Imaging. http://mri.beckman.illinois.edu/resources/liang_1992_constrained_imaging_review.pdf D. Nishimura. Principles of Magnetic Resonance Imaging. https://www.lulu.com/en/us/shop/dwight-nishimura/principles-of-magnetic-resonance-imaging/paperback/product-1nqdq4j2.html?page=1&pageSize=4 M. Bernstein. Handbook of MRI Pulse Sequences. https://www.amazon.com/Handbook-Pulse-Sequences-Matt-Bernstein/dp/0120928612

1	**Module name** 96838	**Computational Medicine I**	**2,5 ECTS**
2	Courses / lectures	Vorlesung: Computational Medicine I (2 SWS)	2,5 ECTS
3	Lehrende	PD Dr. Marion Semmler PD Dr.-Ing. Stefan Kniesburges Prof. Dr. Michael Döllinger	

4	**Module coordinator**	Prof. Dr. Michael Döllinger
5	**Contents**	The lecture communicates the application of computer controlled experimental and numerical methods in the area of physiological and pathological speech communication and speech production. It is communicated how learned theory and learned methods can be applied in medical and clinical oriented research. The main focus is on the process of voice production with its complex physical fluid-structure-acoustic interactions (FSAI). The challenge in clinical routine is the limited accessibility of the larynx where the sound is actually produced. This limited access makes it very difficult to place sensors and measurement tools directly in the living human. Hence, the lecture (1) briefly communicates relevant physiology and anatomy being requisite to actually understand the problem. (2) Experimental and numerical model strategies, visual and laser based techniques for visualization and (3) experimental / numerical methods for analysis of the fluid-structure-acoustic interaction are communicated. This includes: 1) Imaging by High-speed-video endoscopy (>4000 fps) 2) Image processing and image analysis: classical approaches and machine learning based 3) 3D laser based high-speed visualization 4) Development of clinical diagnostic approaches for quantitative judgement of disorders 5) Numerical modelling of laryngeal dynamics by lumped-mass and 3D-FVM models 6) Numerical simulation of laryngeal airflow and interaction with the vocal folds 7) Numerical simulation of generated acoustics 8) Experimental model of laryngeal processes using synthetic and ex-vivo cadaver models 9) Parameter optimization of numerical models towards real laryngeal dynamics 10) How to analyse generated data
6	**Learning objectives and skills**	The systematic process chain including generation, simulations, analysis and interpretation of multi-modal based data (clinical/ experimental/numerical) within basic and clinical research will be communicated.
7	**Prerequisites**	-
8	**Integration in curriculum**	no Integration in curriculum available!

9	**Module compatibility**	Medical Data Science Master of Science Data Science 20212
10	**Method of examination**	mündlich Oral, 100%
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 45 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german german or english
16	**Bibliography**	

1	**Module name** 44200	**Computational Neurotechnology / Numerische Neurotechnologie** Computational neurotechnology / Numerical neurotechnology	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Computational Neurotechnology (SoSe 2025)	-
3	Lehrende	Prof. Dr. Tobias Reichenbach	

4	**Module coordinator**	Prof. Dr. Tobias Reichenbach
5	**Contents**	Foundations of Computational Neuroscience and the processing of neural signals. Applications in the areas of artificial neural networks, Brain-Machine-Interfaces (BCIs) and neural prosthesis.
6	**Learning objectives and skills**	• Can understand the principles of the analysis of neural signals • Can apply information theory for the description of neural activity • Can perform simulations of the dynamics of single neurons as well as of neural networks • Can evaluate different approaches to construct Brain-Machine-Interfaces (BCIs) • Can explain concepts for the design of neural prosthesis
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Klausur Written exam (60 minutes) *
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Dayan, Peter, and Laurence F. Abbott. Theoretical neuroscience: computational and mathematical modeling of neural systems. Computational Neuroscience Series, 2001. Gerstner, Wulfram, et al. Neuronal dynamics: From single neurons to networks and models of cognition. Cambridge University Press, 2014. Oweiss, Karim G., ed. Statistical signal processing for neuroscience and neurotechnology. Academic Press, 2010.

		Maurits, Natasha. From neurology to methodology and back: an introduction to clinical neuroengineering. Springer Science & Business Media, 2011. Clément, Claude. Brain-Computer Interface Technologies. Springer International Publishing, 2019. DiLorenzo, Daniel J., and Joseph D. Bronzino, eds. Neuroengineering. CRC Press, 2007.

1	**Module name** 43822	**Computer Graphics** Computer graphics	**5 ECTS**
2	Courses / lectures	Vorlesung: Computer Graphics (3 SWS) Übung: CGTut (1 SWS)	3,75 ECTS 1,25 ECTS
3	Lehrende	Prof. Dr. Marc Stamminger Nikolai Hofmann Linus Franke Laura Fink	

4	**Module coordinator**	Prof. Dr. Marc Stamminger
5	**Contents**	Die Vorlesung gibt eine Einführung in die Computergraphik: • Graphik Pipeline • Clipping • 3D Transformationen • Hierarchische Display Strukturen • Perspektive und Projektionen • Visibilitätsbetrachtungen • Rastergraphik und Scankonvertierung • Farbmodelle • Lokale und globale Beleuchtungsmodelle • Schattierungsverfahren • Ray Tracing und Radiosity • Schatten und Texturen Contents: This lecture covers the following aspects of Computer Graphics: • graphics pipeline • clipping • 3D transformations • hierarchical display structures • perspective transformations and projections • visibility determination • raster graphics and scan conversion • color models • local and global illumination models • shading models • ray tracing and radiosity • shadows and textures
6	**Learning objectives and skills**	Die Studierenden • geben die unterschiedlichen Schritte der Graphik Pipeline wieder • erklären die Funktionsweise der Clippingalgorithmen für Linien und Polygone • beschreiben, charakterisieren und berechnen affine und perspektivische Transformationen in 3D und veranschaulichen die allgemeine Form der Transformationsmatrix in homogener Koordinaten • skizzieren die Verfahren zur Tiefe- und Visibilitätsberechnung

		• vergleichen die unterschiedlichen Farbmodelle der Computergraphik • illustrieren und untersuchen die Datenstrukturen zur Beschreibung virtueller 3D Modelle und komplexer Szenen • erläutern die Funktionsweise der Rasterisierung und Scankonvertierung in der Graphikpipeline • lösen Aufgaben zu Beleuchtung und Texturierung von 3D virtuellen Modellen • klassifizieren Schattierungsverfahren • bestimmen den Unterschied zwischen lokaler und globaler Beleuchtung und formulieren Algorithmen für Ray Tracing und Radiocity *Educational objectives and skills:* Students should be able to • describe the processing steps in the graphics pipeline • explain clipping algorithms for lines and polygons • explain, characterize and compute affine and perspective transformations in 2D and 3D, and provide an intuitive description of the general form of corresponding transformation matrices in homogeneous coordinates • depict techniques to compute depth, occlusion and visibility • compare the different color models • describe data structures to represent 3D virtual models and complex scenes • explain the algorithms for rasterization and scan conversion • solve problems with shading and texturing of 3D virtual models • classify different shadowing techniques • explain the difference between local and global illumination techniques and formulate algorithms for ray tracing and radiosity
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212 Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Übungsleistung Klausur (60 Minuten) Die Übungen ("Computer Graphics Basic Tutorials") bestehen aus insgesamt 10 wöchentlichen Aufgabenblättern mit kleinen Programmieraufgaben. The exercises ("Computer Graphics Basic Tutorials") consist of weekly worksheets (10 worksheets in total) with small programming tasks. *
11	**Grading procedure**	Übungsleistung (bestanden/nicht bestanden) Klausur (100%)

		Zum Bestehen des Moduls müssen 50% der Punkte in den Übungen erreicht und die Abschlussprüfung bestanden werden. Die Modulnote ergibt sich zu 100% aus der Prüfung. The module is passed when 50% of the points in the exercises are reached and when the final exam is passed. The grade of the module is entirely determined by the grade in the final exam.
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english
16	**Bibliography**	• P. Shirley: Fundamentals of Computer Graphics. AK Peters Ltd., 2002 • Hearn, M. P. Baker: Computer Graphics with OpenGLD. Pearson • Foley, van Dam, Feiner, Hughes: Computer Graphics - Principles and Practice • Rauber: Algorithmen der Computergraphik • Bungartz, Griebel, Zenger: Einführung in die Computergraphik • Encarnação, Strasser, Klein: Computer Graphics

1	**Module name** 67080	**Computerphysik und numerische Methoden** Computational physics and numerical methods	**5 ECTS**
2	Courses / lectures	Übung: Übungen zur Computerphysik und numerischen Methoden (3 SWS) Hauptseminar: Computerphysik und numerische Methoden (2 SWS)	- 5 ECTS
3	Lehrende	Dr. Christian Wick Prof. Dr. Ana-Suncana Smith	

4	**Module coordinator**	PD Dr. Michael Schmiedeberg
5	**Contents**	• Integration gewöhnlicher und partieller Differentialgleichungen • Molekulardynamik, Finite-Elemente-Methode • Lösung linearer Gleichungssysteme, Methode der konjugierten Gradienten • Lineare Regression • Zufallszahlen, Monte-Carlo-Integration und Markov-Chain-Monte-Carlo • Schnelle Fourier-Transformation
6	**Learning objectives and skills**	Die Studierenden • wählen geeignete numerische Methoden aus und wenden sie an, um Problemstellungen aus der Mechanik, Elektrodynamik, Quantenmechanik und aus der Statistischen Physik zu lösen • schätzen die Genauigkeit numerischer Lösungen ab und identifizieren Fehlerquellen • erschließen praktische Programmiererfahrung im wissenschaftlichen Rechnen für Studium und Forschung
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Physics Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 75 h Independent study: 75 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	William H. Press |et al.|, Numerical Recipes in C, Cambridge University Press, 1992 Paul L. DeVries, A First Course in Computational Physics, John Wiley & Sons, 1993

1	**Module name** 713618	**Computer vision**	**5 ECTS**
2	Courses / lectures	Übung: Computer Vision Exercise (2 SWS) (SoSe 2025) Vorlesung: Computer Vision (2 SWS) (SoSe 2025)	2,5 ECTS 2,5 ECTS
3	Lehrende	Dr.-Ing. Vanessa Klein Muhammad Sohail Prof. Dr. Tim Weyrich Prof. Dr. Bernhard Egger	

4	**Module coordinator**	Prof. Dr. Tim Weyrich
5	**Contents**	This lecture discusses important algorithms from the field of computer vision. The emphasis lies on 3-D vision algorithms, covering the geometric foundations of computer vision, and central algorithms such as stereo vision, structure from motion, optical flow, and 3-D multiview reconstruction. Participants of this advanced course are expected to bring experience from prior lectures either from the field of pattern recognition or from the field of computer graphics.
6	**Learning objectives and skills**	Die Vorlesung stellt eine Auswahl von Methoden aus dem Gebiet der Computer Vision vor, die in dem Feld eine zentrale Stellung einnehmen. In den Übungen implementieren und evaluieren die Studierenden selbständig diese Methoden. Die Studierenden arbeiten die ganze Zeit über an populären Computer Vision-Methoden wie zum Beispiel Stereosehen, optischer Fluss und 3D-Rekonstruktion aus mehreren Ansichten. Für diese Probleme • beschreiben die Studierenden perspektivische Projektion, Rotationen und verwandte geometrische Grundlagen, • erklären die Studierenden die behandelten Methoden, • diskutieren die Studierenden Vor- und Nachteile verschiedener Modalitäten zur Erfassung von 3D-Informationen, • implementieren die Studierenden einzeln und gemeinschaftlich in Kleingruppen Code, • entdecken die Studierenden optimale Vorgehensweisen in der Datenaufnahme, • erkunden und bewerten die Studierenden unterschiedliche Möglichkeiten für die Evaluation, • diskutieren und präsentieren die Gruppenarbeiter in Gruppen die Vor- und Nachteile ihrer Implementierungen, • diskutieren und reflektieren die Studierenden gesellschaftliche Auswirkungen von Anwendungen des 3D-Rechnersehens. The lecture introduces computer vision algorithms that are central to the field. In the exercises, participants autonomously implement and evaluate these algorithms. The participants work throughout the time on popular computer vision algorithms, like for example stereo vision, optical flow, and 3-D multiview reconstruction. For these problems, the participants • describe perspective projection, rotations, and related geometric foundations,

		• explain the presented methods, • discuss the advantages and disadvantages of different modalities for acquiring 3-D information, • implement individually and in small groups code, • discover best practices in data acquisition, • explore and rank different choices for evaluation, • discuss and present in groups the advantages and disadvantages of their implementations, • discuss and reflect the social impact of applications of computer vision algorithms.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Variabel (90 Minuten) Dieses Modul wird mit einer Klausur (90 Minuten) geprüft. The form of examination is a written exam of 90 minutes. *
11	**Grading procedure**	Variabel (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Richard Szeliski: "Computer Vision: Algorithms and Applications", Springer 2011.

1	**Module name** 65093	**Control, machine learning and numerics**	**10 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the summer semester.	
3	Lehrende	-	

4	**Module coordinator**	Prof. Dr. Enrique Zuazua Iriondo
5	**Contents**	• several topics related to the control of Ordinary Differential Equations (ODE) and Partial Differential Equations (PDE), including controllability, observability, and some of the most fundamental work that has been done in the subject in recent years. • an introduction to Machine Learning, focusing mainly on the use of control techniques for the analysis of Deep Neural Networks as a tool to address, for instance, the problem of Supervised Learning. • some classical computational techniques related to the control of ODE and PDE, and machine learning.
6	**Learning objectives and skills**	Students are able to • understand some basic theory on control and machine learning. • learn about recent advances on control and machine learning. • implement some computational techniques using their own or specified software and critically evaluate the results, • set out their approaches and results in a comprehensible and convincing manner, making use of appropriate presentation techniques.
7	**Prerequisites**	Basic knowledge of calculus, linear algebra, ODE and PDE. Familiarity with scientific computing is helpful.
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Simulation and Numerics Master of Science Data Science 20212
10	**Method of examination**	Variabel
11	**Grading procedure**	Variabel (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 75 h Independent study: 225 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	1) L. Bottou, F. E. Curtis, and J. Nocedal, Optimization methods for large-scale machine learning. SIAM Review, 60 (2) (2018) , 223-311. 2) J. M. Coron, Control and Nonlinearity, Mathematical Surveys and Monographs, 143, AMS, 2009.

		3) I. Goodfellow, Y. Bengio, & A. Courville, Deep Learning. MIT press, 2016. 4) R. Glowinski, J. L. Lions, and J. He, Exact and Approximate Controllability for Distributed Parameter Systems: A Numerical Approach, Encyclopedia Math. Appl., Cambridge University Press, Cambridge, UK, 2008. 5) C. F. Higham, and D. J. Higham, Deep learning: An introduction for applied mathematicians. SIAM Review, 61 (4) (2019), 860-891. 6) J. Nocedal, and S. Wright, Numerical Optimization. Springer Science & Business Media, 2006. 7) D. Ruiz-Balet, and E. Zuazua, Neural ODE control for classification, approximation and transport. arXiv preprint arXiv:2104.05278, (2021). 8) E. Zuazua, Propagation, observation, and control of waves approximated by finite difference methods, SIAM Review, 47 (2) (2005), 197-243. 9) E. Zuazua, Controllability and observability of partial differential equations: some results and open problems, in Handbook of Differential Equations: Evolutionary Equations. Vol. 3. North-Holland, 2006. 527-621.

1	**Module name** 65086	**Convex Geometry and Applications** Convex geometry and applications	**5 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt!	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	Prof. Dr. Timm Oertel
5	**Contents**	The module comprises of two parts. The first part is a general introduction to convex geometry, where basic concepts and tools will be introduced, such as separation and the classical results of Carathéodory, Helly, and Radon. The second part will be more specialized, focusing on ellipsoids, including ellipsoidal approximation and volume concentration. Applications in optimization and data science will be highlighted throughout.
6	**Learning objectives and skills**	Students • will learn the foundations of classical convex geometry • apply concepts and tools from convex geometry to modern applications in optimization and data science
7	**Prerequisites**	Linear algebra and calculus are required. Basic knowledge in probability theory is recommended.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Studienrichtung Databased optimization Master of Science Data Science 20212 Studienrichtung Mathematische Theorie / Grundlagen der Data Science Master of Science Data Science 20212
10	**Method of examination**	mündlich
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 65876	**Data-driven methods for dynamical systems**	**5 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt!	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	Prof. Dr. Giovanni Fantuzzi
5	**Contents**	This course introduces students to modern data science techniques for interpreting, analyzing, forecasting, and controlling dynamic data. Classical problems from the theory of dynamical systems will be re-examined using state-of-the-art computational methods based on data. Course topics will include: • Dynamic mode decomposition • The Koopman operator • Kernel methods for dynamics • System identification and forecasting Theory will be complemented by programming assignments, where students will have the chance to implement the theory and reproduce results presented in the lectures.
6	**Learning objectives and skills**	By the end of the course, students should be able to: # Explain and apply dynamic mode decomposition and its extensions • Explain and apply the basic notions of Koopman operator theory • Explain and utilize system identification techniques • Implement data-driven methods for dynamical system in a programming language of choice
7	**Prerequisites**	This course requires: • A basic understanding of differential equations / maps • The ability to program in at least one scientific programming language (e.g. MATLAB, Python, Julia, etc.)
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Studienrichtung Mathematische Theorie / Grundlagen der Data Science Master of Science Data Science 20212
10	**Method of examination**	mündlich (30 Minuten)
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	
16	**Bibliography**	Lecture materials will be provided as the course progresses. A reading list will also be provided at the start of the course.

1	**Module name** 65794	**Data Governance Applications**	**2,5 ECTS**
2	Courses / lectures	Seminar: Data Governance Applications (2 SWS) (SoSe 2025) Participation in all seminar sessions is mandatory.	2,5 ECTS
3	Lehrende	Prof. Dr. Daniel Tenbrinck Anna Leschanowsky	

4	**Module coordinator**	Prof. Dr. Daniel Tenbrinck
5	**Contents**	This seminar builds upon the foundational concepts introduced in the Data Governance Foundations seminar, which covers the management of legal requirements, ethical considerations, and implementation of data governance. The Data Governance Applications seminar extends these foundations by focusing on the practical application of data governance for AI systems. It emphasizes the implementation of frameworks that ensure data security, privacy, and compliance with legal and ethical standards. Students will explore key topics such as data quality and data classification, privacy-enhancing technologies for data security, and methods for analyzing data bias, specifically in the context of speech, image, and natural language processing. A strong emphasis will be placed on practical, hands-on activities, including creating data cards for databases, using Python and Jupyter Notebooks to assess data quality, engaging in data cleaning, implementing privacy-enhancing techniques, and analyzing bias in voice data and its applications. The seminar will culminate in a group project where students will design and implement a comprehensive data governance framework for a chosen AI application.
6	**Learning objectives and skills**	Students • understand the principles of data governance, including legal and ethical requirements and how to translate these into technical measures. • gain practical skills in applying data governance measures, such as creating data cards, to ensure transparency and compliance. • learn to assess and improve data quality by applying techniques for data cleaning, re-annotation, and data visualization. • master anonymization methods and privacy-enhancing technologies (PETs) to protect sensitive data. • understand the ethical challenges of data bias and develop the ability to analyze and mitigate biases. • apply and implement governance strategies to real-world case studies while ensuring compliance with legal standards. • develop skills in presentation, and collaborative group work.
7	**Prerequisites**	The following can be beneficial to enhance the learning experience: • completion of the Data Governance Foundations course (or equivalent background in data governance) • basic programming skills in Python

		• experience working with Jupyter or Colab notebooks • familiarity with data visualization techniques • general understanding of data concepts and terminology
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung Seminar presentation and a short essay. *
11	**Grading procedure**	Seminarleistung (100%) Seminar presentation (50%) + short essay (50%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 45 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Breaux, Travis D. (Ed.), An Introduction to Privacy For Technology Professionals, 2020 • Open North, Data Governance Framework of Montreal in Common: Towards a more responsible, effective and collaborative data governance, https://opennorth.ca/wp-content/uploads/2023/02/Data-Governance-Framework-EN-2.pdf, 2022 • Abraham et al., Data Governance: A conceptual framework, structured review and research agenda, International Journal of Information Management, https://doi.org/10.1016/j.ijinfomgt.2019.07.008, 2019 • Marcucci et al., Mapping and Comparing Data Governance Frameworks: A benchmarking exercise to inform global data governance deliberations, https://arxiv.org/abs/2302.13731, 2023 • Leschanowsky et al., "A Data Perspective on Ethical Challenges in Voice Biometrics Research," in IEEE Transactions on Biometrics, Behavior, and Identity Science, vol. 7, no. 1, pp. 118-131, Jan. 2025, https://ieeexplore.ieee.org/document/10643178 • Bucerius, Gerd and ZEIT-Stiftung Ebelin (Pub.), Charter of digital fundamental rights of the european union, Unofficial English translation of the German original text, https://digitalcharta.eu/wp-content/uploads/2016/12/Digital-Charta-EN.pdf, 2016

1	**Module name** 65793	**Data Governance Foundations**	**2,5 ECTS**
2	Courses / lectures	Seminar: Data Governance Foundation	-
3	Lehrende	Anna Leschanowsky Prof. Dr. Daniel Tenbrinck	

4	**Module coordinator**	Prof. Dr. Daniel Tenbrinck
5	**Contents**	This seminar introduces the foundations of Data Governance, focusing on the management of legal requirements, ethical considerations, metadata management and implementation of data governance. Starting from ethical and legal foundations, we explore their practical implementation using current AI topics such as training large language models and handling voice recordings. Students engage in interactive tasks including analyzing real-world governance failures and successes, making design choices based on different international laws, and role-playing ethical dilemmas. Additional hands-on activities involve meta data management exercises, culminating in a group project to create a data governance plan for a hypothetical organization. These practical experiences are designed to equip students with the knowledge and tools to implement effective data governance strategies in real-world settings.
6	**Learning objectives and skills**	Students • understand the fundamentals of data governance, including legal and ethical requirements, and their application in managing organizational data. • implement practical data governance strategies in AI contexts, such as training large language models and handling voice recordings. • analyze and manage metadata effectively, ensuring compliance and data quality through hands-on exercises. • evaluate real-world case studies, identifying best practices and common pitfalls in data governance. • design comprehensive data governance plans for hypothetical organizations, integrating legal, ethical, and technical aspects. • engage in ethical decision-making, using role-playing exercises to navigate complex dilemmas in data governance. • learn how to compile a written essay, scientific writing, correct citations. • learn how to create an appealing visual presentation in a group, review and successively optimize it. • learn how to present the topic in front of other students, how to train presentation skills.
7	**Prerequisites**	Prerequisites: No specific knowledge is mandatory for participation in the course. However, the following can be beneficial to enhance the learning experience: • Basic understanding of data concepts and terminology

		• Prior experience or knowledge in data management, processing, machine learning, statistical analysis or related fields • Interest in data governance and ethical data practices.
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung
11	**Grading procedure**	Seminarleistung (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 45 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	
16	**Bibliography**	• Breaux, Travis D. (Ed.), An Introduction to Privacy For Technology Professionals, 2020 • Open North, Data Governance Framework of Montreal in Common: Towards a more responsible, effective and collaborative data governance, https://opennorth.ca/wp-content/uploads/2023/02/Data-Governance-Framework-EN-2.pdf <https://opennorth.ca/wp-content/uploads/2023/02/Data-Governance-Framework-EN-2.pdf>, 2022 • Abraham et al., Data Governance: A conceptual framework, structured review and research agenda, International Journal of Information Management, https://doi.org/10.1016/j.ijinfomgt.2019.07.008 <https://doi.org/10.1016/j.ijinfomgt.2019.07.008>, 2019 • Marcucci et al., Mapping and Comparing Data Governance Frameworks: A benchmarking exercise to inform global data governance deliberations, https://arxiv.org/abs/2302.13731 <https://arxiv.org/abs/2302.13731>, 2023 • Bucerius, Gerd and ZEIT-Stiftung Ebelin (Pub.), Charter of digital fundamental rights of the european union, Unofficial English translation of the German original text, https://digitalcharta.eu/wp-content/uploads/2016/12/Digital-Charta-EN.pdf <https://digitalcharta.eu/wp-content/uploads/2016/12/Digital-Charta-EN.pdf>, 2016

1	**Module name** 47677	**Data Science Survival Skills** Data science survival skills	**5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Andreas Kist
5	**Contents**	Data Scientists need a comprehensive toolbox for their work. This consists for example of data acquisition, data cleaning, data processing and data visualization. In this course, we highlight good practices and approaches, and provide intensive hands-on experience. In particular, this course covers: Data handling and storage Lossy and lossless data compression Data acquisition and API usage Data visualization in scientific figures and movies Data analysis platforms Multithreading and multiprocessing Code vectorization and just-in-time compilation Code profiling Prototyping Graphical User Interfaces Workflow optimization techniques
6	**Learning objectives and skills**	Students will be able to create own code for working with data can carry out research projects in data science can apply code optimization strategies can design own graphical user interfaces for convenient interaction with data can produce high-quality data visualization as needed for scientific publications
7	**Prerequisites**	It is recommended to have prior knowledge of the programming language Python (e.g. through GSProg or SciProgPy) and first exposure to data.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Variabel (60 Minuten) Compulsory: Written Exam, 60 min Optional: Homework (12-14 units) *
11	**Grading procedure**	Variabel (100%) The grade consists of the exam grade to 100%. We grant bonus points according to passed homework units (up to a grade advantage of 0.7, if the exam was passed with at least grade 4.0).
12	**Module frequency**	Only in winter semester

13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Edward Tufte: The Visual Display of Quantitative Information Cole Nussbaum Knaflic: Storytelling with data Wes McKinney: Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython Gabriele Lanaro: Python High Performance Micha Gorelick, Ian Ozsvald: High Performance Python Alan D Moore: Mastering GUI Programming with Python

<table>
<tr><td>1</td><td>Module name
681735</td><td>Datenbanken in Rechnernetzen und Transaktionssysteme
Distributed databases and transaction systems</td><td>5 ECTS</td></tr>
<tr><td>2</td><td>Courses / lectures</td><td>Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt!</td><td></td></tr>
<tr><td>3</td><td>Lehrende</td><td>No lecturers available since there are no courses / lectures for this module for this semester!</td><td></td></tr>
</table>

<table>
<tr><td>4</td><td>Module coordinator</td><td>Prof. Dr.-Ing. Richard Lenz</td></tr>
<tr><td>5</td><td>Contents</td><td>DBRN:
Rechnernetze entsprechen dem momentanen Stand der Technik; isolierte Rechnersysteme nehmen an Zahl und Bedeutung ab. Das Betreiben von Datenbanksystemen in Rechnernetzen erfordert neuartige Konzepte, die über die einer zentralisierten Datenbankverwaltung hinausgehen. In der Vorlesung werden Ansätze zur Datenbankverwaltung in verteilten Systemen vorgestellt. Verteilte Datenbanken, Parallele Datenbanken, DB-Sharing und heterogene Datenbanksysteme werden untersucht. Darüber hinaus widmet sich ein weiteres Hauptkapitel der Vorlesung der Verwendung und dem Betrieb von Datenbanksystemen im Internet.

TAS:
Transactions are the core mechanism to guarantee database consistency in the presence of failures. The lecture introduces the cornerstones of the Transaction Concept and related techniques and system architectures.
Topics are:
Reconstructing the Transaction Model
Advanced Transaction Models
Queued transaction processing
Implementing the ACID properties of transactions: Concurrency control, logging and recovery
TP Monitors: TRPC, Architecture of TP Monitor, Transaction Manager
This course generalizes the transaction concept from its traditional database system domain to the broader context of client-server computing. The course begins by defining basic terminology and concepts. The role of a transaction processing system in application design, implementation, and operation is covered. Subsequent lectures cover the theory and practice of implementing locking, logging, and the more generic topic of implementing transactional resource managers.</td></tr>
<tr><td>6</td><td>Learning objectives and skills</td><td>DBRN:
Die Studierenden
Benennen Ziele verteilter Datenhaltungssysteme
Erklären verschiedene Zielkonflikte, insbesondere das CAP-Theorem</td></tr>
</table>

- Unterscheiden verschiedene Varianten verteilter Datenhaltungssysteme
- Erläutern die Optionen zur Metadatenverwaltung in verteilten Datenbanken
- Definieren horizontale und vertikale Fragmentierungen für relationale Datenbanken
- Erklären die Transformationsschritte und Optimierungen der verteilten Anfrageverarbeitung anhand konkreter Beispiele
- Erklären Algorithmen zur verteilten Ausführung von Verbund-Operationen
- Erläutern die Problematik der Deadlock-Erkennung bei verteilten Sperrverfahren
- Unterscheiden die Funktionsweise von Sperrverfahren, Zeitstempelverfahren und Optimistischen Verfahren zur Synchronisation verteilter Transaktionen
- Benennen und erklären verschiedene Verfahren zur Replikationskontrolle
- Erläutern Techniken und Verfahren zur Abschwächung der Konsistenzanforderungen an replizierte Datenbestände
- Erklären die Funktionsweise hochskalierbarer No-SQL Datenbanken am Beispiel der Replikationsmechanismen im Datenbanksystem Cassandra
- Unterscheiden und erläutern Realisierungsalternativen zur Kopplung und Integration heterogener autonomer Datenbanken
- Erläutern die erweiterte Schema-Architektur für föderative Datenbanksysteme
- Erklären die Abbildungsvarianten GaV und LaV für die Implementierung Föderativer Datenbanken

TAS:

Die Studierenden

- Erklären die Zielsetzungen und Grenzen transaktionaler Systeme
- Unterscheiden verschiedene erweiterte Transaktionsmodelle
- Erläutern wie die Verfügbarkeit verteilter transaktionaler Systeme durch Queued Transactions" verbessert werden kann
- Erklären typische Nebenläufigkeitsanomalien
- Erläutern mit konkreten Beispielen was Wiederherstellbarkeit und Striktheit bedeuten
- Erklären Ziele und Funktionsweise von Sperrverfahren, hierarchischen Sperrverfahren und zusätzlichen Sperrmodi
- Erläutern Isolationsstufen zur Abschwächung des Synchronisationsaufwands
- Erklären die grundlegenden Aufgaben und Funktionen eines Recovery Managers"
- Unterscheiden verschiedene Klassen von Wiederherstellungsalgorithmen
- Erklären Zweck und Funktionsweise von Checkpoints" und Fuzzy Checkpoints"

		• Erklären im Detail wie das Zwei-Phasen Freigabeprotokoll funktioniert • Erläutern Ziele und Funktionsweise des Drei-Phasen-Freigabeprotokolls und Paxos-Commit • Erläutern die Funktionsweise verteilter Transaktionssysteme auf der Basis der standardisierten Schnittstellen in X-Open/DTP
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Studienrichtung Data bases and knowledge representation Master of Science Data Science 20212
10	**Method of examination**	Klausur (60 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english
16	**Bibliography**	siehe Lehrveranstaltungen

1	**Module name** 39155	**Daten erfassen in den DH** Collecting data in DH	**5 ECTS**
2	Courses / lectures	Seminar: Data Collection in Digital Humanities Seminar: Collecting and Annotating Multimodal Corpora Seminar: Computational Approaches to Storytelling Seminar: Building a TV Archive for Research	- - - -
3	Lehrende	Prof. Dr. Anastasia Glawion Prof. Dr. Peter Uhrig Dr. Sabine Lang Katrin Rohrbacher Prof. Dr. Agnes Michaela Mahlberg	

4	**Module coordinator**	Dr. Sabine Lang
5	**Contents**	• Festlegung des Zwecks eines Datenverwaltungssystems (zur gezielten Dimensionierung des Erfassungsaufwands) • Dazu Definition von geisteswissenschaftlichen Fragestellungen • Definition von dazu passenden Datenauswertungen (Berichte, Statistiken, Übersichten, graphische Darstellungen, Tabellen u. dergl.) • Formulierung von (Such- und Auswertungs-) Anfragen an das Speicherungssystem, Anfragesprachen wie SQL, SPARQL, Cypher und ähnlichem • Auswahl von Speicherungssystemen (relational, Graph-DB, NoSQL, XML-Datenbanken, Document Stores etc.) • Entwurf von Multimedia-Datenbanken (Schema) • Formulieren von Anfragen an Multimedia-Datenbanken • Programmentwicklung (mit Web-Schnittstelle und DatenbankZugriff, nicht unbedingt Programmieren, aber Spezifizieren, z.B. mit der UML) • Oberflächengestaltung (besonders wichtig für einfaches Erfassen!)
6	**Learning objectives and skills**	Die Studierenden können die erlernten Kompetenzen über Multimediadatenbanken auf Themenfelder der Geisteswissenschaften übertragen Die Studierenden • lernen unterschiedliche Anwendungsgebiete von Multimedialen und objektorientierten Datenbanken in den Digital Humanities kennen. • übertragen die in der Informatik erlernten Kompetenzen auf kulturwissenschaftliche Fragestellungen. • abstrahieren die Logik von Datenbanksystemen und bewerten bereits existierende Datenbanken. • entwickeln selbstständig geeignete Konzepte für die Fallstudien. Selbstkompetenz Die Studierenden

		• erweitern eigenständig den Umgang mit komplexen Anwendungen durch Eigenstudium. • überwachen eigenständig ihren Arbeitsfortschritt und die Einhaltung vorgegebener Termine. • festigen grundlegende Kompetenzen des Selbstmanagements und reflektieren den eigenen Lernprozess Sozialkompetenz Die Studierenden • tragen durch kritisches Feedback und Ergebnisdiskussion zum kooperativen und konstruktiven Arbeiten in der Gruppe bei. • verbessern die Diskussionskultur, indem sie auf hohem Niveau Inhalte und methodische Zugänge argumentativ vertreten. • erlernen den Umgang mit Kritik als Kritisierende und Kritisierte.
7	**Prerequisites**	Parallel wird dazu empfohlen: eBusiness Technologies und Evolutionäre Informationssysteme
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Digital Humanities Master of Science Data Science 20212 MA Digital Humanities
10	**Method of examination**	schriftlich/mündlich
11	**Grading procedure**	schriftlich/mündlich (100%)
12	**Module frequency**	Only in winter semester Wird in der Regel im Wintersemester angeboten.
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english
16	**Bibliography**	Wird auf studon bekannt gegeben und laufend aktualisiert.

1	**Module name** 39160	**Daten visualisieren in den DH** Visualising data in DH	**5 ECTS**
2	Courses / lectures	Masterseminar: Seminar vertiefte Methoden der Kulturgeographie MA: Qualitiative Methoden in der Gesellschaft-Umweltforschung (2 SWS)	5 ECTS
		Masterseminar: Seminar vertiefte Methoden der Kulturgeographie MA: GIS in der Human-/ Kulturgeographie (2 SWS)	5 ECTS
		Seminar: Pattern Recognition in the Humanities	-
3	Lehrende	Lena Schlegel Prof. Dr. Blake Walker Dr. Sabine Lang	

4	**Module coordinator**	Christian Sandig
5	**Contents**	Datenbestände der Geisteswissenschaften werden dank graphischer Oberflächen, die die entstehenden hochdimensionalen Metadaten großer Bestände visualisieren können, aufbereitet. Die Visualisierungsstrategien der Informationswissenschaft und der Datenanalyse sollen ausführlich diskutiert und auf ihre wissenschaftliche Aussagekraft überprüft werden. Im Gegensatz zum manuellen Ansatz kann in diesem Fall mit einer signifikanten Verbesserung im Hinblick auf Schnelligkeit, Genauigkeit sowie Reproduzierbarkeit gerechnet werden. Die Visualisierung von Daten ist von unschätzbarem Wert zum eigenen Verständnis für Zusammenhänge in großen Datensätzen, und zum Aufbereiten der Informationen für Dritte. Das Auffinden von Tendenzen in Daten wird oftmals wesentlich beschleunigt oder erst möglich durch gezieltes Darstellen und Gegenüberstellen von Informationen. Die im Informatik-Modul erworbenen technischen Kompetenzen werden dazu in die Geisteswissenschaften übertragen und die erlernten Darstellungsmöglichkeiten werden in Bezug auf ihre Vor- und Nachteile für spezifische gegebene Datensätze evaluiert.
6	**Learning objectives and skills**	Die Studierenden: • Analysieren die Struktur der Daten in Fallbeispielen und übertragen die erlernten Kompetenzen aus den Informationswissenschaften in die geisteswissenschaftlichen Themen. • Bewerten diverse technische Möglichkeiten zur Visualisierung von Daten hinsichtlich ihrer Anwendbarkeit für spezifische geisteswissenschaftliche Datensätze • Wenden unter impulsgebender Anleitung die erlernten Konzepte auf konkrete ausgewählte Anwendungsfälle an • Erkennen wesentliche Merkmale eines Datensatzes und stellen diese grafisch gegenüber • Unterscheiden zwischen der Visualisierung zu Publikationszwecken und der Exploration von Zusammenhängen zu Forschungszwecken

		• Eröffnen sich im interdisziplinären Austausch Zugänge zu verwandten Disziplinen • Erlernen unterschiedliche Vorgehensweisen zur Markierung von Daten • Entwickeln Konzepte zur Darstellung von hochdimensionalen Metadaten Selbstkompetenz Die Studierenden • erweitern eigenständig den Umgang mit komplexen Anwendungen durch Eigenstudium. • überwachen eigenständig ihren Arbeitsfortschritt und die Einhaltung vorgegebener Termine. • festigen grundlegende Kompetenzen des Selbstmanagements und reflektieren den eigenen Lernprozess Sozialkompetenz Die Studierenden • tragen durch kritisches Feedback und Ergebnisdiskussion zum kooperativen und konstruktiven Arbeiten in der Gruppe bei. • verbessern die Diskussionskultur, indem sie auf hohem Niveau Inhalte und methodische Zugänge argumentativ vertreten. • erlernen den Umgang mit Kritik als Kritisierende und Kritisierte.
7	**Prerequisites**	Multimedia- und objektorientierte Datenbanken (empfohlen) Teilnahme Daten erfassen in den DH (empfohlen) Informationsvisualisierung (parallel dazu empfohlen)
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Digital Humanities Master of Science Data Science 20212
10	**Method of examination**	schriftlich/mündlich
11	**Grading procedure**	schriftlich/mündlich (100%)
12	**Module frequency**	Only in winter semester Wird in der Regel im Wintersemester angeboten.
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english
16	**Bibliography**	Wird auf studon bekannt gegeben und laufend aktualisiert.

1	**Module name** 901895	**Deep Learning** Deep learning	**5 ECTS**
2	Courses / lectures	Vorlesung: Deep Learning (2 SWS) Übung: DL Exercise (2 SWS)	2,5 ECTS 2,5 ECTS
3	Lehrende	Tomas Arias Vergara Dr.-Ing. Dr. Soroosh Tayebi Arasteh Prof. Dr.-Ing. Andreas Maier Zijin Yang	

4	**Module coordinator**	Prof. Dr.-Ing. Andreas Maier
5	**Contents**	Deep Learning (DL) has attracted much interest in a wide range of applications such as image recognition, speech recognition and artificial intelligence, both from academia and industry. This lecture introduces the core elements of neural networks and deep learning, it comprises: • (multilayer) perceptron, backpropagation, fully connected neural networks • loss functions and optimization strategies • convolutional neural networks (CNNs) • activation functions • regularization strategies • common practices for training and evaluating neural networks • visualization of networks and results • common architectures, such as LeNet, Alexnet, VGG, GoogleNet • recurrent neural networks (RNN, TBPTT, LSTM, GRU) • deep reinforcement learning • unsupervised learning (autoencoder, RBM, DBM, VAE) • generative adversarial networks (GANs) • weakly supervised learning • applications of deep learning (segmentation, object detection, speech recognition, ...) The accompanying exercises will provide a deeper understanding of the workings and architecture of neural networks.
6	**Learning objectives and skills**	The students • explain the different neural network components, • compare and analyze methods for optimization and regularization of neural networks, • compare and analyze different CNN architectures, • explain deep learning techniques for unsupervised / semi-supervised and weakly supervised learning, • explain deep reinforcement learning, • explain different deep learning applications, • implement the presented methods in Python, • autonomously design deep learning techniques and prototypically implement them, • effectively investigate raw data, intermediate results and results of Deep Learning techniques on a computer,

		• autonomously supplement the mathematical foundations of the presented methods by self-guided study of the literature, • discuss the social impact of applications of deep learning applications.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 2
9	**Module compatibility**	Pflichtmodul Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten) Written exam, 90 min. *
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Ian Goodfellow, Yoshua Bengio, Aaron Courville: Deep Learning. MIT Press, 2016. • Christopher Bishop: Pattern Recognition and Machine Learning, Springer Verlag, Heidelberg, 2006 • Yann LeCun, Yoshua Bengio, Geoffrey Hinton: Deep learning. Nature 521, 436444 (28 May 2015)

1	**Module name** 39150	**DH Vertiefung** DH specialisation	**5 ECTS**
2	Courses / lectures	Seminar: Vertiefung in die Digital Humanities (2 SWS)	5 ECTS
3	Lehrende	Dr. Marianna Grachova Prof. Dr. Agnes Michaela Mahlberg	

4	**Module coordinator**	Dr. Dominik Kremer
5	**Contents**	In kritischer Auseinandersetzung werden den Studierenden neben der Geschichte und den Entwicklungen auch die aktuellen Fachdebatten und unterschiedlichen Standpunkte der Digital Humanities auf internationaler Ebene vermittelt. In Fallstudien wird so ein vertiefter Einstieg in die Fachkultur gegeben. Dabei werden in Themenschwerpunkten aktuelle Forschungsansätze und Methoden hinterfragt und mit profunden Kenntnissen der hermeneutischen Analyse strukturiert, kategorisiert und reflektiert.
6	**Learning objectives and skills**	Die Studierenden verfügen über ein vertieftes Fachwissen, das sie befähigt, wissenschaftliche Herausforderungen und Methoden in den Digital Humanities zu verstehen und kritisch einzuschätzen. Die Studierenden sind nach erfolgreichem Abschluss in der Lage, die Vielfalt digitaler Methoden in den Geistes- und Kulturwissenschaften zu kennen und können ihre Anwendungsfelder selbständig spezifizieren. Fachkompetenz Wissen Die Studierenden • kennen die thematische Breite des Faches • kennen fachspezifische Terminologie und können sie in Diskussionen und schriftlichen Arbeiten anwenden • erlernen die Grundlagen der theoretischen Methoden Verstehen Die Studierenden • können durch die Geschichte und Inhalte des Faches reflektiert wiedergeben Anwenden Die Studierenden Evaluieren Beurteilen Die Studierenden • können die fachspezifische Terminologie in Diskussionen und schriftlichen Arbeiten anwenden • übertragen die Standards zur guten wissenschaftlichen Praxis in den eigenen Arbeiten • entscheiden auf Grund ihrer Kenntnisse über die notwendige methodologische Vorgehensweise bei Datenanalysen • stellen passende Kriterien für anwendungs- und Methodentheoretisches Arbeiten auf • gewichten unterschiedliche Forschungsmeinungen und • stufen theoretische Ansätze nach Machbarkeit ein

7	**Prerequisites**	Keine
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Digital Humanities Master of Science Data Science 20212
10	**Method of examination**	schriftlich/mündlich (90 Minuten)
11	**Grading procedure**	schriftlich/mündlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	Wird auf studon bekannt gegeben

1	**Module name** 44361	**Dienstgüte von Kommunikationssystemen** Quality of service in communication systems	**5 ECTS**
2	Courses / lectures	Vorlesung: Quality of Service in Communications (2 SWS) (SoSe 2025) Übung: Quality of Service in Communications (Ex-QoSiC) (2 SWS) (SoSe 2025)	2,5 ECTS 2,5 ECTS
3	Lehrende	Prof. Dr. Reinhard German Anna Baron	

4	**Module coordinator**	Prof. Dr. Reinhard German
5	**Contents**	Zunächst wird der Begriff der Dienstgüte (Quality-of-Service, QoS) eingegrenzt und es werden die wichtigsten Ansätze zur Erzielung von Dienstgüte besprochen und in ausgewählten Netztechnologien untersucht. Dann werden unterschiedliche Methoden vorgestellt, mit denen Systeme bezüglich ihrer Dienstgüte bewertet und ausgelegt werden können: • Netzplanung und optimierung, • stochastische Analyse (Markow-Ketten, Warteschlangen), • Netzwerksimulation, • deterministische Analyse mit Network Calculus zur Ermittlung von Dienstgütegarantien • Messung (HW-, SW-, Hybrid-Monitoring, Benchmarks). Alle Methoden werden an Beispielen demonstriert. *Contents:* We introduce the term quality-of-service (QoS), discuss important approaches to achieve certain degrees of QoS, and show how the implementation in computer networks. Then a number of methodologies to assess and design systems with respect to their QoS: • network planning and optimization, • network simulation, • stochastic analysis (Markov chains, non-Markovian models, queuing systems), • deterministic analysis with network calculus to determine QoS guarantees • measurements (hardware, software, and hybrid monitoring, benchmarks). All methods are illustrated by examples.
6	**Learning objectives and skills**	Die Studierenden erwerben • Kenntnisse in Methoden zur Modellierung und Bewertung von quantitativen, nicht-funktionalen Eigenschaften von vernetzten Systemen • Kenntnisse in Mechanismen von vernetzten Systemen zur Erzielung von Dienstgüte *Learning targets and competences:* The students get • experience in methods to model and evaluate quantitative, non-functional properties of computer networks and related systems

		• knowledge of mechanisms of computer networks to achieve quality-of-service
7	**Prerequisites**	Rechnerkommunikation, Kommunikationssysteme, grundlegende Programmierkenntnisse (optimal in R und C++)
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Simulation and Numerics Master of Science Data Science 20212
10	**Method of examination**	schriftlich oder mündlich (90 Minuten)
11	**Grading procedure**	schriftlich oder mündlich (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Kurose, Ross. Computer Networking: A Top-Down Approach Featuring the Internet. 6th Ed., Addison Wesley, 2013 • W. Stallings. Data and Computer Communications, 10th ed., Pearson Education, 2014 • W. Stallings. Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud, Pearson Education, 2016

1	**Module name** 65879	**Differentialgeometrie** Differential geometry	**10 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt!	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	apl. Prof. Dr. Jens Habermann
5	**Contents**	Eine Auswahl aus den folgenden Themen: • Mannigfaltigkeiten (Tangentialvektoren, Vektorfelder, Flüsse) • Vektorbündel (Tensorbündel und (Semi-)Riemannsche Strukturen) • Differentialformen (Orientierung, Integration) • Affine Zusammenhänge (Paralleltransport, Krümmung) • Geodäten (Distanz, Jacobi Vektorfelder) • Einführung in der geometrischen Analysis • Symplektische und Poisson-Strukturen • Liegruppen und glatte Wirkungen
6	**Learning objectives and skills**	Die Studierenden • nennen und erklären die grundlegende Theorie der Mannigfaltigkeiten und ihrer Struktur, • erkennen und verwenden zusätzliche geometrische Strukturen auf Mannigfaltigkeiten wie zum Beispiel affine Zusam-menhänge, Riemannsche Metriken oder symplektische Formen.
7	**Prerequisites**	Grundkenntnisse in Topologie, Analysis, Lineare Algebra und Gewöhnliche Differentialgleichungen
8	**Integration in curriculum**	semester: 2
9	**Module compatibility**	Studienrichtung Mathematische Theorie / Grundlagen der Data Science Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 210 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	
16	**Bibliography**	• S. Lang: "Differential and Riemannian manifolds" • J.M. Lee: "Introduction to Riemannian Manifolds" • R.L. Bishop and R.J. Crittenden, "Geometry of manifolds"

		• F. Warner: "Foundations of Differentiable Manifolds and Lie Groups" • M. Do Carmo: “Riemannian Geometry”

1	**Module name** 46538	**Digital Chemistry**	**5 ECTS**
2	Courses / lectures	Seminar: Digital chemistry (3 SWS) (SoSe 2025)	5 ECTS
3	Lehrende	Prof. Dr. Carolin Müller	

4	**Module coordinator**	Prof. Dr. Carolin Müller
5	**Contents**	• examination of practical application of data science methods in handling chemical data with a focus on both categorical or numerical data, such as catalytic turnover numbers or reaction yields, and discrete/continuous data, e.g., from spectroscopic experiments (such as, IR-, NMR- or UVvis absorption spectra); • introduction to structural representations and electronic descriptors; • practical introduction to computational methods for high-throughput generation of reference data (e.g., DFT, DFTB+, and MD simulations); • curation and construction of a database and usage of database in practical applications
6	**Learning objectives and skills**	Students are able to ... • apply data science methods effectively in handling chemical data. • utilize structural representations and electronic descriptors to analyse chemical data and draw meaningful insights. • employ computational methods for (high-throughput) generation of chemical reference data. • construct and curate a database of (quantum) chemical data, and demonstrate the ability to utilize it in practical applications. • independently apply the acquired expertise in data science and computational chemistry to address scientific questions. • categorize their scientific results according to given instructions and articulate them accurately in written form, adhering to linguistic conventions. • present their findings and the scientific context of their projects in graphically appealing presentations, communicating proficiently in English during discussions and presentations.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Chemistry Master of Science Data Science 20212
10	**Method of examination**	Variabel pÜL: Completion of a programming project with submission of both code and documentation and 6-minute presentation (+20 minutes discussion) of the project *
11	**Grading procedure**	Variabel (bestanden/nicht bestanden) pÜL 0% - pass/fail
12	**Module frequency**	Only in summer semester

13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• T. Engel, Thomas and J. Gasteiger, “Chemoinformatics: Basic Concepts and Methods”, Wiley-VCH, Weinheim 2018, ISBN 978-3-527-33109-3 (book) • A. Szabo and N. S. Ostlund, “Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory”, Courier Corporation, 2012, ISBN 0-486-69186-2 (book) • P. O. Dral, “Quantum Chemistry in the Age of Machine Learning”, Elsevier 2022, DOI 10.1016/C2020-0-03124-5 (book)

1	**Module name** 93500	**Digitale Signalverarbeitung** Digital signal processing	**5 ECTS**
2	Courses / lectures	Übung: Übung zu Digitale Signalverarbeitung (1 SWS) Vorlesung: Digitale Signalverarbeitung (3 SWS)	- 5 ECTS
3	Lehrende	Dr.-Ing. Heinrich Löllmann	

4	**Module coordinator**	Dr.-Ing. Heinrich Löllmann

5	**Contents**	• A/D and D/A conversion
		•
		  º Time-domain and z-domain reprenstations
		  º Signal flow graphs
		  º Analytic computation of the frequency response
		  º Special systems (allpass, minimum phase, and linear phase systems)
		• Design of recursive and non-recursive filters
		• Multirate systems and filter banks
		• Frequency-domain signal analysis
		• Effects of finite wordlength

6	**Learning objectives and skills**	The students • analyze discrete-time linear time-invariant systems by determining the describing function and parameters • apply fundamental approaches for the design of discrete-time systems and evaluate their performance • understand the differences between various methods for spectral analysis and apply them to the analysis of given signals • understand methods to represent multirate systems and apply them for the representation of filter banks • know basic methods for the analysis of finite word length effects and apply them to discrete-time linear time-invariant systems.
7	**Prerequisites**	The course assumes knowledge of the basic theory of discrete-time deterministic signals as taught in lectures such as Signals and Systems II.
8	**Integration in curriculum**	semester: 5
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten) Written exam of 90 min duration. The following resources are allowed for this exam: a handwritten formulary totalling a two-sided DIN A4 sheet of paper and a non-programmable calculator. Answers can be given either in English or German
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h

		Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• A.V. Oppenheim and R. W. Schafer: Discrete-Time Signal Processing, Prentice Hall • J.G. Proakis and D.G. Manolakis: Digital Signal Processing, Prenctice Hall

1	**Module name** 39195	**Digital Humanities Seminar** DH specialisation	**5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Agnes Michaela Mahlberg
5	**Contents**	In kritischer Auseinandersetzung werden den Studierenden neben der Geschichte und den Entwicklungen auch die aktuellen Fachdebatten und unterschiedlichen Standpunkte der Digital Humanities auf internationaler Ebene vermittelt. In Fallstudien wird so ein vertiefter Einstieg in die Fachkultur gegeben. Dabei werden in Themenschwerpunkten aktuelle Forschungsansätze und Methoden hinterfragt und mit profunden Kenntnissen der hermeneutischen Analyse strukturiert, kategorisiert und reflektiert.
6	**Learning objectives and skills**	Die Studierenden verfügen über ein vertieftes Fachwissen, das sie befähigt, wissenschaftliche Herausforderungen und Methoden in den Digital Humanities zu verstehen und kritisch einzuschätzen. Die Studierenden sind nach erfolgreichem Abschluss in der Lage, die Vielfalt digitaler Methoden in den Geistes- und Kulturwissenschaften zu kennen und können ihre Anwendungsfelder selbständig spezifizieren. Fachkompetenz Wissen Die Studierenden - kennen die thematische Breite des Faches - kennen fachspezifische Terminologie und können sie in Diskussionen und schriftlichen Arbeiten anwenden - erlernen die Grundlagen der theoretischen Methoden Verstehen Die Studierenden - können durch die Geschichte und Inhalte des Faches reflektiert wiedergeben Anwenden Die Studierenden - können die fachspezifische Terminologie in Diskussionen und schriftlichen Arbeiten anwenden - übertragen die Standards zur guten wissenschaftlichen Praxis in den eigenen Arbeiten Evaluieren (Beurteilen) Die Studierenden - entscheiden auf Grund ihrer Kenntnisse über die notwendige methodologische Vorgehensweise bei Datenanalysen - stellen passende Kriterien für anwendungs- und Methodentheoretisches Arbeiten auf - gewichten unterschiedliche Forschungsmeinungen und - stufen theoretische Ansätze nach Machbarkeit ein
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Digital Humanities Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung
11	**Grading procedure**	Seminarleistung (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h

14	**Module duration**	1 semester
15	**Teaching and examination language**	
16	**Bibliography**	Wird auf studon bekannt gegeben

1	**Module name** 65917	**Discrete optimization I**	**5 ECTS**
2	Courses / lectures	Vorlesung: Discrete Optimization I (2 SWS) Übung: Tutorial zu Discrete Optimization I (1 SWS)	5 ECTS -
3	Lehrende	Florian Rösel Dr. Kevin-Martin Aigner	

4	**Module coordinator**	Prof. Dr. Frauke Liers-Bergmann
5	**Contents**	Theoretical and practical fundamentals of solving difficult mixed-integer linear optimization problems (MIPs) constitute the main focus of this lecture. At first, the concept of NP-completeness and a selection of common NP-complete problems will be presented. As for polyhedral theory, fundamentals concerning the structure of faces of convex polyhedra will be covered. Building upon these fundamentals, cutting plane algorithms as well as branch-and-cut algorithms for solving MIPs will be taught. Finally, some typical problems of discrete optimization, e.g., the knapsack problem, the traveling salesman problem or the set packing problem will be discussed.
6	**Learning objectives and skills**	Students • will gain basic theoretical knowledge of solving mixed-integer linear optimization problems (MIPs), • are able to solve MIPs with the help of state-of-the-art optimization software.
7	**Prerequisites**	Recommended: Linear and Combinatorial Optimization
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Databased optimization Master of Science Data Science 20212
10	**Method of examination**	Klausur (60 Minuten) Klausur (60min) *
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 65933	**Discrete optimization II**	**5 ECTS**
2	Courses / lectures	Vorlesung: Discrete Optimization II (2 SWS) (SoSe 2025) Übung: Übung Diskrete Optimierung II (1 SWS) (SoSe 2025)	5 ECTS -
3	Lehrende	Prof. Dr. Timm Oertel	

4	**Module coordinator**	Prof. Dr. Timm Oertel
5	**Contents**	In this lecture, we cover theoretical aspects and solution strategies for difficult integer and mixed-integer optimization problems. First, we show the equivalence between separation and optimization. Then, we present solution strategies for large-scale optimization problems, e.g., decomposition methods and approximation algorithms. Finally, we deal with conditions for the existence of integer polyhedra. We also discuss applications for example from the fields of engineering, finance, energy or public transport.
6	**Learning objectives and skills**	Students • use basic terms of discrete optimization • model real-world discrete optimization problems, determine their complexity and solve them with appropriate mathematical methods.
7	**Prerequisites**	Recommended: Knowledge in linear and combinatorial optimization, discrete optimization I
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Databased optimization Master of Science Data Science 20212
10	**Method of examination**	mündlich (20 min) *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Lecture notes • Bertsimas, Weismantel: Optimization over Integers, Dynamic Ideas, 2005 • Conforti, Cornuéjols, Zambelli: Integer Programming, Springer 2014

		• Nemhauser, Wolsey: Integer and Combinatorial Optimization, Wiley 1994 • Schrijver: Combinatorial optimization Vol. A-C, Springer 2003 • Schrijver: Theory of Linear and Integer Programming, Wiley, 1986 • Wolsey: Integer Programming, Wiley, 2021

1	**Module name** 65910	**Discrete optimization III**	**5 ECTS**
2	Courses / lectures	Vorlesung: Diskrete Optimierung III (Optimization in Industry and Economy) (2 SWS) Übung: Tutorial zu Diskrete Optimierung III (1 SWS)	5 ECTS -
3	Lehrende	Sebastian Denzler Prof. Dr. Frauke Liers-Bergmann	

4	**Module coordinator**	Prof. Dr. Timm Oertel
5	**Contents**	In this lecture we will discuss selected topics in discrete and mixed-integer optimization. Possible topics include lattice methods, integer programming in fixed dimension, recent research on (mixed) integer linear and/or (mixed) integer nonlinear programming and so on. The specific topics may vary and will be announced in due time. FORMERLY: In this lecture, we cover theoretical aspects and solution strategies for difficult integer and mixed-integer optimization problems. First, we show the equivalence between separation and optimization. Then, we present solution strategies for large-scale optimization problems, e.g., decomposition methods and approximation algorithms. Finally, we deal with conditions for the existence of integer polyhedra. We also discuss applications for example from the fields of engineering, finance, energy or public transport.
6	**Learning objectives and skills**	Students • use basic terms of discrete optimization • model real-world discrete optimization problems, determine their complexity and solve them with appropriate mathematical methods.
7	**Prerequisites**	Recommended: Knowledge in linear and combinatorial optimization, discrete optimization I and II
8	**Integration in curriculum**	semester: 2
9	**Module compatibility**	Studienrichtung Databased optimization Master of Science Data Science 20212
10	**Method of examination**	mündlich (15 Minuten)
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Lecture notes

		• Bertsimas, Weismantel: Optimization over Integers, Dynamic Ideas, 2005 • Conforti, Cornuéjols, Zambelli: Integer Programming, Springer 2014 • Nemhauser, Wolsey: Integer and Combinatorial Optimization, Wiley 1994 • Schrijver: Combinatorial optimization Vol. A - C, Springer 2003 • Schrijver: Theory of Linear and Integer Programming, Wiley, 1986 • Wolsey: Integer Programming, Wiley, 2021

1	**Module name** 65872	**Dynamical System Theory for Data Scientists**	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Dynamical System Theory for Data Scientists (3 SWS) Übung: Übungen zu Dynamical System Theory for Data Scientists (1 SWS)	5 ECTS -
3	Lehrende	Prof. Dr. Marius Yamakou	

4	**Module coordinator**	Prof. Dr. Marius Yamakou
5	**Contents**	• The anatomy of a dynamical system • Fixed points, stability, Eigenvalues, and eigenvectors • Bifurcations and Limit cycles • Normal forms and center manifolds and Invariant manifolds • Chaos • Network dynamics and dynamical systems on a network • Controllability • Numerical and computational techniques • Interaction between dynamical system theory and machine learning • Applications in e.g., physics, biology, engineering, economics, and social sciences • The accompanying exercises will provide a deeper understanding of dynamical system theory necessary for analysis of data generated by a dynamical systems
6	**Learning objectives and skills**	The Students will learn: • Component of dynamical system, its state variables and evolution in phase space • How to identify and analyze fixed points and limit cycles • How to find bifurcation points and their significances • About invariant manifolds and their role in dynamical systems • How to derive and use of normal forms to simplify nonlinear systems • Center manifolds and their relevance • How to characterize chaotic systems • Understand emergent behaviors of dynamical systems on a network • Understand the concept of controllability in a dynamical system • Exploration of the relationship between dynamical systems and machine learning – • Understand how dynamical systems theory contributes to understanding and solving problems in different domains
7	**Prerequisites**	• Basics Calculus and Linear algebra • Very good programming skills in Python or Matlab
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Mathematische Theorie / Grundlagen der Data Science Master of Science Data Science 20212

10	**Method of examination**	Variabel
11	**Grading procedure**	Variabel (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	
16	**Bibliography**	• Ghosh, Asish. Dynamic systems for everyone: understanding how our world works. Springer, 2016. • Lynch, Stephen. Dynamical systems with applications using python. Switzerland: Springer International Publishing, 2018.

1	**Module name** 741318	**Einführung in die Bioinformatik für die Translationale Medizin**	**5 ECTS**
2	Courses / lectures	Vorlesung: Einführung in die Bioinformatik für die Translationale Medizin (2 SWS)	2,5 ECTS
3	Lehrende	PD Dr. Meik Kunz	

4	**Module coordinator**	PD Dr. Meik Kunz
5	**Contents**	Das Zeitalter des Big Data produziert immer größere Datenmengen in der Medizin, die es gilt, wissenschaftlich auszuwerten. Die Bioinformatik stellt Werkzeuge und Analysetools bereit, die erlauben, Muster und Zusammenhänge in Daten zu erkennen, welche zu einem besseren Verständnis von Krankheitsmechanismen und neuen diagnostischen und therapeutischen Ansätzen beitragen. In der Vorlesung lernen die Studierenden Grundlagen, Methoden und Konzepte der Bioinformatik für die medizinische Forschung kennen.

6	**Learning objectives and skills**	Die Studierenden
		• haben einen grundlegenden Überblick über Werkzeuge, Forschungsplattformen und Fragestellungen der Bioinformatik in Bezug auf die medizinische Anwendung
		• kennen grundlegende Konzepte, Algorithmen und statistische Grundlagen der Bioinformatik für die medizinische Forschung
		• kennen grundlegende Konzepte der Informationssysteme und Datamining für die Bioinformatik
		• kennen Methoden der Hochdurchsatz-Sequenzierung und Molekulardiagnostik
		• kennen Standardmethoden für DNA-, RNA- und Protein-Omicsanalysen
		• kennen Standardmethoden für das Drug-Targeting und die molekulare Modellierung
		• kennen grundlegende Methoden für die klinische Entscheidungsunterstützung (personalisierte Medizin)
		• können selbstständig bioinformatische Analysen für medizinische Fragestellungen durchführen
		Fachkompetenz
		Wissen
		•
		  ◦ Methoden der Analyse von Hochdurchsatzdaten
		  ◦ Methoden der Sequenzanalyse
		  ◦ Methoden der RNA- und Proteinstrukturanalyse
		  ◦ Methoden der statistischen Analyse in der Bioinformatik
		  ◦ Methoden des Maschinellen Lernens für die klinische Entscheidungsunterstützung
		  ◦ Methoden für das Drug-Targeting und die molekulare Modellierung
		  ◦ Methoden für die Modellierung von Signalwegen und biologischer Systeme
		  ◦ wenden Techniken und Algorithmen der Bioinformatik auf biologische und medizinische Fragestellungen an

		Erschaffen entwickeln Analysewege und -skripte für bioinformatische Analysen
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Medical Data Science Master of Science Data Science 20212
10	**Method of examination**	mündlich Die Prüfungsdauer ist 30 Minuten. *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	

1	**Module name** 65070	**Einführung in die Darstellungstheorie** Introduction to representation theory	**10 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Peter Fiebig
5	**Contents**	• Darstellungen endlicher Gruppen • Module über Ringen • Halbeinfache Ringe • Kategorien und Funktoren • Anwendungen Die Präsentation des Stoffes erfolgt in Vorlesungsform. Die weitere Aneignung der wesentlichen Begriffe und Techniken erfolgt durch wöchentliche Hausaufgaben.
6	**Learning objectives and skills**	Die Studierenden • nennen und erläutern die grundlegenden Begriffe der Darstellungstheorie anhand beispielhaft ausgewählter Kapitel und erkennen und erklären deren Zusammenhänge; • ordnen Methoden aus der Algebra in einen übergreifenden Kontext ein und wenden diese an; • analysieren und bewerten algebraische Strukturen und erkennen Zusammenhänge; • klassifizieren und lösen selbstständig algebraische Probleme
7	**Prerequisites**	empfohlen: Modul Algebra
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Mathematische Theorie / Grundlagen der Data Science Master of Science Data Science 20212
10	**Method of examination**	Übungsleistung mündlich (20 Minuten) Übungsleistung: wöchentliche Hausaufgaben (ca 4 Aufgaben pro Woche) *
11	**Grading procedure**	Übungsleistung (bestanden/nicht bestanden) mündlich (100%)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 105 h Independent study: 195 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	• C. Meusburger, Vorlesungsskript "Einführung in die Darstellungstheorie" • S. Sternberg, "Group Theory and Physics", CUP 1994

		• M. Artin, "Algebra", Pearson, 2011.

<table>
<tr><td>1</td><td>Module name
47576</td><td>Enterprise Application Development und Evolutionäre Informationssysteme
eBusiness technologies and evolutionary information systems</td><td>5 ECTS</td></tr>
<tr><td>2</td><td>Courses / lectures</td><td>Vorlesung: Enterprise Application Development (ehemals eBusiness Technologies) (2 SWS) (SoSe 2025)

Vorlesung: Evolutionäre Informationssysteme (2 SWS) (SoSe 2025)</td><td>2,5 ECTS

2,5 ECTS</td></tr>
<tr><td>3</td><td>Lehrende</td><td>Nadja Deuerlein
Florian Irmert
Prof. Dr.-Ing. Richard Lenz</td><td></td></tr>
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<table>
<tr><td>4</td><td>Module coordinator</td><td>Prof. Dr.-Ing. Richard Lenz</td></tr>
<tr><td>5</td><td>Contents</td><td>EAD

Themen u.a. aus den folgenden Bereichen:
Softwareengineering wie z. B. Design Pattern
Softwarearchitektur wie z. B. Skalierbarkeit, Wartbarkeit und Erweiterbarkeit
Web Frameworks wie z. B. React
User Experience und Usability wie z. B. UI Guidelines
Agile Softwarentwicklung wie z. B. Scrum
DevOps wie z. B. Continuous Integration
EIS:
Grundlagen rechnergestützter Informationssysteme und organisatorisches Lernen
Erfolgsfaktoren für Projekte
Software Wartung vs. Software Evolution
Architekturmodelle
Grundprinzipien evolutionärer Systeme
Datenqualität in Informationssystemen</td></tr>
<tr><td>6</td><td>Learning objectives and skills</td><td>EAD:
Die Studierenden
können einen Überblick über die Entwicklung von Web-Applikationen geben
wiederholen Grundlagen des Webs, von Datenaustauschformaten und serverseitige Technologien
unterscheiden Herangehensweisen zur dynamischen Generierung von Webseiten
wiederholen Grundlagen des SW-Engineerings
verstehen wichtige Design-Patterns
verstehen die Bedeutung von Software-Architektur
verstehen grundlegende Eigenschaften eines Web-Frameworks
können wichtige Zusammenhänge und Kriterien im Bereich UX erläutern
verstehen agile Vorgehensmodelle zur Software-Entwicklung</td></tr>
</table>

- verstehen die Herausforderungen in Bezug auf den Betrieb von Anwendungen (DevOps)

EIS:

Die Studierenden:

- definieren die Begriffe "Informationssysteme", "evolutionäre Informationssyste" und "organisatorisches Lernen"
- grenzen die Begriffe "Wissen" und "Information" gegeneinander ab
- charakterisieren die in der Vorlesung erläuterten Formen der organisatorischen Veränderung
- erklären das SEKI Modell nach Nonaka und Takeuchi
- nennen Beispiele für die in der Vorlesung behandelten Formen der Wissensrepräsentation in IT-Systemen
- nennen typische Erfolgs- und Risikofaktoren für große IT-Projekte
- erklären die Kraftfeldtheorie nach Kurt Lewin
- unterscheiden Typen von Software gemäß der Klassifikation nach Lehman und Belady
- unterscheiden die in der Vorlesung vorgestellten Arten der Software Wartung
- benennen die Gesetzmäßigkeiten der Software-Evolution nach Lehman und Belady
- bewerten die in der Vorlesung vorgestellten Vorgehensmodelle zur Softwareerstellung im Kontext der E-Typ-Software
- nennen die in der Vorlesung vorgestellten Aspekte der Evolutionsfähigkeit von Software
- erklären, wie die in der Vorlesung vorgestellten Methoden zur Trennung von Belangen beitragen
- erklären das Konzept des "Verzögerten Entwurfs"
- erklären die Vor- und Nachteile generischer Datenbankschemata am Beispiel von EAV und EAV/CR
- charakterisieren die in der Vorlesung vorgestelten Architekurkonzepte
- grenzen die in der Vorlesung vorgestellten Integrationsanforderungen gegeneinander ab
- erklären wie Standards zur Systemintegration beitragen und wo die Grenzen der Standardisierung liegen
- erklären das Prinzip eines Kommunikationsservers und der nachrichtenbasierten Integration
- erklären den Begriff "Prozessintegration"
- definieren den Begriff "Enterprise Application Integration" (EAI)
- unterscheiden die in der Vorlesung vorgestellten Integrationsansätze
- erklären die in der Vorlesung vorgestellten Dimensionen der Datenqualität
- unterscheiden die grundlegenden Messmethoden für Datenqualität
- erklären das Maßnahmenportfolio zur Verbesserung der Datenqualität nach Redman

		• benennen die in der Vorlesung vorgestellten Methoden zur Verbesserung der Datenqualität
7	**Prerequisites**	Programmieren in Java, Datenbanken (SQL)
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Data bases and knowledge representation Master of Science Data Science 20212
10	**Method of examination**	Klausur (60 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	
16	**Bibliography**	siehe Lehrveranstaltungsbeschreibungen

1	**Module name** 65064	**Entscheidungstheorie / Decision Theory** Decision Theory	**5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Frauke Liers-Bergmann
5	**Contents**	• Basic model of decision theory • Decision-making under certainty, uncertainty, and risk • Individual and group decision-making • Multi-criteria decision problems
6	**Learning objectives and skills**	The students • can explain and apply the basic model of decision theory and the presented decision criteria • are familiar with various approaches to determine decision-makers' preferences • recognize and analyze decision situations • are capable of implementing the presented methods • collect and evaluate relevant information and establish connections
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	Studienrichtung Databased optimization Master of Science Data Science 20212 Studienrichtung Data bases and knowledge representation Master of Science Data Science 20212 Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212 Studienrichtung Mathematische Theorie / Grundlagen der Data Science Master of Science Data Science 20212 Studienrichtung Mathematisch statistische Datenanalyse Master of Science Data Science 20212 Studienrichtung Simulation and Numerics Master of Science Data Science 20212 M.Sc. Data Science
10	**Method of examination**	Klausur (60 Minuten) Mündliche Prüfung (30 min.) oder Klausur (60 min.) Oral exam (30 min.) or written exam (60 min.) *
11	**Grading procedure**	Klausur (100%) Exam (100%)
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h

14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Will be announced by the lecturer.

1	**Module name** 66063	**Experimentalphysik 1 + 2: Mechanik, Wärmelehre und Elektrodynamik** Experimental physics 1 + 2: Mechanics, thermodynamics and electrodynamics	**15 ECTS**
2	Courses / lectures	Übung: Übungen zur Experimentalphysik 1 für Physikstudierende: Mechanik (2 SWS, WiSe 2025)	-
		Vorlesung: Experimentalphysik 1 für Physikstudierende: Mechanik (5 SWS, WiSe 2025)	7,5 ECTS
		Vorlesung: Experimentalphysik 2 für Physikstudierende: Wärmelehre und Elektrodynamik (5 SWS, SoSe 2025)	7,5 ECTS
		Übung: Übungen zur Experimentalphysik 2 für Physikstudierende: Wärme und Elektrodynamik (2 SWS, SoSe 2025)	-
		Praktikum: Physikalisches Praktikum zu Experimentalphysik 1+2 (SoSe 2025)	-
3	Lehrende	Prof. Dr. Janina Maultzsch Prof. Dr. Stefan Funk Prof. Dr. Christopher van Eldik Prof. Dr. Claudio Kopper Dr. Jürgen Hößl	

4	**Module coordinator**	Prof. Dr. Peter Hommelhoff Prof. Dr. Janina Maultzsch Prof. Dr. Christopher van Eldik Prof. Dr. Joachim Zanthier
5	**Contents**	**Mechanik** • Einführendes: Gebiete der Physik, Längen- und Geschwindigkeitsskalen, Abgrenzung klassische/ Quanten-/ relativistische Physik; Physikalische Größen; Messungen und Messfehler • Mechanik eines Massenpunktes: Bewegung auf Raumkurven, Geschwindigkeit, Beschleunigung, Drehbewegungen, Längen- und Zeitmessung; Masse, Impuls, Impulserhaltung; Newtonsche Gesetze; Kraftfelder, Arbeit, Potential, Energie, Energiesatz, Leistung; Bewegungsgleichungen; Drehimpuls, Drehmoment • Bewegte Bezugssysteme und spezielle Relativitätstheorie: Klassisch: Inertialsysteme und Galilei-Transformation; Beschleunigte Bezugssysteme, Scheinkräfte (insb. Zentrifugal, Coriolis); Spezielle Relativitätstheorie: Konstanz der Lichtgeschwindigkeit und ihre Konsequenzen; Lorentz-Transformation; relativistische Phänomene (insbesondere Zeitdilatation, Längenkontraktion, Zwillingsparadoxon); Vierervektoren, Lorentz-Skalarprodukt, relativistische Energie-Impuls-Beziehung • Systeme von Massenpunkten und Stöße: Schwerpunkt, Schwerpunktbewegung, Erhaltungssätze; Stöße: Elastische/

inelastische Stöße, Streuprozesse, relativistische Stöße; Gravitation und Planetenbewegungen, Keplersche Gesetze

- Dynamik starrer Körper: Darstellung von Volumen und Masse als Volumenintegrale; Rotationsenergie, Drehimpuls, Trägheitsmoment; Bewegung des starren Körpers (Kinematik, Gleichgewichtslage, Abrollen); Bewegungsgleichungen (Rotation um feste Achse, freier Kreisel: Nutation, Präzession, Stabilität von Drehachsen)
- Deformierbare feste und flüssige Materialien: Reibung zwischen festen Körpern; Elastische Deformationen (Hooke, Kontraktion, Scherung, Torsion, Biegung); Hydrostatik (Statischer Druck, Auftrieb); Flüssigkeitsgrenzflächen (Oberflächenspannung, Kapillarität); Strömungen (Reibungsfrei: Bernoulli; mit Reibung: Laminar (Hagen-Poiseuille), turbulent (Navier-Stokes); Aerodynamik, cw-Wert, aerodynamische Phänomene)
- Gase: Kompressibilität, barometrische Höhenformel; kinetische Gastheorie (Druck, Verbindung zu absoluter Temperatur, Stoßquerschnitt, freie Weglänge); Maxwell-Verteilung
- Schwingungen und Wellen: Schwingungen: Freier Oszillator, erzwungene Schwingungen, Resonanz, gekoppelte Schwingungen, Überlagerung von Schwingungen; Wellen: Beschreibung, Wellengleichung, Wellenphänomene (Reflexion, Brechung, Beugung, Überlagerung), stehende Wellen, bewegte Sender und Empfänger

Wärmelehre

- Temperatur und Wärmemenge: Wärmephänomene, Temperaturmessung; absolute Temperaturskala; innere Energie und spezifische Wärme; Schmelz- und Verdampfungswärme
- Wärmetransport: Konvektion, Wärmeleitung, Strahlung
- Hauptsätze der Thermodynamik: Zustandsgrößen; Zustandsänderungen und der erste Hauptsatz; Kreisprozesse, zweiter Hauptsatz; Entropie, reversible und irreversible Prozesse, dritter Hauptsatz
- Thermodynamik realer Flüssigkeiten und Gase: Van-der-Waals-Zustandsgleichung; Aggregatzustände und -umwandlungen, Phasendiagramme, kritischer und Tripelpunkt

Elektrodynamik:

- Elektrostatik: Elektrische Ladung; Coulomb-Gesetz; elektrostatisches Feld (Feldstärke, Fluss, 1. Maxwell, Potenzial, Spannung, Multipolentwicklung); Materie in elektrischen Feldern: Leiter, Influenz und Flächenladungen, Kondensatoren, Dielektrika; Energie des E-Feldes
- Elektrischer Strom: Ladungstransport und elektrischer Widerstand (Strom, Stromdichte, Ohm, Kirchhoffsche Regeln, Auf-/Entladen von Kondensatoren); Leitungsmechanismen, T-Abhängigkeit von Widerständen (Metalle, Halbleiter,

		dotierte Halbleiter, Diode, Transistor, Isolatoren, Phänomen der Supraleitung); Stromerzeugung und Strommessung (Galvanisches Element, Spannungsreihe, Brennstoffzelle, Akku, Thermoelement, Peltier-Effekt, Innenwiderstand) • Statische Magnetfelder: Magnetische Wirkungen; Magnetfelder stationärer Ströme (gerader Leiter, Spule); Ampèresches Gesetz; magnetischer Fluss, 2. Maxwell; Vektorpotenzial; Magnetfelder beliebiger Stromverteilungen, Biot-Savart, Ringstrom, Helmholtz-Spulen; Kräfte auf bewegte Ladungen im Magnetfeld (Lorentz-Kraft, Fadenstrahlrohr, e/m, Hall-Effekt, Definition des Ampère); Relativität von E- und B-Feldern • Materie in Magnetfeldern: Magnetische Dipole (auch atomar); Magnetisierung und magnetische Suszeptibilität, Para-, Dia- und Ferromagnetismus (Hysterese, Curie-Temperatur), Antiferro- und Ferrimagnete; Feldgleichungen in Materie, Felder an Grenzflächen, Elektromagnet • Zeitlich veränderliche Felder: Faradaysches Induktionsgesetz; 3. Maxwell; Induktionsphänomene, Selbstinduktion; Energie des magnetischen Feldes; Verschiebungsstrom, 4. Maxwell; Wechselspannung und Wechselstrom (Wechselstromkreise, Generator, Elektromotor, Transformator) • Elektromagnetische Schwingungen und Wellen: Schwingkreise; Hertzscher Dipol (offene Schwingkreise, Dipol-Strahlungsfeld, elektromagnetische Strahlungsquellen); Elektromagnetische Wellen im Vakuum (Wellengleichung, elektromagnetisches Frequenzspektrum); Polarisation; Energie- und Impulstransport, Poynting-Vektor; elektromagnetische Wellen in Resonatoren und Hohlleitern; elektromagnetische Wellen in Materie
6	**Learning objectives and skills**	Die Studierenden • erläutern und erklären die experimentellen Grundlagen und die quantitativ-mathematische Beschreibung mechanischer Vorgänge, der Wärmelehre und elektromagnetischen Phänomene gemäß den detaillierten Themen im Inhaltsverzeichnis • wenden die physikalischen Gesetze und jeweiligen mathematischen Methoden auf konkrete Problemstellungen an • führen Messungen mit Messgeräten typisch für Physiklabore durch • werten Messungen aus, stellen Fehleranalysen auf, führen ein Protokoll und präsentieren die Ergebnisse • arbeiten in kleinen Teams zusammen
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Physics Master of Science Data Science 20212

10	**Method of examination**	Praktikumsleistung Klausur (120 Minuten) Die Note für das Modul wird grundsätzlich durch die Klausur am Ende des zweisemestrigen Zyklus bestimmt. In beiden Semestern werden wöchentlich freiwillig zu lösende Übungsaufgaben angeboten. Die Abgabe der Lösungen innerhalb eines vorgegebenen Zeitraums kann in Gruppen von maximal 3 Studierenden erfolgen. Eine Abgabe handschriftlicher Lösungen online in digitaler Form ist grundsätzlich möglich, gedruckte Lösungen sind in jedem Fall unzulässig. Wird mindestens die Hälfte der in der Summe eines Semesters maximal zu erreichenden Punktzahl aus den abgegebenen Lösungen zu den Übungsaufgaben erreicht, wird ein Bonus von 0.3 bzw. 0.4 pro Semester auf die erzielte Klausurnote gewährt. Maximal kann daraus ein Bonus von 0.6 bzw. 0.7 Notenpunkten für die Gesamtnote des Moduls erzielt werden. *
11	**Grading procedure**	Praktikumsleistung (bestanden/nicht bestanden) Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 180 h Independent study: 270 h
14	**Module duration**	2 semester
15	**Teaching and examination language**	german
16	**Bibliography**	**Allgemeine Lehrbuchreihe zur Experimentalphysik:** • Wolfgang Demtröder, Experimentalphysik 1: Mechanik und Wärme, Springer (2015) • Wolfgang Demtröder, Experimentalphysik 2: Elektrizität und Optik, Springer (2017) **Speziell für Lehramtsstudierende mit didaktischen Hinweisen zur Schulphysik:** • Rainer Müller, Physik für Lehramtsstudierende: Mechanik, de Gruyter Studium (2020) • Roger Erb, Physik für Lehramtsstudierende: Elektrizität und Magnetismus, de Gruyter Studium (2021) • Jan-Peter Meyn, Physik für Lehramtsstudierende: Wärme und Energie, de Gruyter Studium (2020)

1	**Module name** 93174	**Fantastic datasets and where to find them**	**2,5 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt! Yes. We expect compulsory attendance in the first three and in the last seminar sessions, which is to be communicated at the beginning of the seminar.	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	Prof. Dr. Andreas Kist
5	**Contents**	Datasets are crucial to train modern artificial intelligence algorithms. In this seminar, students will be first faced with the theoretical background of datasets, how datasets are created and disseminated, as well as comply to the FAIR principles. We will cover dataset repositories and data types. In the first three weeks, students will create their own set of data and metadata and will experience the design and creation process of a dataset. In the second block of the seminar, students are assigned to a given dataset from a pre-selection of datasets important in the field of machine learning and artificial intelligence. The students' task is to create an open educational resource (OER), similar to a YouTube video, about their assigned dataset explaining the back story of the dataset, as well as its usage in a contemporary context. The generation of the OER will be self-paced with the option to work on the OER during the normal seminar hours. In the third block, students will be assigned to two other dataset OERs of their peer group and will give constructive feedback. The constructive feedback and the OERs will be discussed in the full group. Finally, the students will incorporate the feedback to their OERs and publish them openly on a dedicated seminar YouTube channel.
6	**Learning objectives and skills**	**Subject competence** Students acquire broad knowledge of (biomedical) datasets and how they are created (Knowledge). Through the course, students will be able to reproduce examples of different dataset modalities and describe advantages and disadvantages of datasets (Understanding). Through the course, students will be able to classify and grade the quality of a dataset, and explain the limitations of a given dataset (Apply and Evaluate/Judge). Students will be further able to characterize data sets independently (Analyze). Students gain a comprehensive insight into which criteria are important in the construction of new data sets by creating their own one (Create). **Learning or methodological competence and self-competence** Students learn to present a data set in a structured and coherent way through the creation of an open educational resource (OER) video. The also learn how to record, edit, compile and disseminate content.

		Students are given the opportunity to learn how to communicate effectively using their own words and give constructive feedback to others.
7	**Prerequisites**	We strongly recommend previous knowledge and ideally hands-on experience in Artificial Intelligence and/or Deep Learning to understand the implications discussed in the seminar.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung Seminar aim is to successfully create an OER (open educational resource), i.e. a Video that lasts at least 10 min *
11	**Grading procedure**	Seminarleistung (100%) The grade consists of the OER storyboard (2x weighted) and the final OER (1x weighted), which will be assessed using the following metrics: content, comprehensiveness, storyline, clarity, precise and concise presentation, quality of material and fitting the scope.
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Hylén, J. (2020). Open educational resources: Opportunities and challenges. • Ehlers, U. D. (2011). Extending the territory: From open educational resources to open educational practices. Journal of open, flexible and distance learning, 15(2), 1-10. • Nichols, T. E. et al. Best practices in data analysis and sharing in neuroimaging using MRI. Nat. Neurosci. 20, 299–303 (2017). • Horien, C. et al. A hitchhiker’s guide to working with large, open-source neuroimaging datasets. Nat Hum Behav 5, 185–193 (2021). • Wilkinson, M. D. et al. The FAIR Guiding Principles for scientific data management and stewardship. Sci. Data 3, 160018 (2016).

1	**Module name** 65065	**Fortgeschrittene Themen der Stochastik** Advanced topic in probability	**5 ECTS**
2	Courses / lectures	Vorlesung: Interacting Particle Systems (2 SWS) (SoSe 2025) Übung: Übungen zu Interacting Particle Systems (SoSe 2025)	- 2 ECTS
3	Lehrende	Dr. Markus Ebke Prof. Dr. Torben Krüger	

4	**Module coordinator**	Prof. Dr. Torben Krüger
5	**Contents**	• Themen, welche die in den vorbereitenden Vorlesungen erworbenen Basiskenntnisse der Stochastik vertiefen. • Anwendungsfelder der Wahrscheinlichkeitstheorie • Zusammenhang zwischen Stochastik und anderen Themenbereichen der Mathematik • Analytische Methoden in der Stochastik Die Prašentation des Stoffes erfolgt in Vorlesungsform. Die weitere Aneignung der wesentlichen Begriffe und Techniken erfolgt durch Präsenzübungen und Hausaufgaben. • Topics that deepen the basic knowledge of stochastics acquired in the preparatory lectures. • Fields of application of probability theory • Relationship between stochastics and other areas of mathematics • Analytical methods in stochastics *The material is presented in lecture form. Further acquisition of the essential concepts and techniques takes place through classroom exercises and homework.*
6	**Learning objectives and skills**	Die Studierenden • wenden die formalen Grundlagen der Wahrscheinlichkeitstheorie an und übertragen diese auf fortgeschrittene Themenbereiche • erfassen und formulieren randomisierte Phaňomene mathematisch. • nennen und erklaȓen die wichtigsten stochastisch-mathematischen Objekte, die in den Anwendungen eine Rolle spielen. • sammeln und bewerten relevante Informationen und erkennen Zusammenhaňge zu anderen mathematischen Themenfeldern. • klassifizieren und lošěn selbststaňdig Probleme analytisch. The students • apply the formal foundations of probability theory and transfer them to advanced subject areas • grasp and formulate randomized phenomena mathematically.

		• name and explain the most important stochastic mathematical objects that play a role in the applications. • collect and evaluate relevant information and recognize connections to other mathematical topics. • independently classify and solve problems analytically.
7	**Prerequisites**	empfohlen: Wahrscheinlichkeitstheorie, sowie Grundlagen in Analysis und Linearer Algebra *recommended: Probability theory, as well as basics in analysis and linear algebra*
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Studienrichtung Mathematische Theorie / Grundlagen der Data Science Master of Science Data Science 20212 Studienrichtung Mathematisch statistische Datenanalyse Master of Science Data Science 20212 • MSc Mathematik (Theoretische Mathematik, Angewandte Mathematik) • MSc Wirtschaftsmathematik • MSc Data Science • MSc Technomathematik • BSc Mathematik
10	**Method of examination**	mündlich (20 Minuten) • Übungsleistungen (unbenotet) • Mündliche Prüfung (20 min) • weekly assignments (ungraded) • oral exam (20 min) *
11	**Grading procedure**	mündlich (100%) Mündliche Prüfung (100%) *Oral Exam (100%)*
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 52 h Independent study: 98 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german or english
16	**Bibliography**	

1	**Module name** 57320	**Foundations of linked data**	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Foundations of Linked Data (4 SWS) (SoSe 2025)	5 ECTS
3	Lehrende	Prof. Dr. Andreas Harth	

4	**Module coordinator**	Prof. Dr. Andreas Harth
5	**Contents**	The Linked Data principles provide a unified interface to data and software systems based on web architecture. Linked Data is increasingly popular in scenarios where data and systems from multiple providers have to be integrated, both in an enterprise setting and on open data from the web. The module covers foundational techniques to access, process and integrate data, both from a theoretical and a practical perspective, and provides a coherent treatment of protocols and languages specified by the World Wide Web Consortium. The module combines techniques from different areas, such as databases and artificial intelligence, adapted for use in a decentralised setting on the web. The overarching topic is to facilitate data integration on the basis of resource-oriented modelling, knowledge representation, hyperlinks and state transfer between user agents and servers. The module sets out with a history of hypertext systems, followed from an introduction to web architecture and knowledge representation, including algorithms for query evaluation and deductive reasoning. The module closes with a user agents for querying integrated data from sources attainable through the web.
6	**Learning objectives and skills**	You will learn how to describe data in a way that facilitates integrated access. You will be able to write queries that access large amounts of data within a unified logical framework. You will be able to apply the technologies and techniques around Linked Data to support data integration in an enterprise setting and on the web, and therefore have the necessary skills for a broad variety of data science applications.
7	**Prerequisites**	Students should have a basic understanding of how the internet and the web work. Some knowledge of relational databases is beneficial.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	International Information Systems Master of Science Data Science 20212
10	**Method of examination**	Klausur (60 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	english
16	**Bibliography**	All relevant material will be provided during the lecture. The following books give an overview of the topics of the lecture: Tim Berners-Lee. Weaving the Web. Harper, 1999 Tom Heath, Christian Bizer. Linked Data: Evolving the Web into a Global Data Space. Morgan & Claypool, 2011. Dean Allemang. Semantic Web for the Working Ontologist: Effective Modeling in RDFS and OWL. Morgan Kaufmann, 2008. For a brief motivation read tyfair.com/news/2018/07/the-man-who-created-the-world-wide-web-has-some-regrets

1	**Module name** 65110	**Funktionalanalysis** Functional analysis	**10 ECTS**
2	Courses / lectures	Vorlesung: Funktionalanalysis I (4 SWS) (SoSe 2025) Übung: Übung zur Funktionalanalysis I (2 SWS) (SoSe 2025)	10 ECTS -
3	Lehrende	Prof. Dr. Carsten Gräser	

4	**Module coordinator**	Prof. Dr. Günther Grün
5	**Contents**	Grundlagen zu folgenden Themen: • Hilbert- und Banach-Räume • Sobolev-Räume • Lineare Operatoren • Lineare Funktionale und der Satz von Hahn-Banach • Prinzip der gleichmäßigen Beschränktheit • Kompakte Operatoren • Lösbarkeit linearer Gleichungen (inklusive Fredholm'sche Alternative) • Spektraltheorie kompakter Operatoren und Anwendungen Die Präsentation des Stoffes erfolgt in Vorlesungsform. Die weitere Aneignung der wesentlichen Begriffe und Techniken erfolgt durch wöchentliche Hausaufgaben.
6	**Learning objectives and skills**	Die Studierenden • nennen und erklären die Grundprinzipien der linearen Funktionalanalysis und verwenden diese; • kennen und erklären die Topologien von Hilbert- und Banachräumen, weisen Konvergenz von Folgen in unterschiedlichen Topologien nach (stark, schwach) und zeigen Implikationen aus kompakten Einbettungen auf; • beweisen Aussagen zu Existenz und Eindeutigkeit von Lösungen linearer Operatorgleichungen und zeigen insbesondere die Existenz schwacher Lösungen zu Randwertproblemen bei linearen elliptischen Differentialgleichungen; • treffen Aussagen zur Integrierbarkeit bzw. Glattheit von Sobolev-Funktionen.
7	**Prerequisites**	empfohlen: Drei der vier Module Lineare Algebra I und II, Analysis I und II müssen bestanden sein.
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Mathematische Theorie / Grundlagen der Data Science Master of Science Data Science 20212
10	**Method of examination**	mündlich (20 Minuten) Übungsleistung Übungsleistung: wöchentliche Hausaufgaben (ca 4 Aufgaben pro Woche) *

11	**Grading procedure**	mündlich (100%) Übungsleistung (bestanden/nicht bestanden)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 210 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	• Vorlesungsskripte zu diesem Modul • H.W. Alt: Lineare Funktionalanalysis; Springer • D. Werner: Funktionalanalysis; Springer

1	**Module name** 97278	**Geometric Numerical Integration**	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Geometric Numerical Integration (2 SWS) (SoSe 2025)	5 ECTS
3	Lehrende	Dr. Rodrigo Sato Martin de Almagro Prof. Dr.-Ing. Sigrid Leyendecker	

4	**Module coordinator**	Prof. Dr.-Ing. Sigrid Leyendecker Dr. Rodrigo Sato Martin de Almagro
5	**Contents**	• o Existence and uniqueness of solutions o Flows • o Recurrences o Error, stability, convergence o Numerical quadrature o Runge-Kutta (RK) and collocation methods o Adjoints and composition • o Conditions for RK and collocation methods o Discrete gradient methods • o Hamilton’s principle and Euler-Lagrange equations o Hamilton’s equations and symplecticity o Generating functions o Noether’s theorem • o Symplectic RK methods o Discrete Hamilton’s principle and variational integrators o Discrete Noether’s theorem • o Variational error o Backward error analysis and symplecticity In this lecture, numerical integration methods that preserve the geometric properties of the flow of a differential equation are presented. The course is divided into two parts. In the first part, we provide an overview of numerical integration of IVPs of ODEs. We will begin with a review of the basics of ODEs, followed by the introduction of concepts of numerical integration such as error and convergence rate.Several integration methods such as RK and collocation methods will be presented and analysed. In the second part, we explore the conservation properties of these methods and the geometric structure underlying many important systems. Conditions for the preservation of first integrals are derived

		and proven, followed by a brief introduction into symmetric methods. Next, we provide an overview of Lagrangian and Hamiltonian mechanics and some insight on the geometric structure of these systems (symplecticity, Noether's theorem). Finally, we introduce the concept of symplectic integration and the construction of variational integrators. To conclude, we will present and discuss some important results explaining the properties of these. During the course, an introduction to Python will be given to help the students implement these methods and test their properties.
6	**Learning objectives and skills**	The students • understand what an ordinary differential equation is • know what an initial value problem is, when a solution exists and when it is unique • know what a numerical solution to an initial value problem is • can characterise a numerical method in terms of error and convergence • know standard numerical integration techniques (quadrature, Runge-Kutta methods, collocation, composition…) • are familiar with the concept of first integral / conserved quantity • can argument about the conservation properties of the previously introduced methods • are familiar with Lagrangian and Hamiltonian systems • are familiar with Noether's theorem • are familiar with the concept of symplecticity and its relation with Hamiltonian flows • know how to characterise basic symplectic integrators • are familiar with discrete Lagrangian systems • can construct simple variational integrators • understand the concept of backward error analysis
7	**Prerequisites**	Recommended: solid mathematical background, notions of programming, Lagrangian mechanics and ordinary differential equations.
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Simulation and Numerics Master of Science Data Science 20212
10	**Method of examination**	mündlich (30 Minuten) Übungsleistung Three graded reports Oral exam (30 min) *
11	**Grading procedure**	mündlich (50%) Übungsleistung (50%)

		In order to pass the course, students must submit three compulsory reports on given assignments AND pass the oral exam. The first report consists on performing some simple coding task. The second and third reports will be graded according the degree of completion of the tasks and the quality and clarity of the explanations and conclusions provided. The weighting for the final mark is as follows First report: 10% Second report: 20% Third report: 20% Oral exam: 50%
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• E. Hairer, G. Wanner and C. Lubich, Geometric Numerical Integration: Structure-Preserving Algorithms for Ordinary Differential Equations. Springer, 2006. • E. Hairer, S. Nørsett, and G. Wanner, Solving ordinary differential equations. I Nonstiff problems. Springer, 1993. • E. Hairer and G. Wanner, Solving ordinary differential equations. II Stiff and differential-algebraic problems. Springer, 2010. • J. E. Marsden and M. West, Discrete mechanics and variational integrators. Acta Numerica, 2001. • E. Hairer, C. Lubich and G. Wanner. Geometric numerical integration illustrated by the StörmerVerlet method. Acta Numerica, 2003. • E. Süli and D. F. Mayers, An Introduction to Numerical Analysis. Cambridge University Press, 2003.

1	**Module name** 65976	**Geometrie von Mannigfaltigkeiten** Geometry of manifolds	**10 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Karl Hermann Neeb
5	**Contents**	Eine Auswahl aus den folgenden Themen: • Mannigfaltigkeiten (Tangentialvektoren, Vektorfelder, Flüsse) • Vektorbündel (Tensorbündel und (Semi-)Riemannsche Strukturen) • Differentialformen (Orientierung, Integration) • Affine Zusammenhänge (Paralleltransport, Krümmung) • Geodäten (Distanz, Jacobi Vektorfelder) • Einführung in der geometrischen Analysis • Symplektische und Poisson-Strukturen • Liegruppen und glatte Wirkungen
6	**Learning objectives and skills**	Die Studierenden • nennen und erklären die grundlegende Theorie der Mannigfaltigkeiten und ihrer Struktur, • erkennen und verwenden zusätzliche geometrische Strukturen auf Mannigfaltigkeiten wie zum Beispiel affine Zusammenhänge, Riemannsche Metriken oder symplektische Formen.
7	**Prerequisites**	Grundkenntnisse in Topologie, Analysis und Gewöhnliche Differentialgleichungen
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Mathematische Theorie / Grundlagen der Data Science Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 210 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	• S. Lang: "Differential and Riemannian manifolds" • J.M. Lee: "Introduction to Riemannian Manifolds" • R.L. Bishop and R.J. Crittenden, "Geometry of manifolds" • F. Warner: "Foundations of Differentiable Manifolds and Lie Groups"

1	**Module name** 43375	**Global Illumination** Global illumination	**5 ECTS**
2	Courses / lectures	Vorlesung: Global Illumination (2 SWS) (SoSe 2025)	2,5 ECTS
3	Lehrende	Prof. Dr. Marc Stamminger	

4	**Module coordinator**	Prof. Dr. Marc Stamminger
5	**Contents**	Globale Beleuchtungsberechnung ist ein Kerngebiet der Computergrafik. Ziel ist die Simualation globaler Beleuchtungseffekte wie Schatten, Spiegelungen, indirektes Licht, Kaustiken etc. In der Vorlesung wird in die theoretischen Grundlagen der globalen Beleuchtungsrechnung eingeführt und es werden Raytracing-basierte Lösungsverfahren erläutert. Themen der Vorlesung sind: • Rekonstruktion und Sampling • BRDFs • Importance Sampling • Umgebungsbeleuchtung • Rendering Gleichung • Path Tracing • Irradiance Caching • Photon Mapping • ...
6	**Learning objectives and skills**	Fachkompetenz Verstehen Lernende haben ein Verständnis von Verfahren der globalen Beleuchtungsrechnung, unter anderem Monte-Carlo-Ray-Tracing, bidirectional Path-Tracing, Photon Mapping, Light Cuts, können diese in eigenen Worten wiedergeben und Beispiele anführen. Lernende können Importance Sampling für verschiedene Teilaspekte der globalen Beleuchtungsrechnung illustrieren und vergleichen und den Zusammenhang mit Multiple Importance Sampling erklären. Anwenden Lernende können verschiedene Samplingverfahren erklären für verschiedene hochdimensionale Integrationsprobleme der globalen Beleuchtungsrechnung anwenden. Analysieren Lernende können Zusammenhänge und Unterschiede von Verfahren zur globalen Beleuchtungsrechnung erkennen und Folgerungen ableiten.
7	**Prerequisites**	Die Übungen setzen Kenntnisse in C/C++ voraus.
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	Übungsleistung Variabel
11	**Grading procedure**	Übungsleistung (bestanden/nicht bestanden) Variabel (100%)
12	**Module frequency**	Only in summer semester

13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english
16	**Bibliography**	Pharr et al.: Physically Based Rendering

1	**Module name** 22802	**Grundlagen der Anatomie und Physiologie** Foundations of anatomy and physiology	**5 ECTS**
2	Courses / lectures	Vorlesung: Grundlagen der Anatomie und Physiologie für Medizintechniker, Naturwissenschaftler und Ingenieure (2 SWS, WiSe 2025)	-
3	Lehrende	Dr. Jana Dahlmanns Prof. Dr. Peter Soba Prof. Dr. Christian Alzheimer	

4	**Module coordinator**	Prof. Dr.-Ing. Aldo Boccaccini
5	**Contents**	Die Grundlagen der menschlichen Physiologie und Anatomie werden betrachtet. Dabei wird das grundlegende menschliche Nervensystem, Auge, Ohr, das somatosensorische System und die zentrale Motorik des Menschen betrachtet. Im zweiten Teil der Vorlesung wird das Herz-Kreislauf System sowie das Magen-Darm System und der Blut- und Atmungskreislauf erklärt. **Content:** The fundamentals of human physiology and anatomy are contemplated. At the same time, the underlying human nervous system, the eye, the ear, the somatosensory system and the central motor function of humans is detailed. In the second part of the lecture course, the cardiovascular system as well as the gastrointestinal and the blood circulation and breathing circuit are explained.
6	**Learning objectives and skills**	Die Studierenden • kennen den grundlegen Aufbau des menschlichen Körpers. • verstehen die Mechanismen des Blut- und Atmungskreislaufs, Motorik und des Herz- Kreislaufsystems. **Educational Goals and Competences:** The students • know the fundamental structure of the human body. • understand the mechanisms of blood and breathing circulation, motor function and the cardiovascular system.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Medical Data Science Master of Science Data Science 20212 derzeit mündliche Prüfung (15 Min.) currently taking an oral exam (15 min.)
10	**Method of examination**	Klausur (60 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h

14	**Module duration**	2 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Geeignete begleitende Literatur wird in der Vorlesung genannt./ Relevant accompanying literature will be detailed during the lecture.

1	**Module name** 93080	**Grundlagen der Rechnerarchitektur und -organisation** Foundations of computer architecture and computer organisation	**5 ECTS**
2	Courses / lectures	Übung: Übungen zu Grundlagen der Rechnerarchitektur und -organisation (PG 6) (2 SWS) (SoSe 2025)	2,5 ECTS
		Übung: Übungen zu Grundlagen der Rechnerarchitektur und -organisation (PG 5) (2 SWS) (SoSe 2025)	2,5 ECTS
		Übung: Übungen zu Grundlagen der Rechnerarchitektur und -organisation (PG 4) (2 SWS) (SoSe 2025)	2,5 ECTS
		Übung: Übungen zu Grundlagen der Rechnerarchitektur und -organisation (PG 1) (2 SWS) (SoSe 2025)	2,5 ECTS
		Übung: Übungen zu Grundlagen der Rechnerarchitektur und -organisation (PG 8) (2 SWS) (SoSe 2025)	2,5 ECTS
		Übung: Übungen zu Grundlagen der Rechnerarchitektur und -organisation (PG 9) (2 SWS) (SoSe 2025)	2,5 ECTS
		Übung: Übungen zu Grundlagen der Rechnerarchitektur und -organisation (PG 3) (2 SWS) (SoSe 2025)	2,5 ECTS
		Übung: Übungen zu Grundlagen der Rechnerarchitektur und -organisation (PG 2) (2 SWS) (SoSe 2025)	2,5 ECTS
		Übung: Übungen zu Grundlagen der Rechnerarchitektur und -organisation (PG 7) (2 SWS) (SoSe 2025)	2,5 ECTS
		Vorlesung: Grundlagen der Rechnerarchitektur und -organisation (2 SWS) (SoSe 2025)	-
3	Lehrende	Tobias Baumeister Prof. Dr.-Ing. Dietmar Fey	

4	**Module coordinator**	Prof. Dr.-Ing. Dietmar Fey
5	**Contents**	Ziel der Vorlesung ist, die Grundlagen beim Aufbau eines Rechners zu vermitteln. Dies beinhaltet die Grundkomponenten, wie das Leitwerk, das Rechenwerk, das Speicherwerk und das Ein-/Ausgabewerk. Ausgehend vom klassischen von Neumann-Rechner wird der Bogen bis zu den Architekturen moderner Rechner und Prozessoren geschlagen. Grundprinzipien der Ablaufstuerung bei der Berarbeitung von Befehlen werden ebenso behandelt wie Aufbau und Funktionsweise eines Caches und die Architektur von Speichern im Allgemeinen. Das Konzept der Mikroprogrammierung wird erläutert. Ferner wird der Einstieg in die hardwarenahe Programmierung moderner CPUs mittels Assembler vorgestellt und erprobt. Aufbau und Funktionsweise peripherer Einheiten und Bussysteme werden ebenfalls behandelt. Die Studierenden sollen am Ende der Vorlesung den Aufbau und die Funktionsweise der Architektur eines Rechners, z.B. eines PCs, und des darin enthaltenen Prozessors nicht nur kennen, sondern auch die Gründe für deren Zustandekommen verstanden haben.

6	**Learning objectives and skills**	Nach dem Besuch der Lehrveranstaltung kennen die Studierenden die Grundkomponenten eines Rechners, z. B. eines PCs, und können diese auch im Zusammenspiel als Gesamtsystem erklären, sowie die Eigenheiten verschiedener Architekturen diskutieren. Sie können die Funktionsweise von Grundkomponenten wie Leitwerk, Rechenwerk, Speicherwerk, Ein-/Ausgabewerk, Bussystemen, sowie peripherer Komponenten erläutern und in die Struktur eines Computerssystems einordnen. Sie kennen den Aufbau von Caches, bzw. von Speichern im Allgemeinen und verstehen die Funktionsweise der Ablaufstuerung, insbesondere in Bezug auf die Abarbeitung von Befehlen. Weiterhin können die Studierenden Konzepte der Mikroprogrammierung unterscheiden, sowie hardwarenahe Programme in Assembler verstehen, modifizieren und erstellen.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	Hennessy/Patterson: Computer Architecture - A quantitative approach, 4.Auflage, 2006, MorganKaufmann. Patterson/Hennessy: Computer Organization & Design, 4.Auflage, 2008, MorganKaufmann. Stallings, Computer Organization & Architecture, 8.Auflage, 2009, Prentice Hall. Märtin, Rechnerarchitekturen, 2001, Fachbuchverlag Leipzig.

1	**Module name** 57458	**Hot topics in web technologies and the Internet of Things**	**5 ECTS**
2	Courses / lectures	Seminar: Hot Topics in Web Technologies and the Internet of Things	5 ECTS
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Andreas Harth
5	**Contents**	The Internet and the Web connect the modern world which makes it imperative for students to understand and apply current Internet and Web technologies, but also to identify relevant challenges. Topics focus on current challenges or new software libraries that evolved. Students can propose their own topics in this field, especially when they plan to do their thesis in this field. Cooperation with companies is allowed and supported.
6	**Learning objectives and skills**	The students • learn how to set up and conduct a software project involving web technologies • train their social and presentation skills • improve their understanding of modern web applications
7	**Prerequisites**	Students should have proficient programming skills in one general-purpose programming language (e.g. C/C++, C#, Java, Javascript or Python). The non-mandatory standard would be Python/Java for Logic, Backend development and Javascript/Typescript for Frontend development.
8	**Integration in curriculum**	semester: 2
9	**Module compatibility**	International Information Systems Master of Science Data Science 20212
10	**Method of examination**	Präsentation
11	**Grading procedure**	Präsentation (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 15 h Independent study: 135 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Will be announced in class

1	**Module name** 645618	**Human Computer Interaction** Human computer interaction	**5 ECTS**
2	Courses / lectures	Übung: Human Computer Interaction Exercises (1 SWS) (SoSe 2025) Vorlesung: Human Computer Interaction (3 SWS) (SoSe 2025)	1,25 ECTS 3,75 ECTS
3	Lehrende	Syrine Slim Prof. Dr. Björn Eskofier Björn Nieth Madeleine Flaucher Ann-Kristin Seifer	

4	**Module coordinator**	Prof. Dr. Björn Eskofier Madeleine Flaucher
5	**Contents**	Das Modul vermittelt Konzepte, Prinzipien, Modelle, Methoden und Techniken für die effektive Entwicklung von benutzerfreundlichen Mensch-Computer-Schnittstellen. Das Thema moderner Benutzungsschnittstellen wird dabei für klassische Computer aber auch für mobile Geräte, eingebettete Systeme, Automobile und intelligente Umgebungen betrachtet. Die folgenden Themen werden im Modul behandelt: • Einführung in die Grundlagen der Mensch-Computer-Interaktion, historische Entwicklung • Entwurfsprinzipien und Modelle für moderne Benutzungsschnittstellen und interaktive Systeme • Informationsverarbeitung des Menschen, Wahrnehmung, Motorik, Eigenschaften und Fähigkeiten des Benutzers • Interaktionskonzepte und -stile, Metaphern, Normen, Regeln und Style Guides • Ein- und Ausgabegeräte, Entwurfsraum für interaktive Systeme • Analyse-, Entwurfs- und Entwicklungsmethoden und -werkzeuge für Benutzungsschnittstellen • Prototypische Realisierung und Implementierung von interaktiven Systemen, Werkzeuge • Architekturen für interaktive Systeme, User Interface Toolkits und Komponenten • Akzeptanz, Evaluationsmethoden und Qualitätssicherung Contents: The module aims to teach basic knowledge of concepts, principles, models, methods and techniques for developing highly user-friendly Human-Computer Interfaces. Beyond traditional computer systems, modern user interfaces are also discussed in the context of automobile and intelligent environments, mobile devices and embedded systems. This module addresses the following topics: • Introduction to the basics of Human-Computer Interaction

		• Design principles and models for modern user interfaces and interactive systems • Information processing of humans, perception, motor skills, properties and skills of the users • Interaction concepts, metaphors, standards, norms and style guides • In- and output devices, design space for interactive systems • Analysis-, design- and development of methodologies and tools for easy-to-use user interfaces • Prototypic implementation of interactive systems • Architectures for interactive systems, User Interface Toolkits and components • Acceptance, evaluation methods and quality assurance
6	**Learning objectives and skills**	• Studierende entwickeln ein Verständnis für Modelle, Methoden und Konzepte der Mensch-Computer-Interaktion. • Sie lernen verschiedene Ansätze für den Entwurf, die Entwicklung und Bewertung von Benutzungsschnittstellen kennen und verstehen deren Vor- und Nachteile. • Die Teilnahme an der Veranstaltung versetzt Studierende in die Lage, einen Entwicklungsprozess in der Mensch-Computer-Interaktion zu verstehen und umzusetzen. • Sie werden weiterhin in die Lage versetzt, dies vor dem Hintergrund der Informationsverarbeitungsfähigkeit, Wahrnehmung und Motorik des Benutzers zu gestalten. • Passende Methoden der Evaluation sowie Akzeptanz- und Qualitätssicherung werden erlernt. Learning Objectives and Competences: • Students develop an understanding of models, methods and concepts in the field of Human-Computer Interaction. • They learn different approaches for designing, developing and evaluating User Interfaces and their advantages and disadvantages. • Joining the course enables students to understand and execute a development process in Human-Computer Interaction. • Students will be able to do a UI evaluation by learning the basics of information processing, perception and motoric skills of the user. • Appropriate evaluation methods, as well as acceptance and quality assurance aspects, will be learned.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	elektronische Prüfung Electronic exam (in presence), 90min *

11	**Grading procedure**	elektronische Prüfung (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 96310	**Image and Video Compression** Image and video compression	**5 ECTS**
2	Courses / lectures	Vorlesung: Image and Video Compression (IVC) (4 SWS) (SoSe 2025) Übung: Übung zu Image and Video Compression (SoSe 2025)	5 ECTS -
3	Lehrende	Prof. Dr.-Ing. Andre Kaup Anna Meyer	

4	**Module coordinator**	Prof. Dr.-Ing. Andre Kaup
5	**Contents**	**Multi-Dimensional Sampling** • Sampling theorem revisited, 2D sampling, spatiotemporal sampling, motion in 3D sampling **Entropy and Lossless Coding** • Entropy and information, variable length codes, Huffman coding, unary coding, Golomb coding, arithmetic coding **Statistical Dependency** • Joint entropy and statistical dependency, run-length coding, fax compression standards **Quantization** • Rate distortion theory, scalar quantization, Lloyd-Max quantization, entropy coded scalar quantization, embedded quantization, adaptive quantization, vector quantization **Predictive Coding** • Lossless predictive coding, optimum 2D linear prediction, JPEG-LS lossless compression standard, differential pulse code modulation (DPCM) **Transform Coding** • Principle of transform coding, orthonormal transforms, Karhunen-Loève transform, discrete cosine transform, bit allocation, compression artifacts **Subband Coding** • Principle of subband coding, perfect reconstruction property, discrete wavelet transform, bit allocation for subband coding **Visual Perception and Color** • Anatomy of the human eye, sensitivity of the human eye, color spaces, color sampling formats **Image Coding Standards** • JPEG and JPEG2000 **Interframe Coding** • Interframe prediction, motion compensated prediction, motion estimation, motion compensated hybrid coding **Video Coding Standards** • H.261, H.263, MPEG-1, MPEG-2 / H.262, H.264 / MPEG-4 AVC, H.265 / MPEG-H HEVC
6	**Learning objectives and skills**	The students • visualize multi-dimensional sampling and the influence of motion within the video signal

		• differentiate and evaluate different methods for lossless image and video coding • understand and analyze mutual entropy and statistical dependencies in image and video data • determine scalar and vector quantization for different optimization criteria (minimum mean square error, entropy coding, embedded quantization) • determine and evaluate optimal one-dimensional and two-dimensional linear predictor • apply prediction and quantization for a common DPCM system • understand the principle and effects of transform and subband coding for image data including optimal bit allocation • describe the principles of the human visual system for brightness and color • analyze block diagrams and the functioning of hybrid coders and decoders for video signals • know the prevailing international standards of ITU and MPEG for image and video compression.
7	**Prerequisites**	Lectures on Signal and Systems and Communication Systems strongly recommended
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	schriftlich oder mündlich (90 Minuten) Written exam of 90 min duration
11	**Grading procedure**	schriftlich oder mündlich (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	J.-R. Ohm: Multimedia Communications Technology, Springer, 2004

1	**Module name** 93020	**Implementierung von Datenbanksystemen** Implementation of database systems	**5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	Prof. Dr.-Ing. Richard Lenz
5	**Contents**	Die Vorlesung führt ein in den Aufbau und die Architektur von Datenbanksystemen, die Modularisierung und Schichtenbildung mit Abstraktionen verwenden. Schwerpunkt sind deshalb systemtechnische Aspekte von Datenbanksystemen. Die Übungen vertiefen verschiedene Aspekte an Beispielrechnungen und erweitern gelegentlich auch noch den Stoff um einige Facetten (z.b. Mehrattribut-Zugriffspfade). Ausgangspunkt einer Reihe von aufeinander aufbauenden Abstraktionen ist die Speicherung von Daten auf Hintergrundspeichern. Die erste Abstraktion ist die Datei. Dann werden Sätze eingeführt und auf verschiedene Weisen in Blöcken organisiert (sequenziell, mit Direktzugriff, indexsequentiell). Das schließt die Organisation eines Blockpuffers und Zugriffspfade (Indexstrukturen) unterschiedlichen Typs ein. Als zweite große Abstraktion werden Datenmodelle eingeführt und hier insbesondere das relationale. Das ist bereits aus dem Modul "Konzeptionelle Modellierung" bekannt, wird hier aber aus einer ganz anderen Perspektive heraus entwickelt. Der zweite Teil befasst sich mit der Realisierung der Leistungen eines Datenbanksystems unter Verwendung der vorher eingeführten Sätze und Zugriffspfade ("top-down"). Das umfasst die Anfrageverarbeitung und -optimierung, aber auch die Mechanismen zur Protokollierung von Aktionen und zur Wiederherstellung von Datenbankzuständen nach einem Fehler oder Ausfall. Ein laufend vervollständigtes Schichtenmodell fasst abschließend die Aufgaben in einer Architektur für Datenbank-Verwaltungssysteme zusammen. Ziel des Moduls ist es also, ein grundlegendes Verständnis für den Aufbau und die Funktionsweise eines Datenbanksystems zu vermitteln.
6	**Learning objectives and skills**	Die Studierenden • kennen das Schichtenmodell eines Datenbankverwaltungssystems; • verstehen das Prinzip der Datenunabhängigkeit (Datenabstraktion); • beherrschen das Aufbauprinzip einer Software-Schicht; • unterscheiden die Begriffe "Datenbank", "Datenbanksystem" und "Datenbankverwaltungssystem"; • unterscheiden die Begriffe "Datenmodell" und "Schema"; • zeigen das Konzept der blockorientierten Datei mit ihren Zugriffsoperationen auf; • unterscheiden einen Satz von einem Block; • erklären das Konzept der sequentiellen Satzdatei; • schildern das Prinzip der Wechselpuffertechnik;

		• charakterisieren den Schlüsselzugriff auf Sätze; • stellen Gestreute Speicherung (Hashing) auf der Basis von Blöcken (Buckets) dar; • formulieren die Funktionsweise des Virtuellen Hashings; • fassen die Funktionsweise eines B-Baums zusammen; • unterscheiden die Dienste eines B-Baums von denen des Hashings; • können für eine Folge von Schlüsselwerten einen B-Baum aufbauen; • unterscheiden einen B-Baum von einem B-Stern-Baum (B+-Baum); • veranschaulichen einen Bitmap-Index; • unterscheiden die Primär- und Sekundärorganisation von Sätzen; • zählen Ersetzungsstrategien der Pufferverwaltung auf und vergleichen sie; • benennen die Dienste einer Pufferverwaltung; • erklären die Konzepte "Seite" und "Segment" im Gegensatz zu "Block" und "Datei"; • unterscheiden direkte und indirekte Seitenzuordnung; • interpretieren in Programmiersprachen eingebettete Anfragesprachen und Datenbank-Unterprogrammaufrufe; • charakterisieren Datenbank-Transaktionen; • kennen die Aufrufe zur Definition von Transaktionen; • erläutern die spaltenweise Abspeicherung von Relationen; • diskutieren die algebraische Optimierung von Anfragen; • stellen Planoperatoren eines Datenbanksystems dar; • unterscheiden Planoperatoren für den Verbund; • beschreiben Kostenformeln für die Abschätzung von Anfrageausführungen; • schildern die verschiedenen Anomalien im Mehrbenutzerbetrieb; • beschreiben die Serialisierbarkeit von Transaktionen; • erläutern das Konzept der Sperren in Datenbanksystemen; • unterscheiden physische und logische Konsistenz; • kennen die vier Recovery-Klassen; • erläutern die verschiedenen Arten von Sicherungspunkten.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Klausur mit MultipleChoice (90 Minuten)
11	**Grading procedure**	Klausur mit MultipleChoice (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h

14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	KEMPER, Alfons ; EICKLER, André: Datenbanksysteme : Eine Einführung. 9., aktual. u. erweit. Aufl. München : Oldenbourg, 2013. ISBN 978-3-486-72139-3. Kapitel 7 bis 11 KEMPER, Alfons ; WIMMER, Martin: Übungsbuch Datenbanksysteme. 2., aktual. u. erweit. Aufl. München : Oldenbourg, 2009. ISBN 978-3-486-59001-2. Kapitel 7 bis 11 HEUER, Andreas ; SAAKE, Gunter: Datenbanken : Konzepte und Sprachen. 3., aktual. u. erw. Aufl. Bonn : mitp, 2007. - ISBN 3-8266-1664-2 HÄRDER, Theo ; RAHM, Erhard: Datenbanksysteme : Konzepte und Techniken der Implementierung. Berlin : Springer, 1999 - ISBN 3-540-65040-7 SAAKE, Gunter ; HEUER, Andreas: Datenbanken : Implementierungstechniken. 2., aktual. u. erw. Aufl. Bonn : mitp, 2005. ISBN 3-8266-1438-0

1	**Module name** 83466	**Implementing innovation**	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Digital Innovation: Platforms and Systems for Innovation (2 SWS) (SoSe 2025) Vorlesung: Innovation Design (2 SWS) (WiSe 2025)	2,5 ECTS 2,5 ECTS
3	Lehrende	Matthäus Wilga Prof. Dr. Kathrin Möslein Joni Riihimäki Nina Lugmair Dr. Karl Rabes	

4	**Module coordinator**	Prof. Dr. Kathrin Möslein
5	**Contents**	Der Veranstaltungszyklus vermittelt zentrale Inhalte der Unterstützung und Gestaltung innovationsorientierter Unternehmens- und Wertschöpfungsstrategien im internationalen Kontext.
6	**Learning objectives and skills**	Die Studierenden • erwerben fundierte Kenntnisse über die Analyse, Unterstützung und Gestaltung innovationsorientierter Unternehmens- und Wertschöpfungsstrategien. • kennen die Stärken und Schwächen alternativer Gestaltungskonzeptionen. • erwerben praktische Einblicke in die Durchführung und methodische Unterstützung von Innovationsprojekten. • eignen sich durch gezielte Gruppenarbeiten und die interaktive Veranstaltungsform soziale Kompetenzen an, • erarbeiten sich Reflexionsvermögen und können Kommilitonen wertschätzendes Feedback geben.
7	**Prerequisites**	Erfolgreiches Absolvieren der Assessmentphase
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	International Information Systems Master of Science Data Science 20212
10	**Method of examination**	Präsentation Hausarbeit Written assignment approx. 7 pages Presentation approx. 30 minutes *
11	**Grading procedure**	Präsentation (50%) Hausarbeit (50%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english

16	**Bibliography**	Werden in der Vorlesung bekanntgegeben

1	**Module name** 48410	**Information Theory and Coding** Information theory and coding	**5 ECTS**
2	Courses / lectures	Übung: Tutorial for Information Theory and Coding (1 SWS) Vorlesung: Information Theory and Coding (3 SWS)	- 5 ECTS
3	Lehrende	Johanna Fröhlich Dr. Sebastian Lotter	

4	**Module coordinator**	Prof. Dr.-Ing. Ralf Müller
5	**Contents**	1. Introduction: binomial distribution, (7,4)-Hamming code, parity-check matrix, generator matrix 2. Probability, entropy, and inference: entropy, conditional probability, Bayes law, likelihood, Jensens inequality 3. Inference: inverse probability, statistical inference 4. The source coding theorem: information content, typical sequences, Chebychev inequality, law of large numbers 5. Symbol codes: unique decidability, expected codeword length, prefix-free codes, Kraft inequality, Huffman coding 6. Stream codes: arithmetic coding, Lempel-Ziv coding, Burrows-Wheeler transform 7. Dependent random variables: mutual information, data processing lemma 8. Communication over a noisy channel: discrete memory-less channel, channel coding theorem, channel capacity 9. The noisy-channel coding theorem: jointly-typical sequences, proof of the channel coding theorem, proof of converse, symmetric channels 10. Error-correcting codes and real channels: AWGN channel, multivariate Gaussian pdf, capacity of AWGN channel 11. Binary codes: minimum distance, perfect codes, why perfect codes are bad, why distance isnt everything 12. Message passing: distributed counting, path counting, low-cost path, min-sum (=Viterbi) algorithm 13. Exact marginalization in graphs: factor graphs, sum-product algorithm 14. Low-density parity-check codes: density evolution, check node degree, regular vs. irregular codes, girth 15. Lossy source coding: transform coding and JPEG compression -- 1. Einleitung: Binomialverteilung, (7,4)-Hamming-Code, Paritätsmatrix, Generatormatrix 2. Wahrscheinlichkeit, Entropie und Inferenz: Entropie, bedingte Wahrscheinlichkeit, Bayessches Gesetz, Likelihood, Jensensche Ungleichung 3. Inferenz: Inverse Wahrscheinlichkeit, statistische Inferenz 4. Das Quellencodierungstheorem: Informationsgehalt, typische Folgen, Tschebyschevsche Ungleichung, Gesetz der großen Zahlen 5. Symbolcodes: eindeutige Dekodierbarkeit, mittlere Codewortlänge, präfixfreie Codes, Kraftsche Ungleichung, Huffmancodierung

		6. Stromcodes: arithmetische Codierung, Lempel-Ziv-Codierung, Burrows-Wheeler-Transformation 7. Abhängige Zufallsvariablen: Transinformation, Datenverarbeitungslemma 8. Kommunikation over gestörte Kanäle: diskreter gedächtnisloser Kanal, Kanalcodierungstheorem, Kanalkapazität 9. Das Kanalcodierungstheorem: verbundtypische Folgen, Beweis des Kanalcodierungstheorems, Beweis des Umkehrsatzes, symmetrische Kanaäle 10. Fehlerkorrigierende Codes und reale Kanäle: AWGN-Kanal, mehrdimensionale Gaußsche WDF, Kapazität des AWGN-Kanals 11. Binäre Codes: Minimaldistanz, perfekte Codes, Warum perfekte Codes schlecht sind, Warum Distanz nicht alles ist 12. Nachrichtenaustausch: verteiltes Zählen, Pfadzählen, günstigster Pfad, Minimumsummenalgorithmus 13. Exakte Marginalisierung in Graphen: Faktorgraph, Summenproduktalgorithmus 14. LDPC-Codes: Dichteevolution, Knotenordnung, reguläre und irreguläre Codes, Graphumfang 15. Verlustbehaftete Quellencodierung: Transformationscodierung und JPEG-Kompression
6	**Learning objectives and skills**	The students apply Bayesian inference to problems in both communications and everyday's life. The students explain the concept of digital communications by means of source compression and forward-error correction coding. For the design of communication systems, they use the concepts of entropy and channel capacity. They calculate these quantities for memoryless sources and channels. The students proof both the source coding and the channel coding theorem. The students compare various methods of source coding with respect to compression rate and complexity. The students apply source compression methods to measure mutual information. The students factorize multivariate functions, represent them by graphs, and marginalize them with respect to various variables. The students explain the design of error-correcting codes and the role of minimum distance. They decode error-correcting codes by means of maximum-likelihood decoding and message passing. The students apply distributed algorithms to problems in both communications and everydays life. The students improve the properties of low-density parity-check codes by widening the girth and/or irregularity in the degree distribution. The students transform source images into the frequency domain to improve lossy compression. -- Die Studierenden wenden Bayessche Inferenz auf Probleme in der Nachrichtentechnik und im Alltagsleben an.

		Die Studierenden erklären die konzeptuelle Trennung von digitaler Übertragung in Quellen- und Kanalcodierung. Kommunikationssysteme entwerfen sie unter Betrachtung von Entropie und Kanalkapazität. Sie berechnen diese Größen für gedächtnislose Quellen und Kanäle. Die Studierenden beweisen sowohl das Quellen- als auch das Kanalcodierungstheorem. Die Studierenden vergleichen verschiedenartige Quellencodierungsverfahren hinsichtlich Komplexität und Kompressionsrate. Die Studierenden verwenden Quellencodierverfahren zur Messung von Transinformation. Die Studierenden faktorisieren Funktionen mehrerer Veränderlicher, stellen diese als Graph dar und marginalisieren sie bezüglich mehrerer Veränderlicher. Die Studierenden erklären den Entwurf von Kanalcodes und den Einfluss der Minimaldistanz. Sie decodieren Kanalcodes gemäß maximaler Likelihood und Nachrichtenaustausch. Die Studierenden wenden verteilte Algorithmen auf Probleme der Nachrichtentechnik und des Alltagslebens an. Die Studierenden verbessern die Eigenschaften von LDPC-Codes durch Erhöhung des Umfangs und/oder durch irreguäre Knotenordnungsverteilungen. Die Studierenden transformieren Bildquellen zur Verbesserung verlustbehafteter Kompression iin den Frequenzbereich.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Data bases and knowledge representation Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten) Die Prüfung besteht aus einem 120-minütigen schriftlichen Test. --- The examination is a 120-minute written test. *
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	MacKay, D.: Information Theory, Inference, and Learning Algorithms, Cambridge University Press, Cambridge, 2003.

1	**Module name** 57053	**Innovation and leadership**	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Innovation and Leadership (4 SWS)	5 ECTS
3	Lehrende	Matthäus Wilga Prof. Dr. Kathrin Möslein Joni Riihimäki Nina Lugmair	

4	**Module coordinator**	Prof. Dr. Kathrin Möslein
5	**Contents**	The lecture focuses on the challenges of leading and communicating innovation and change in IT enabled companies and networked organizations. Based upon that, creating a sustainable innovative environment is a leadership task. In order to succeed at this task, leaders must develop innovative abilities to deal with the challenges inherent in a business environment characterized by fluid, unstructured and changing information. The aim of this course is thereby twofold. First, the course delineates and describes different yet emerging innovation tools, organizing them into a coherent set of classes. Each class of tools is described using a set of up-to-date business cases that depict the current status of the information systems. The second aim of this course is to get an overview of how to structure leadership systems towards innovation, how leaders can motivate to foster innovative thinking and what new forms of innovation (e.g. open innovation) mean for the definition of leadership. In doing so, this lecture represents an Idea Transformation Class as students are encouraged not only to merely develop, but to actively deploy specifically developed concepts.
6	**Learning objectives and skills**	The students • will understand and explore the theories and practicalities of leadership in open innovation contexts. • will gain knowledge on leading and communicating innovation and translate it in leadership behavior in real case contexts. • will learn to assess, reflect and feedback the impact of practical leadership for innovation
7	**Prerequisites**	• Basic understanding of innovation management • Basic understanding of management processes • First experience in team projects
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	International Information Systems Master of Science Data Science 20212
10	**Method of examination**	Präsentation schriftlich Presentation approx. 40 minutes Written assignment approx. 22 pages (partly in group) *
11	**Grading procedure**	Präsentation (bestanden/nicht bestanden)

		schriftlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Huff, Möslein & Reichwald: Leading Open Innovation; 2013 MIT Press,ISBN-13: 978-0262018494

1	**Module name** 43371	**Interactive Computer Graphics** Interactive computer graphics	**5 ECTS**
2	Courses / lectures	Vorlesung: Interactive Computer Graphics (2 SWS) (SoSe 2025) Übung: Tutorials to Interactive Computer Graphics (2 SWS) (SoSe 2025)	2,5 ECTS 2,5 ECTS
3	Lehrende	Prof. Dr. Marc Stamminger Laura Fink	

4	**Module coordinator**	Prof. Dr. Marc Stamminger
5	**Contents**	In dem Modul werden GPUs und dafür maßgeschneiderte Algorithmen behandelt: • Architektur von GPUs und Echtzeit-Rendering-Pipeline • Deferred Shading und Anti-Aliasing-Verfahren • Simulation von Umgebungsbeleuchtung • Verfahren zur Generierung von Schatten • Level-of-Detail-Verfahren zur Darstellung komplexer Szenen • Animation von Objekten
6	**Learning objectives and skills**	Fachkompetenz Verstehen Lernende können verschiedene in der Vorlesung behandelte Verfahren der interaktiven Computergraphik mit eigenen Worten erklären. Anwenden Lernende können Zusammenhänge zwischen den in der Vorlesung behandelten Verfahren der interaktiven Computergraphik erkennen, und Ideen auf neue Anwendungen übertragen. Analysieren Lernende können Unterschiede und Ähnlichkeiten der in der Vorlesung behandelten Verfahren erkennen und daraus neue Lösungen entwickeln.
7	**Prerequisites**	Die Übungen setzen Kenntnisse in C/C++ voraus.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	Variabel Übungsleistung
11	**Grading procedure**	Variabel (100%) Übungsleistung (bestanden/nicht bestanden)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english
16	**Bibliography**	• Möller, Haines: "Real-Time Rendering"

1	**Module name** 44157	**Interfacing the Neuromuscular system: Applications for Human/Machine Interfaces and Neurophysiology** Interfacing the neuromuscular system: Applications for Human/machine interfaces and neurophysiology	**5 ECTS**
2	Courses / lectures	Vorlesung: Interfacing the Neuromuscular system: Applications for Human/Machine Interfaces and Neurophysiology (4 SWS) (SoSe 2025)	5 ECTS
3	Lehrende	Prof. Dr. Alessandro Del Vecchio Charlotte Rohleder	

4	**Module coordinator**	Prof. Dr. Alessandro Del Vecchio
5	**Contents**	Module: Principles of Neural control of movement and neuroengineering How the central nervous system controls muscle forces; Neurons, upper and lower motoneurons, Cortical and brainstem function, Interneurons and Motor Units. Neuroengineering applications for studying the neural control of movement; invasive and non-invasive recordings, electrical stimulation of the nervous system. Module: Electrophysiology Generation of an action potential; HodgkinHuxley model, difference between intracellular and extracellular action potential, sparsity of the action potential in a matrix of electrodes. Recording electrophysiological data in humans; examples of EMG and EEG recordings. Module: Applications to Human/Machine Interfaces Biosignal processing; data with high temporal resolution, identification of individual neurons, associations between neuronal discharge times and behaviour; control of prosthetic devices from EMG signals in amputees and neurodegenerative and neurotraumatic diseases. Module: Applications to Neurophysiology Neuronal encoding of behaviour; motor unit physiology in humans; motoneuron properties, longitudinal assessment of neuronal function. Module: MATLAB / Python practical coursework Extraction of neural information from electrophysiological signals; associations of information between electrophysiological signals and behavioural data; Experiment in humans.
6	**Learning objectives and skills**	The students will acquire in-depth skills in the acquisition, analysis, and interpretation of electrophysiological data with a specific focus on human recordings in health and pathological conditions (e.g., spinal cord injury, stroke, and Parkinsons disease). The goal of this course is to teach the current methods in man/machine interfaces and neurophysiological applications. The course will provide information on the neural circuitries that determine coordinated movement. The specific focus is on the motor system that regulates skilled motor behaviour. We will study the physiological pathways of the motor system and the effect of neurodegenerative diseases that affect this system. Ultimately, this course will give students a robust overview of how to use electrophysiology in order to assist individuals with neural impairments.
7	**Prerequisites**	No compulsory prerequisites.

		Recommended: Basic biology and neurophysiology, Computer programming (Matlab and/or Python), Biosignal processing.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Klausur Written examination (60 min.) *
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	
16	**Bibliography**	• Principles of Neuroscience from Eric R. Kandel, MD • Motor unit from Heckman and Enoka, DOI: 10.1002/cphy.c100087 • Surface Electromyography, Physiology, Engineering, and Applications Edited by Roberto Merletti and Dario Farina • Neural Engineering, Edited by Bin He • Tutorial: Analysis of motor unit discharge characteristics from high-density surface EMG signals, Del Vecchio et al. https://doi.org/10.1016/j.jelekin.2020.102426 • Restoring sensorimotor function through intracortical interfaces: progress and looming challenges, Bensmaia and Miller https://www.nature.com/articles/nrn3724

1	**Module name** 65067	**Introduction to control and machine learning**	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Introduction to Control and Machine Learning (2 SWS)	5 ECTS
3	Lehrende	Ziqi Wang Prof. Dr. Enrique Zuazua Iriondo	

4	**Module coordinator**	Prof. Dr. Enrique Zuazua Iriondo
5	**Contents**	• Several topics related to the control of Ordinary Differential Equations (ODE) and Partial Differential Equations (PDE), including controllability, observability, and some of the most fundamental work that has been done in the subject in recent years. • An introduction to Machine Learning, focusing mainly on the use of control techniques for the analysis of Deep Neural Networks as a tool to address, for instance, the problem of Supervised Learning.
6	**Learning objectives and skills**	Students are able to • understand some basic theory on control and machine learning. • learn about recent advances on control and machine learning. • set out their approaches and results in a comprehensible and convincing manner, making use of appropriate presentation techniques.
7	**Prerequisites**	Recommended: basic knowledge of calculus, linear algebra, ODE and PDE.
8	**Integration in curriculum**	semester: 2
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212 Studienrichtung Simulation and Numerics Master of Science Data Science 20212 • Mandatory elective module for MSc Data Science in the field of study "Simulation and Numerics" • Mandatory elective module for MSc Computational and Applied Mathematics in the specialization "OPTI"
10	**Method of examination**	mündlich (15 Minuten)
11	**Grading procedure**	mündlich (100%) 100% based on oral exam
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 37,5 Independent study: 62,5
14	**Module duration**	1 semester
15	**Teaching and examination language**	english

16	**Bibliography**	1) L. Bottou, F. E. Curtis, and J. Nocedal, Optimization methods for large-scale machine learning. SIAM Review, 60 (2) (2018) , 223-311. 2) J. M. Coron, Control and Nonlinearity, Mathematical Surveys and Monographs, 143, AMS, 2009. 3) I. Goodfellow, Y. Bengio, & A. Courville, Deep Learning. MIT press, 2016. 4) C. F. Higham, and D. J. Higham, Deep learning: An introduction for applied mathematicians. SIAM Review, 61 (4) (2019), 860-891. 5) J. Nocedal, and S. Wright, Numerical Optimization. Springer Science & Business Media, 2006. 6) D. Ruiz-Balet, and E. Zuazua, Neural ODE control for classification, approximation and transport. arXiv preprint arXiv:2104.05278, (2021). 7) E. Zuazua, Propagation, observation, and control of waves approximated by finite difference methods, SIAM Review, 47 (2) (2005), 197-243. 8) E. Zuazua, Controllability and observability of partial differential equations: some results and open problems, in Handbook of Differential Equations: Evolutionary Equations. Vol. 3. North-Holland, 2006. 527-621.

1	**Module name** 93074	**Introduction to Cybersecurity Fundamentals in Networking**	**5 ECTS**
2	Courses / lectures	Vorlesung: Introduction to Cybersecurity Fundamentals in Networking (2 SWS) Übung: Introduction to Cybersecurity Fundamentals in Networking Exercises (2 SWS)	2,5 ECTS 2,5 ECTS
3	Lehrende	Loui Al Sardy	

4	**Module coordinator**	Loui Al Sardy Prof. Dr. Reinhard German
5	**Contents**	In today's interconnected world, cybersecurity plays a critical role in safeguarding sensitive information and ensuring the integrity, confidentiality, and availability of digital assets. The "Introduction to Cybersecurity Fundamentals in Networking" course provides students with a comprehensive understanding of the foundational principles, concepts, and practices of cybersecurity within the context of networking environments. Through a combination of theoretical lectures, hands-on lab exercises, and real-world case studies, students will explore key topics including security principles, risk management, access controls, cryptography, network security protocols, and emerging technologies. The course also covers the importance of cybersecurity for businesses and individuals, emphasizing the identification and mitigation of common security threats, vulnerabilities, and attack vectors. Additionally, students will learn about compliance with industry standards and regulations, such as GDPR and HIPAA, and explore emerging trends in network security, including blockchain and IoT. By the end of the course, students will have developed a solid foundation in cybersecurity fundamentals, equipped with the knowledge, skills, and competencies needed to address the evolving challenges of cybersecurity in today's digital landscape.
6	**Learning objectives and skills**	• Understand core cybersecurity principles and their significance for businesses. • Identify and mitigate common network threats and vulnerabilities. • Develop skills in securing network devices, implementing access controls, enforcing security policies, and best practices. • Knowledge of fundamental principles and concepts of cybersecurity. • Knowledge of cryptographic techniques and various network security protocols. • Gain practical experience through hands-on lab exercises and case studies.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212

10	**Method of examination**	Variabel 90-minute final exam or 30-minute oral exam on the content of the lecture and exercises, depending on the number of participants (will be announced at the start of the semester). *
11	**Grading procedure**	Variabel (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: approx. 60 h Independent study: approx. 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• "Computer Security: Principles and Practice" by • William Stallings and Lawrie Brown • "Cybersecurity for Beginners" by Raef Meeuwisse • "Network Security Essentials" by William Stallings • "Introduction to Computer Security" by Michael Goodrich and Roberto Tamassia • "Cryptography and Network Security: Principles and Practice" by William Stallings • "Network Security Bible" by Eric Cole and Ronald Krutz

1	**Module name** 165919	**Introduction to simulation, network and data analysis in Medical Systems Biology**	**2,5 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt! **Please contact the lecturer via email to inquire about time and date of the lecture and to register.**	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	Prof. Dr. Julio Vera González
5	**Contents**	Systems Biology is a novel approach, in which quantitative biomedical data are investigated using advanced computational tools for data analysis, modeling and simulation. The ultimate aim is to elucidate the structure and regulation of biochemical networks, giving support in the construction of hypotheses and the design of experiments to biomedical researchers, but also in the interpretation of high throughput patient biomedical data. The targeted audience are master students, PhD students and young post-docs in the area of Medical Engineering, Bioinformatics, Computational Biology and Bioengineering. Course Sections: 1. Introduction to the Systems Biology approach 2. Biological and biomedical highthroughput data processing and analysis 3. Biochemical network reconstruction and analysis 4. Mathematical modeling and simulation of biochemical systems
6	**Learning objectives and skills**	• After finishing this module, students can explain and analyse the basic concepts and tools for data analysis, network reconstruction and modeling used in systems biology. • They are be able to apply these concepts in the context of real case studies from biomedicine.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Medical Data Science Master of Science Data Science 20212
10	**Method of examination**	mündlich
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 45 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 47703	**Introduction to simulation, network and data analysis in Medical Systems Biology**	**5 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt! Please contact the lecturer to inquire about time and date of the lecture and to register.	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	Prof. Dr. Julio Vera González
5	**Contents**	Systems Biology is a novel approach, in which quantitative biomedical data are investigated using advanced computational tools for data analysis, modeling and simulation. The ultimate aim is to elucidate the structure and regulation of biochemical networks, giving support in the construction of hypotheses and the design of experiments to biomedical researchers, but also in the interpretation of high throughput patient biomedical data. The targeted audience are master students, PhD students and young post-docs in the area of Medical Engineering, Bioinformatics, Computational Biology and Bioengineering. Course Sections: 1. Introduction to the Systems Biology approach 2. Biological and biomedical highthroughput data processing and analysis 3. Biochemical network reconstruction and analysis 4. Mathematical modeling and simulation of biochemical systems
6	**Learning objectives and skills**	• After finishing this module, students can explain and analyse the basic concepts and tools for data analysis, network reconstruction and modeling used in systems biology. • They are be able to apply these concepts in the context of real case studies from biomedicine.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Medical Data Science Master of Science Data Science 20212
10	**Method of examination**	mündlich Oral exam, 30 min. *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 45 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	

1	**Module name** 47697	**Jüngste Entwicklungen der Medizinischen Systembiologie/Advances in Medical Systems Biology (AdvMedSys)** Advances in Medical Systems Biology (AdvMedSys)	**2,5 ECTS**
2	Courses / lectures	Seminar: Jüngste Entwicklungen der Medizinischen Systembiologie I (AdvMedSys1) (2 SWS)	-
3	Lehrende	Prof. Dr. Julio Vera González	

4	**Module coordinator**	Prof. Dr. Julio Vera González
5	**Contents**	In this subject the students will be introduced to new approaches in medical systems biology. Medical systems biology aims to simulate, to analyse and to discuss biomedical mathematical models. This is a multidisciplinary approach to understand biomedical systems. The following skills are expected from a student that has accomplished this subject. • Literature research and discussion as well as performing a critical view of a topic. • The ability to summarize and simplify broad biological information into a theoretical framework. • To create and to simulate a mathematical model. • To discuss the results from an in silico exercise and conclude biological insights from the model. We evaluate these skills applying the principles of learning-by-doing.
6	**Learning objectives and skills**	The students are faced to a real problem in biomedicine that they should solve and discuss in a report. The following learning goals should be satisfied to perform this exercise. • Learning the basic concepts of molecular biology. • Understanding the principles of systems biology and mathematical modeling. • Applying the concepts of molecular biology to a specific biomedical problem to propose a theoretical framework. • Analyse a real problem in biomedicine and propose a workflow to solve it. • Evaluate the literature to enrich the biomedical knowledge of the theoretical framework. • Create a mathematical model out of the theoretical framework to solve a biomedical problem
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Medical Data Science Master of Science Data Science 20212 Oral exam, 30 min.
10	**Method of examination**	Variabel
11	**Grading procedure**	Variabel (100%)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 45 h

		Independent study: 30 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 22991	**Klinische Datenwissenschaften** Clinical data science	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Klinische Datenwissenschaften (4 SWS) (SoSe 2025)	5 ECTS
3	Lehrende	PD Dr. Dennis Toddenroth Prof. Dr. med. Thomas Ganslandt	

4	**Module coordinator**	PD Dr. Dennis Toddenroth
5	**Contents**	Der zunehmende Umfang elektronisch vorliegender klinischer Daten erweitert die Möglichkeiten, diese auch zur automatisierten Analyse bisher unentdeckter medizinischer Zusammenhänge und zur Erzeugung neuen medizinischen Wissens zu verwenden. Derartige Datenauswertungen hängen oft nicht von einzelnen Fragestellungen oder Hypothesen ab, insofern unterscheiden sich die angewendeten Methoden auch von entsprechend etablierten statistischen Verfahren. Die wissenschaftliche Nutzung von Patientendaten aus dem Behandlungsalltag bringt allerdings auch neue Herausforderungen mit sich, wie beispielsweise eine gezielte Berücksichtigung unterschiedlicher Datenstrukturen und vielfältiger klinischer Formulare. Diese Veranstaltung thematisiert die Anwendung automatisierter Auswertungsmethoden auf Patientendaten. Nach einem vergleichenden Überblick über das übliche Vorgehen zur Generierung medizinischen Wissens (biometrische Grundlagen u. Studientypen) werden Grundprinzipien und Gemeinsamkeiten unterschiedlicher Verfahren zur automatisierten Datenanalyse behandelt; anschließend werden einzelne Methoden und Anwendungsbeispiele vertieft, und Ansätze zur statistischen Bewertung erläutert. Innerhalb der Veranstaltung wird eine praktische Einführung in die Programmiersprache R vermittelt (http://www.r-project.org/). Die Teilnehmer sollen sich dabei in praktischen Übungen auch selbständig in einzelne Analyseverfahren einarbeiten, um diese dann auf klinische Beispieldatensätze praktisch anzuwenden und die so erzeugten Beobachtungen kritisch zu interpretieren.
6	**Learning objectives and skills**	Studierende, die das Modul erfolgreich abgeschlossen haben: • erläutern Grundprinzipien und Einteilung von Machine-Learning-Verfahren. • verstehen Einteilung und Merkmale diverser relevanter klinischer Daten. • verstehen Charakteristika der Programmiersprache R und wenden diese an. • implementieren R-Skripte zur Anwendung von Machine-Learning-Verfahren auf Patientendaten. • überprüfen Resultate automatisierter Analysen vielfältiger klinischer Daten.
7	**Prerequisites**	MSc-Studium in Informatik, Einführung in die Medizinische Informatik.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Medical Data Science Master of Science Data Science 20212

10	**Method of examination**	schriftlich/mündlich Die Prüfungsform ist eine Klausur über 90 Minuten. *
11	**Grading procedure**	schriftlich/mündlich (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	• Han, Kamber, Pei: Data Mining - Concepts and Techniques (3rd ed.) • An Introduction to R (http://cran.r-project.org/doc/manuals/R-intro.pdf) • Kourou et al.: Machine learning applications in cancer prognosis and prediction (2015) • Bellazzi and Zupan: Predictive data mining in clinical medicine: current issues and guidelines (2008)

1	**Module name** 43961	**Knowledge Discovery in Databases mit Übung** Knowledge discovery in databases with tutorial	**5 ECTS**
2	Courses / lectures	Vorlesung: Knowledge Discovery in Databases (2 SWS) (SoSe 2025) Übung: Übungen zu KDD (2 SWS) (SoSe 2025)	- -
3	Lehrende	Dominik Probst Lucas Weber	

4	**Module coordinator**	Dominik Probst
5	**Contents**	Theoretical knowledge on: • Why data mining? • What is data mining? • A multi-dimensional view of data mining • What kinds of data can be mined? • What kinds of patterns can be mined? • What technologies are used? • What kinds of applications are targeted? • Major issues in data mining • A brief history of data mining Practical exercises on: • Introduction to Pandas & scikit-learn • Data analysis & data preprocessing • Frequent Pattern • Classification • Clustering • Outlier
6	**Learning objectives and skills**	Die Studierenden • kennen den typischen KDD-Prozess; • kennen Verfahren zur Vorbereitung von Daten für das Data Mining; • definieren Distanz- oder Ähnlichkeits-Funktionen auf einem speziellen Datenbestand; • überprüfen Attribute eines Datensatzes auf ihre Bedeutung für die Analyse hin und transformieren ggf. Attributwerte geeignet; • wissen, wie ein typisches Data Warehouse aufgebaut ist; • kennen die Definition von Distanz- bzw. Ähnlichkeitsfunktionen für die verschiedenen Typen von Attributen; • sind vertraut mit dem Prinzip des Apriori-Algorithmus zur Bestimmung von Mengen häufiger Elemente (frequent itemsets); • kennen den FP-Growth-Algorithmus zum schnellen Auffinden von Mengen häufiger Elemente; • geben die Definitionen von Support und Confidence für Assoziationsregeln wieder; • beschreiben die Ermittlung von Assoziationsregeln auf der Basis von Mengen häufiger Elemente;

		• sind in der Lage, die Vorgehensweise bei Klassifikationsaufgaben darzustellen; • legen dar, wie ein Entscheidungsbaum auf einem Trainingsdatensatz erzeugt wird; • stellen das Prinzip der Bayes'schen Klassifikation dar; • zählen verschiedene Clustering-Verfahren auf; • beschreiben den Ablauf von k-Means-Clustering; • kennen die verschiedenen Arten von Ausreißern; • können die verschiedenen Schritte eines KDD Prozesses auch praktisch anwenden. The students: • know the typical KDD process; • know procedures for the preparation of data for data mining; • know the definition of distance or similarity functions for the different kinds of attributes; • define distance and similarity functions for a particular dataset; • check attributes of a dataset for their meaning with reference to an analysis and transform attribute values accordingly, if required. • know how a typical data warehouse is structured; • are familar with the principle of the Apriori algorithm for the identification of frequent itemsets; • know the FP-growth algorithm for a faster identification of frequent itemsets: • present the definitions of support and confidence for association rules; • describe the construction of association rules based on frequent itemsets; • are capable of describing the course of action in classification tasks; • present the construction of a decision tree based on a training dataset; • present the principle of Bayes' classification; • enumerate different clustering procedures; • describe the steps of k-means clustering; • know the different kinds of outliers; • are able to practically apply the various steps of a KDD process.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Data bases and knowledge representation Master of Science Data Science 20212
10	**Method of examination**	Klausur mit MultipleChoice (90 Minuten)
11	**Grading procedure**	Klausur mit MultipleChoice (100%)
12	**Module frequency**	Only in summer semester

13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	The lecture is based on the following book: • J. Han, M. Kamber, and J. Pei, Data Mining: Concepts and Techniques, 3rd. San Francisco, CA, USA: Morgan Kaufmann Publishers Inc., 2011, ISBN: 0123814790 Also interesting and related textbooks are: • A. Géron, Hands-on machine learning with Scikit-Learn and TensorFlow : concepts, tools, and techniques to build intelligent systems, 2nd ed. OReilly Media, 2017, ISBN: 978-1491962299 • H. Du, Data Mining Techniques and Applications: An Introduction. Cengage Learning EMEA, May 2010, p. 336, ISBN: 978-1844808915 • I. H. Witten, E. Frank, M. A. Hall, et al., Data Mining, Fourth Edition: Practical Machine Learning Tools and Techniques, 4th. San Francisco, CA, USA: Morgan Kaufmann Publishers Inc., 2016, ISBN: 0128042915

1	**Module name** 65088	**Kolloquiumsvorlesung Digitale Souveränität** Colloquium lecture: Digital sovereignty	**5 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the summer semester.	
3	Lehrende	-	

4	**Module coordinator**	Prof. Dr. Johannes Helbig
5	**Contents**	Die Digitalisierung verändert unsere Welt, disruptiv, umfassend und unumkehrbar: Sie ändert die strukturellen Voraussetzungen für unsere Wirtschaft, unsere Gesellschaft und unser Verständnis von uns selbst. Digitale Souveränität adressiert die Frage, wie wir diesem Umbruch Gestaltung und Führung geben können, nach eigenem Willen und eigenen Wertvorstellungen. Das betrifft insbesondere die Freiheitlichkeit, die soziale Gerechtigkeit und die wirtschaftliche Leistungsfähigkeit der Gesellschafts- und Wirtschaftsordnungen der Zukunft. Viele Disziplinen müssen dazu beitragen, keine kann diese Aufgabe innerhalb des eigenen Horizonts lösen. Die Veranstaltung ist entsprechend in hohem Maße multidisziplinär. Sie richtet sich an fortgeschrittene Studierende aus mathematisch-naturwissenschaftlichen und technischen Studiengängen, aus Wirtschafts-, Sozial- und Rechtswissenschaften sowie aus Philosophie und Ethik. Die Veranstaltung ist als Ringvorlesung mit internen und externen Gästen konzipiert. Auf einen Kolloquiumsvortrag folgt jeweils ein diskursiver Abschnitt in Breakout-Gruppen. Themenschwerpunkte umfassen: • Zukunft der Wertschöpfung und Wettbewerbsfähigkeit • Innere und äußere Sicherheit • Meinungsbildung und öffentlicher Raum • Konstruktive Anpassung des Rechtssystems • Zukunft der Arbeit und partizipative Nutzenverteilung • Strukturvoraussetzungen demokratischer politischer Prozesse und Systeme • Leistungsfähige Bildung • Trustworthy Artificial Intelligence • Souveräne digitale Infrastrukturen • Neue Narrative für die Basis gesellschaftlicher Solidarität • Menschenbild, Weltbild und ethische Reflektion Die Veranstaltung wird ergänzt durch vertiefende Seminare zu ausgewählten Einzelthemen; diese können auch jeweils eigenständig belegt werden.
6	**Learning objectives and skills**	Die Studierenden • kennen die disruptiven Auswirkungen der Digitalisierung in unterschiedlichen Domänen • verstehen zugrundeliegende Veränderungen der strukturellen Voraussetzungen und ihre Wirkzusammenhänge und erkennen wiederkehrende Muster • können Handlungsfelder einschätzen und exemplarisch Maßnahmenansätze entwickeln und beurteilen

		• kennen Denkansätze, Begriffsbildungen und Paradigmen benachbarter Disziplinen und können sie im Dialog miteinander in Beziehung setzen • können eigenständig und im Team ein Teilthema eigenständig und vertiefend erschließen und Gestaltungsansätze entwickeln
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Geographie Master of Science Data Science 20212 Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung Vortrag 45min, schriftliche Ausarbeitung 5-10 Seiten *
11	**Grading procedure**	Seminarleistung (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	wird vom Lehrenden in der Vorlesung bekannt gegeben

1	**Module name** 93130	**Konzeptionelle Modellierung** Conceptual modelling	**5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	Prof. Dr.-Ing. Richard Lenz
5	**Contents**	• Fundamentals of modeling • Data modeling by the example of the Entity-Relationship-Model • Modeling of object-oriented systems based on the example of UML • Relational data modeling and query capabilities • Introduction to metamodeling • XML • Multidimensional data modeling • Domain modeling and ontologies
6	**Learning objectives and skills**	Students will: • define basic terms from database literature • explain the advantages of database systems • explain the different phases of database design • use the Entity-Relationship-Model and the extended Entity-Relationship Model for semantic data modeling • distinguish different notations for ER diagrams • explain the basic concepts of the relational data model • map a given EER diagram to a relational database schema • explain the normal forms 1NF, 2NF, 3NF, BCNF and 4NF • define the operations of the relational algebra • create database tables using SQL • accomplish tasks of data selection and data manipulation through the use of SQL • explain the basic concepts of XML • create DTDs for XML documents • use XPATH to formulate queries to XML documents • define the basic structural elements and operators of the multidimensional data model • explain the Star and Snowflake schemas • use simple UML use-case diagrams • use simple UML activity diagrams • create UML sequence diagrams • create simple UML class diagrams • explain the term "meta-modeling" • define the term "ontology" in the context of computer science • define the terms RDF and OWL
7	**Prerequisites**	Recommended requirement: "Algorithms and Data Structures" and "Logic in Computer Science"
8	**Integration in curriculum**	semester: 2

9	**Module compatibility**	
10	**Method of examination**	Klausur mit MultipleChoice (90 Minuten)
11	**Grading procedure**	Klausur mit MultipleChoice (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	• Elmasri, Ramez, and Sham Navathe. Grundlagen von Datenbanksystemen. Pearson Deutschland GmbH, 2009. - ISBN-10: 9783868940121 • Alfons Kemper, Andre Eickler: Datenbanksysteme : Eine Einführung. 6., aktualis. u. erw. Aufl. Oldenbourg, März 2006. - ISBN-10: 3486576909 • Bernd Oestereich: Analyse und Design mit UML 2.1. 8. Aufl. Oldenbourg, Januar 2006. - ISBN-10: 3486579266 • Ian Sommerville: Software Engineering. 8., aktualis. Aufl. Pearson Studium, Mai 2007. - ISBN-10: 3827372577 • Horst A. Neumann: Objektorientierte Softwareentwicklung mit der Unified Modeling Language. (UML). Hanser Fachbuch, März 2002. - ISBN-10: 3446188797 • Rainer Eckstein, Silke Eckstein: XML und Datenmodellierung. Dpunkt Verlag, November 2003. - ISBN-10: 3898642224

1	**Module name** 65979	**Kryptographie I** Cryptography I	**10 ECTS**
2	Courses / lectures	Übung: Übungen zur Kryptographie I / Kryptographie für Lehramt (2 SWS) Vorlesung: Kryptographie I / Kryptographie für Lehramt (4 SWS) Übung: Rechnerübung zur Kryptographie 1 (2 SWS)	- 10 ECTS -
3	Lehrende	Prof. Dr. Daniel Tenbrinck	

4	**Module coordinator**	Prof. Dr. Daniel Tenbrinck
5	**Contents**	• Einführung in die Kryptographie • Klassische Chiffrierverfahren • Grundeigenschaften der Ringe Z und Z/nZ • Primzahltests • Public-Key-Kryptosysteme RSA • Die Pollard-rho-Methode zur Faktorisierung • Kryptographische Anwendungen diskreter Logarithmen • Kryptographische Hashfunktionen • Digitale Signaturen • Methoden zur Berechnung diskreter Logarithmen • Enigma Die Präsentation des Stoffes erfolgt in Vorlesungsform. Die weitere Aneignung der wesentlichen Begriffe und Techniken erfolgt durch wöchentliche Hausaufgaben.
6	**Learning objectives and skills**	Die Studierenden • erklären wichtige kryptographische Verfahren und wenden diese praktisch an • nützen Software wie Maple, Python3 oder Sage zur Ver- und Entschlüsselung sowie zur Kryptoanalyse • erläutern wichtige zahlentheoretische Algorithmen, ihre theoretischen Hintergründe und ihre Funktion bei der Konstruktion von Public-Key-Kryptosystemen
7	**Prerequisites**	empfohlen: • Grundkenntnisse aus den Modulen Analysis I und Lineare Algebra I
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	schriftlich
11	**Grading procedure**	schriftlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 210 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	german
16	**Bibliography**	• Vorlesungsskript zum Modul • J. Buchmann: Einführung in die Kryptographie • J. Hoffstein, J. Pipher, J. H. Silvermann: An Introduction to Mathematical Cryptography

1	**Module name** 65980	**Kryptographie II** Cryptography II	**10 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	apl. Prof. Dr. Wolfgang Ruppert
5	**Contents**	Die Vorlesung wird mit wechselnden Schwerpunkten angeboten, wobei jeweils ein spezielles zahlentheoretisches Gebiet (wie elliptische Kurven, quadratische Zahlkörper, Gitter) die Grundlage für kryptographische Anwendungen bildet. Die Präsentation des Stoffes erfolgt in Vorlesungsform.
6	**Learning objectives and skills**	Die Studierenden • erklären fortgeschrittene kryptographische Verfahren und ihre mathematischen Hintergründe • setzen geeignete Software zum praktischen Umgang mit den besprochenen Kryptosystemen ein
7	**Prerequisites**	empfohlen: • Kryptographie I • Algebra
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	mündlich Dauer der mündlichen Prüfung: 20 min *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 210 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	Vorlesungsskript zum Modul

1	**Module name** 535405	**Künstliche Intelligenz I** Artificial intelligence I	**7,5 ECTS**
2	Courses / lectures	Übung: KI I - Ü (2 SWS) Vorlesung: Artificial Intelligence I (4 SWS)	- 7,5 ECTS
3	Lehrende	apl. Prof. Dr. Florian Rabe Prof. Dr. Michael Kohlhase	

4	**Module coordinator**	Prof. Dr. Michael Kohlhase
5	**Contents**	This module covers the foundations of Artificial Intelligence (AI), in particular symbolic techniques based on search and inference.
6	**Learning objectives and skills**	• Knowledge: The students learn foundational representations and algorithms in AI. • Application: The concepts learned are applied to examples from the real world (homeworks). • Analysis: By modeling human cognitive abilities, students learn to assess and understand human intelligence better. • Social Competences: Students work in small groups to solve an AI game-play challenge/competition (Kalah). **Contents**: Foundations of symbolic AI, in particular: • Agent Models as foundation of AI • Logic Programming in Prolog • Heuristic Search as a methdod for problem solving • Adversarial Search (automating board games) via heuristic search • Constraint Solving/Propagation • Logical Languages for knowledge representation • Inference and automated theorem proving • Classical Planning • Planning and Acting in the real world.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Data bases and knowledge representation Master of Science Data Science 20212 Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten) Es werden 8-12 Übungsaufgaben gestellt, in denen Bonuspunkte gesammelt werden können. Für das Bestehen des Moduls muss nur die 90-minütige schriftliche Klausur bestanden werden. *
11	**Grading procedure**	Klausur (100%) Die Note ergibt sich hauptsächlich aus der 90-minütigen schriftlichen Klausur. Bei Bestehen der Klausur kann die Note um bis zu 10% durch Punkte aus den Übungsaufgaben aufgebessert werden.
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 90 h

		Independent study: 135 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english
16	**Bibliography**	Die Vorlesung folgt weitgehend dem Buch • Stuart Russell und Peter Norvig: Artificial Intelligence: A Modern Approach. Prentice Hall, 3rd edition, 2009. Deutsche Ausgabe: • Stuart Russell und Peter Norvig: Künstliche Intelligenz: Ein Moderner Ansatz. Pearson-Studium, 2004 (Übersetzung der 2. Auflage). ISBN: 978-3-8273-7089-1.

1	**Module name** 532733	**Künstliche Intelligenz II** Artificial intelligence II	**7,5 ECTS**
2	Courses / lectures	Vorlesung: Artificial Intelligence II (4 SWS) (SoSe 2025) Übung: Übungen zu Artificial Intelligence II (2 SWS) (SoSe 2025)	- -
3	Lehrende	Prof. Dr. Michael Kohlhase	

4	**Module coordinator**	Prof. Dr. Michael Kohlhase
5	**Contents**	Dieses Modul beschäftigt sich mit den Grundlagen der Künstlichen Intelligenz (KI), insbesondere mit Techniken des Schließens unter Unsicherheit, des maschinellen Lernens und der Sprachverarbeitung. Das Modul baut auf dem Modul Künstliche Intelligenz I vom Wintersemester auf und führt dieses weiter.
6	**Learning objectives and skills**	Fach- Lern- bzw. Methodenkompetenz - Wissen: Die Studierenden lernen grundlegende Repräsentationsformalismen und Algorithmen der Künstlichen Intelligenz kennen. - Anwenden: Die Konzepte werden an Beispielen aus der realen Welt angewandt (Übungsaufgaben). - Analyse: Die Studierenden lernen über die Modellierung in der Maschine menschliche Intelligenzleistungen besser einzuschätzen. Sozialkompetenz - Die Studierenden arbeiten in Kleingruppen zusammen um kleine Projekte zu bewältigen. Inhalte: • Inferenz unter Unsicherheit • Bayessche Netzwerke • Rationale Entscheidungstheorie (MDPs and POMDPs) • Machinnelles Learnend und Neuronale Netzwerke • Verarbeitung Natürlicher Sprache --- This course covers the foundations of Artificial Intelligence (AI), in particular reasoning under uncertainty, machine learning and (if there is time) natural language understanding. This course builds on the course Artificial Intelligence I from the preceding winter semester and continues it. Learning Goals and Competencies Technical, Learning, and Method Competencies • Knowledge: The students learn foundational representations and algorithms in AI. • Application: The concepts learned are applied to examples from the real world (homeworks). • Analysis: By modeling human cognitive abilities, students learn to assess and understand human intelligence better. • Social Competences: Students work in small groups to solve the and machine learning challenge/competition. Contents:

		• Inference under Uncertainty • Bayesian Networks • Rational Decision Theory (MDPs and POMDPs) • Machine Learning and Neural Networks • Natural Language Processing
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 2
9	**Module compatibility**	Studienrichtung Data bases and knowledge representation Master of Science Data Science 20212 Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212 Es werden 8-12 Übungsaufgaben gestellt, in denen Bonuspunkte gesammelt werden können. Für das Bestehen des Moduls muss nur die 90-minütige schriftliche Klausur bestanden werden.
10	**Method of examination**	Klausur (90 Minuten) Es werden 8-12 Übungsaufgaben gestellt, in denen Bonuspunkte gesammelt werden können. Für das Bestehen des Moduls muss nur die 90-minütige schriftliche Klausur bestanden werden. *
11	**Grading procedure**	Klausur (100%) Die Note ergibt sich hauptsächlich aus der 90-minütigen schriftlichen Klausur. Bei Bestehen der Klausur kann die Note um bis zu 10% durch Punkte aus den Übungsaufgaben aufgebessert werden.
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 135 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Die Vorlesung folgt weitgehend dem Buch Stuart Russell und Peter Norvig: Artificial Intelligence: A Modern Approach. Prentice Hall, 3rd edition, 2009. Deutsche Ausgabe: Stuart Russell und Peter Norvig: Künstliche Intelligenz: Ein Moderner Ansatz. Pearson-Studium, 2004 (Übersetzung der 2. Auflage). ISBN: 978-3-8273-7089-1. Literature

		The course follows the following textbook: Stuart Russell and Peter Norvig: Artificial Intelligence: A Modern Approach. Prentice Hall, 3rd edition, 2009.

1	**Module name** 97525	**Laborpraktikum Bild- und Videosignalverarbeitung auf eingebetteten Plattformen** Laboratory course: Image and video signal processing on embedded platforms	**2,5 ECTS**
2	Courses / lectures	Praktikum: Laborpraktikum Bild- und Videosignalverarbeitung auf eingebetteten Plattformen (3 SWS)	2,5 ECTS
3	Lehrende	Alexander Kopte PD Dr.-Ing. Jürgen Seiler	

4	**Module coordinator**	Prof. Dr.-Ing. Andre Kaup
5	**Contents**	Today, many image and video signal processing applications are running on embedded systems. However, the computational power and the energy storage is a limiting demand for embedded systems. Nevertheless, daily mobile devices like smartphone and tablet are able to perform signal processing tasks for image and video signals, for example coding of images and videos, the creation of a panorama or the calculation of images with high dynamic range. The image and video signal processing on embedded systems lab course should show the challenges that occur while handling with such mobile devices and the implementation of such algorithm on an embedded system. Therefore, Raspberry Pis as embedded systems and Python as coding language is used in the laboratory. The experiments include the setup of the Raspberry Pi, an introduction to Python and an introduction to image and video signal processing. In addition, a camera will be connected, signal processing will be done with the camera and digital filters are implemented. Moreover, the laboratory includes different computer vision applications like the creation of a panorama.
6	**Learning objectives and skills**	The students • understand the challenges of the embedded system • make use of the coding language Python for image and video signal processing algorithms • implement functional programs with Python • evaluate the blocks of computer vision algorithms • evaluate the self-implemented programs by subjective and objective comparison • reflect the learning process in the laboratory.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	Praktikumsleistung The laboratory is based on nine experiments, which are described in the laboratory script. Every experiment has to be prepared at home and will be checked before every experiment. The results of the prepared tasks in the laboratory will be checked at the end

		of the experiment. For this, the participants have to explain their developed results to the supervisors. The laboratory is passed if all nine experiments are successfully completed.
11	**Grading procedure**	Praktikumsleistung (bestanden/nicht bestanden)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 15 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	The laboratory script "Image and video signal processing on embedded platforms will be handed out in the first session.

1	**Module name** 97651	**Laborpraktikum Image and Video Compression** Laborpraktikum Multimediakommunikation	**2,5 ECTS**
2	Courses / lectures	Praktikum: Lab Course Image and Video Compression (3 SWS) (SoSe 2025)	2,5 ECTS
3	Lehrende	Marc Windsheimer Geetha Ramasubbu	

4	**Module coordinator**	PD Dr. Christian Herglotz
5	**Contents**	**Content** • Introduction to MATLAB • Implementation of the single video codec processing blocks • Integration into the video codec pipeline, tests, and extensions • Participation in a subjective video test of selected implementations • Presentation and discussion of the achieved results
6	**Learning objectives and skills**	The students • create a fully functional program using the programming environment MATLAB, • evaluate the processing blocks of a typical video codec, • design their own video codec and enhance it by extensions of their choice, • evaluate their implemented video codecs in a subjective comparison, • reflect upon the methods conveyed during the laboratory.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	Praktikumsleistung The lab course comprises ten sessions of four hours plus two sessions of two hours, which include 7 work packages, a subjective test, and a final presentation. Each work package requires a preparation in written form and will be checked and reviewed (pass/fail) before the start of each session. During each of the ten mandatory lab sessions, the students are required to work on programming tasks, which will be reviewed at the end of each session (pass/fail). After these ten programming sessions, a working video codec has to be handed in. Besides, the students have to participate a subjective test, where the codec results are evaluated. In the last session, each video codec has to be presented by the students. A certificate confirming the successful participation in the laboratory is received if all work packages have been sufficiently prepared and implemented, if the results of all work packages have been combined into a functional and running video codec which is suitable for subjective testing, if the subjective video test has been participated in, and if the final video codec has been presented during the final presentation.

11	**Grading procedure**	Praktikumsleistung (bestanden/nicht bestanden)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 30 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	The lab course notes will be distributed during the introductory meeting.

1	**Module name** 65981	**Lie-Algebren** Lie algebras	**10 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Peter Fiebig
5	**Contents**	Grundlagen zu folgenden Themen: • Definition einer Lie-Algebra, • Definition von Darstellungen • Nilpotente und auflösbare Lie-Algebren • Halbeinfache Lie-Algebren • Wurzelsysteme und die Klassifikation halbeinfacher Lie-Algebren • Charakterformeln Die Präsentation des Stoffes erfolgt in Vorlesungsform.
6	**Learning objectives and skills**	Die Studierenden • erklären und verwenden die grundlegenden Begriffe in der Struktur- und Darstellungstheorie von Lie-Algebren. • Insbesondere erläutern sie beispielhaft Klassifikationsprinzipien in der Mathematik.
7	**Prerequisites**	empfohlen: Grundkenntnisse in Algebra
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Mathematische Theorie / Grundlagen der Data Science Master of Science Data Science 20212
10	**Method of examination**	mündlich Dauer der mündlichen Prüfung: 20 min *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 210 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	• Vorlesungsskript zu diesem Modul • J. Humphreys: Introduction to Lie algebras and representation theory, Springer

1	**Module name** 65882	**Machine Learning in Finance** Machine learning in finance	**10 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt!	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	apl. Prof. Dr. Jens Habermann
5	**Contents**	• Introduction • Denoising • Time Series • Fractional Differentiation • Principal Component Analysis • Principal Component Reduction • Partial Least Squares • Polynomial Regression • Bayes' priors • Critical Line Algorithm • End-to-End Neural Networks • Portfolio Optimization • Cross Validation • Synthetic Data • Back Testing
6	**Learning objectives and skills**	Basic skills which allow the student to apply machine learning techniques to a wide range of problems in financial mathematics.
7	**Prerequisites**	Python
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212 Studienrichtung Mathematisch statistische Datenanalyse Master of Science Data Science 20212
10	**Method of examination**	Übungsleistung Klausur (120 Minuten)
11	**Grading procedure**	Übungsleistung (20%) Klausur (80%)
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 210 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	
16	**Bibliography**	• Advances in Financial Machine Learning, M. Lopez De Prado, WILEY (2018)

		• Machine Learning in Finance: From Theory to Practice, Matthew F. Dixon, Igor Halperin, Paul Bilokon, Springer (2020) • Machine Learning for Asset Managers (Elements in Quantitative Finance), Marcos Lopez De Prado, Cambridge University Press (2020) • Machine Learning in Asset Pricing, Stefan Nagel, Princeton Lect. in Finance (2021). • Quantitative Asset Management: Factor Investing and Machine Learning for Institutional Investing, Michael Robbins, McGraw Hill (2023). • Time Series Analysis with Long Memory in View, Uwe Hassler, WILEY (2018)

1	**Module name** 48440	**Machine Learning in Signal Processing** Machine learning in signal processing	**5 ECTS**
2	Courses / lectures	Übung: Übung zu Maschinelles Lernen in der Signalverarbeitung (2 SWS) Vorlesung: Maschinelles Lernen in der Signalverarbeitung (2 SWS)	- 5 ECTS
3	Lehrende	Michele De Vita Marc Hölle Prof. Dr. Vasileios Belagiannis	

4	**Module coordinator**	Prof. Dr. Vasileios Belagiannis
5	**Contents**	This course is an introduction into machine learning and artificial intelligence. The special emphasis is on applications to modern signal processing problems. The course is focused on design principles of machine learning algorithms. The lectures start with a short introduction, where the nomenclature is defined. After this, probabilistic graphical models are introduced and the use of latent variables is discussed, concluding with a discussion of hidden Markov models and Markov fields. The second part of the course is about deep learning and covers the use of deep neural networks for machine learning tasks. In the last part of the lecture, the use of deep neural networks for speech processing tasks is introduced. The course is based on the materials and video footage from Dr. Roland Maas. He is an outstanding machine learning expert and a former member of the Chair of Multimedia Communications and Signal Processing.
6	**Learning objectives and skills**	After attending the lecture, students will be able to • understand regression and classification problems • apply PDF estimation algorithms • understand Gaussian mixture models and expectation-maximization • apply principal component analysis and independent component analysis • assess different estimation algorithms • explain the application of machine learning to system identification • apply hidden Markov models • understand different artificial neural network architectures • explain deep learning principles • apply artificial neural networks • devise learning strategies for deep neural networks • assess the application of deep neural networks for speech processing tasks.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Mathematisch statistische Datenanalyse Master of Science Data Science 20212

10	**Method of examination**	Klausur (90 Minuten) Written exam of 90min duration
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Literature: • C. M. Bishop: Pattern Recognition and Machine Learning, http://www.research.microsoft.com/en-us/um/people/cmbishop/PRML • S. Theodoridis and K. Koutroumbas: Pattern Recognition • M. Nielsen: Neural Networks and Deep Learning.

1	**Module name** 122337	**Magnetic Resonance Imaging** Magnetic resonance imaging	**5 ECTS**
2	Courses / lectures	Übung: Magnetic Resonance Imaging 1 - Exercise (2 SWS) Vorlesung: Magnetic Resonance Imaging 1 (2 SWS)	2,5 ECTS 2,5 ECTS
3	Lehrende	Prof. Dr. Frederik Bernd Laun Prof. Dr.-Ing. Andreas Maier Prof. Dr. Armin Michael Nagel	

4	**Module coordinator**	Prof. Dr. Frederik Bernd Laun
5	**Contents**	In this module,the physical and technical basics of MRI are taught in detail. The principles of data acquisition are explained and various examples are shown. Imperfections in the data acquisition lead to image artifacts that cannot be avoided in all cases. Strategies for detecting and avoiding image artifacts are explained. One of the great strengths of MRI in medical diagnostics is the ability to acquire images with different contrasts. The origin of the frequently used T1 and T2 weighted image contrasts is discussed in detail. Various MRI sequence techniques are also discussed."
6	**Learning objectives and skills**	The participants • understand the principles, properties and limits of basic MRI techniques • develop the ability to choose an appropriate basic MRI sequence and to set up the corresponding sequence parameters for a range of basic applications • are able to explain MRI techniques, algorithms and concepts of the lecture to other engineers.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Klausur (120 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 568977	**Magnetic Resonance Imaging 2 + Übung** Magnetic resonance imaging 2 + exercise	**5 ECTS**
2	Courses / lectures	Vorlesung: Magnetic Resonance Imaging 2 (2 SWS) (SoSe 2025)	2,5 ECTS
		Übung: Magnetic Resonance Imaging 2 - Exercise (2 SWS) (SoSe 2025)	2,5 ECTS
3	Lehrende	Prof. Dr. Armin Michael Nagel Prof. Dr. Frederik Bernd Laun Prof. Dr.-Ing. Andreas Maier	

4	**Module coordinator**	Prof. Dr. Frederik Bernd Laun
5	**Contents**	In der Vorlesung werden fortgeschrittene Techniken der Magnetresonanztomographie (MRT) erklärt. Vorausgesetzt werden Kenntnisse über Grundlagen des Gebietes, wie sie z.B. in der Vorlesung Magnetic resonance imaging 1" behandelt werden (Blochgleichungen, T1- und T2-Wichtung, Schichtselektion, k-Raum-Kodierung). U.a. folgende Themen werden behandelt: Echoplanare Bildgebung; Bildgebung des Flusses, der Perfusion, der Diffusion, der magnetischen Suszeptibilität; funktionelle MRT; Ultrahochfeld-MRT; CEST-Bildgebung; MRT-Technik; Beschleunigungsverfahren, z.B. parallele Bildgebung; Angiographie; Bewegungskompensation. The lecture covers advanced topics in magnetic resonance imaging (MRI). Knowledge about the basic principles of MRI are required as they are covered in the lecture Magnetic Resonance Imaging 1" (Bloch equations, T1 and T2 weighting, slice selection, k-space encoding). I.a. the following topics will be treated: echo planar imaging; imaging of flow, perfusion, diffusion, magnetic susceptibility; functional MRI; ultrahigh field MRI; chemical exchange saturation transfer imaging; MRI technique; acceleration methods, e.g. parallel imaging; angiography; motion compensation.
6	**Learning objectives and skills**	The participants • understand the principles, properties and limits of advanced MRI techniques • develop the ability to adapt basic principles of MRI to advanced MRI techniques • are able to explain MRI techniques, algorithms and concepts of the lecture to other engineers.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Klausur (120 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h

		Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 57060	**Managing global projects and information technology**	**5 ECTS**
2	Courses / lectures	Masterseminar: Managing Global Projects and Information Technology (4 SWS) Masterseminar: Managing Information Technology (2 SWS)	5 ECTS 2,5 ECTS
3	Lehrende	Tobias Clement	

4	**Module coordinator**	Prof. Dr. Michael Amberg
5	**Contents**	**Lect1/Ex1:** The traditional role of the Chief Information Officer (CIO) as gatekeeper of technology and protector of corporate information asset activities is changing. Next to the daily duties to keep the IT operations and projects running often facing shrinking budget constraints an enterprise IT manager becomes an important business partner in supporting the transformation of the traditional business to the digital age. The course has a strong focus on the role of IT within different types of enterprises and highlights IT from two different angles: IT as organizational function and IT as driver of organizational transformation. The lecture is divided into two parts (1) IT Management in enterprises (2) IT-driven business models **Lect2/Ex2:** Increasing globalization of business operations and the high importance of project structures for global operations force companies worldwide to develop and strengthen their capabilities for managing global projects. Therefore, future professionals capable of successfully coordinating projects across multiple countries and cultures will have excellent career prospects. To prepare students for the task of managing global projects, the course will focus on the following topics: • Characteristics and organization of global projects • Cultural influences (effects and remedies) • Controlling of globally distributed projects • Challenges of IS outsourcing/offshoring projects For each of these topics, students will be given an introduction to the topic (knowledge transfer) and then work on real-world examples to gain deeper insights into the topic (knowledge application). In addition, students will work in teams on a project during the semester.
6	**Learning objectives and skills**	**Lect1/Ex1 and Lect2/Ex2:** The main goal of the course is to familiarize students with the foundations of successful management in global IT-projects. The students will • describe and explain key IT Management models, • describe the project life cycle,

		• explain and evaluate design options of an IT organization and challenges of the CIO, • explain main organizational IT cost categories and tasks of managing IT costs, • describe components of a (digital) business model, • evaluate (digital) business models, • evaluate challenges caused by distance in globally distributed projects and learn about the approaches of dealing with them, • evaluate IT archetypes and decision domains, • evaluate PMOs in (IT) organization analyze different collaboration tools, • understand the impact of new technologies, such as Big Data Technologies, on value creation.
7	**Prerequisites**	• Lect1/Ex1: None • Lect2/Ex2: Basic knowledge on project management principles and techniques
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	International Information Systems Master of Science Data Science 20212
10	**Method of examination**	schriftlich/mündlich Hausarbeit • IIS exam-no. 70603 Lect1/Ex1: Managing information technology (2 SWS) 2,5 ECTS - Written assignment (100%) • IIS exam-no. 70604 Lect2/Ex2: Managing global projects (2 SWS) 2,5 ECTS - Presentation (30 min. – 33,33%), class participation (33,33%) and discussion paper (4 pages) *
11	**Grading procedure**	schriftlich/mündlich (50%) Hausarbeit (50%) • Lect1/Ex1: 50% of module score • Lect2/Ex2: 50% of module score
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	**Lect1/Ex1** • Carr, N. G. (2003): IT doesnt matter. Harvard Business Review, 81(5), 419, 128. • Christensen, C. M., & Overdorf, M. (2000). Meeting the Challenge of Disruptive Change. Harvard Business Review, 78(2), 6676. **Lect2/Ex2**

			• Binder J.: Global Project Management: Communication, Collaboration and Management Across Borders. Gower Publishing Ltd, ISBN: 0566087065.

1	**Module name** 92270	**Maschinelles Lernen in der klinischen Bioinformatik** Machine learning in clinical bioinformatics	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Maschinelles Lernen in der klinischen Bioinformatik (Vorlesung mit Übung) (4 SWS)	5 ECTS
3	Lehrende	PD Dr. Meik Kunz	

4	**Module coordinator**	PD Dr. Meik Kunz
5	**Contents**	Methoden des Maschinellen Lernens gewinnen zunehmend an Bedeutung in der Bioinformatik. Insbesondere kann auf diese Weise die immer wachsende Datenflut systematisch ausgewertet und Muster erkannt werden, welche zu innovativen diagnostischen und therapeutischen Verfahren in der Medizin beitragen können. In der Vorlesung lernen die Studierenden fortgeschrittene Methoden und Konzepte des Maschinellen Lernens der Bioinformatik für die klinische Forschung kennen.
6	**Learning objectives and skills**	Studenten... Fachkompetenz Wissen • o Methoden der Analyse von Hochdurchsatzdaten o Methoden der Sequenzanalyse und Genvorhersage o Methoden der Identifizierung und Analyse regulatorischer Elemente o Methoden der RNA- und Proteinstrukturanalyse und -klassifikation o Methoden der statistischen Analyse in der Bioinformatik o Methoden der Bewertung von Klassifikationsmodellen o Methoden des Clustering und Regression für die klinische Entscheidungsunterstützung o Methoden der Dimensionsreduktion von Daten o Methoden der funktionellen Enrichmentanalyse von biologischen Molekülen o Methoden der Target-Interaktions-Vorhersage o wenden fortgeschrittene Techniken und Algorithmen des Maschinellen Lernens auf medizinische Fragestellungen an Erschaffen entwickeln Analysewege und -skripte des Maschinellen Lernens für die Bioinformatik
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Medical Data Science Master of Science Data Science 20212
10	**Method of examination**	mündlich (20 Minuten)
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h

14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	

1	**Module name** 1999	**Masterarbeit (M.Sc. Data Science 20212)** Master's thesis	**30 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt!	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	Prof. Dr. Timm Oertel
5	**Contents**	• Independent solution of a scientific task in the field of data science under supervision and written thesis • Supervision by a university lecturer from the Department of Mathematics, the Department of Data Science, the Department of Computer Science or the Department of Artificial Intelligence in Biomedical Engineering
6	**Learning objectives and skills**	The students • work independently on a problem from the field of data science using scientific methods and present these in a structured written form • contribute to the processing of current research topics in a problem-orientated manner and define new research goals based on this knowledge
7	**Prerequisites**	It is strongly recommended that the remaining Master's modules and in particular the Master's seminar as well as all three core modules, are completed before the start of the Master's thesis.
8	**Integration in curriculum**	semester: 4
9	**Module compatibility**	Pflichtmodul Master of Science Data Science 20212
10	**Method of examination**	schriftlich (6 Monate) Master's thesis (approx. 60-80 pages)
11	**Grading procedure**	schriftlich (100%) Master's thesis (100%)
12	**Module frequency**	Every semester
13	**Resit examinations**	The exams of this moduls can only be resit once.
14	**Workload in clock hours**	Contact hours: 0 h Independent study: 900 h
15	**Module duration**	1 semester
16	**Teaching and examination language**	german english
17	**Bibliography**	As specified by the supervisor of the Master's thesis

1	**Module name** 65786	**Masterseminar (Data Science)** Master’s seminar (Data science)	**5 ECTS**
2	Courses / lectures	Hauptseminar: Big Data Seminar (2 SWS)	5 ECTS
		Masterseminar: Masterseminar "Decomposition Methods" (2 SWS)	5 ECTS
		Projekt: Projekt Biomedical Network Science (4 SWS)	10 ECTS
		Projekt: Project Representation Learning (8 SWS)	10 ECTS
		Projekt: Computational Imaging Project (8 SWS)	10 ECTS
		Sonstige Lehrveranstaltung: Projekt Maschinelles Lernen und Datenanalytik (2 SWS)	10 ECTS
		Hauptseminar: Machine Learning in MRI (4 SWS)	5 ECTS
		Hauptseminar: Seminar Humans in the Loop: The Design of Interactive AI Systems (2 SWS)	5 ECTS
		Hauptseminar: Advanced Machine Learning for Anomaly Detection (2 SWS)	5 ECTS
		Seminar: The why and how of human gait simulations (2 SWS)	5 ECTS
		Online-Kurs: Trustworthy Artificial Intelligence (3 SWS)	-
		Online-Kurs: Sovereignty and Public Sphere (3 SWS)	-
		Hauptseminar: Seminar Automatic Analysis of Voice, Speech and Language Disorders in Speech Pathologies (4 SWS)	5 ECTS
		Masterseminar: Numerical solutions for eigenvalue problems	5 ECTS
		Seminar: Project Road Scene Understanding for the Visually Impaired (2 SWS)	5 ECTS
		Hauptseminar: Seminar Digital Pathology and Deep Learning (2 SWS)	5 ECTS
		Seminar: Masterseminar: Zufallsmatrizen (2 SWS)	5 ECTS
		Seminar: Advanced Business Analytics Seminar (2 SWS)	5 ECTS
		Seminar: Spatio-Temporal data analysis techniques with applications in medical imaging (4 SWS)	5 ECTS
		Seminar: Neural Network Approximation (2 SWS)	5 ECTS
		Seminar: Seminar: Research in Movement Analysis (2 SWS)	5 ECTS
		Hauptseminar / Masterseminar: Dynamics, Learning, and Algorithms in Spiking Neural Networks (2 SWS)	5 ECTS
3	Lehrende	Dominik Probst Martin Betz Dr. Kevin-Martin Aigner	

		Dr. Anne Hartebrodt Prof. Dr. David Blumenthal Dr. Dario Zanca Prof. Dr. Björn Eskofier Vanya Saksena Erik Gösche Johanna Müller Prof. Dr. Bernhard Kainz Prof. Dr. Anne Koelewijn Prof. Dr. Johannes Helbig Paula Andrea Pérez Toro Tomas Arias Vergara Prof. Dr. Daniel Tenbrinck Daniel Mosig Hakan Calim Prof. Dr.-Ing. Andreas Maier Prof. Dr. Torben Krüger Prof. Dr. Freimut Bodendorf Yannick Rank Prof. Dr.-Ing. Jana Hutter Nyvenn Castro Michael Kitzberger Smiti Tripathy PD Dr. Cornelia Schneider Markus Gambietz Prof. Dr. Marius Yamakou	

4	**Module coordinator**	Prof. Dr. Timm Oertel
5	**Contents**	The currently offered topics will be announced by the lecturers in advance.
6	**Learning objectives and skills**	The students • acquire in-depth expertise in a subfield of data science • analyse questions and problems from the selected subfield of Data Science and solve them using scientific methods • use relevant presentation and communication techniques and present the mathematical facts in oral and written form • exchange information, ideas, problems and solutions with each other and with lecturers at a scientific level
7	**Prerequisites**	It is highly recommended to follow the individual requirements of the lecturers.
8	**Integration in curriculum**	semester: 3
9	**Module compatibility**	Pflichtmodul Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung Seminar presentation (approx. 30-80 min), possibly with additonal written elaboration (approx. 10-15 pages)
11	**Grading procedure**	Seminarleistung (100%)

12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english
16	**Bibliography**	As specified by the lecturers.

1	**Module name** 92775	**Materials and structure**	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Materials and Structure (CEP) (2 SWS) (SoSe 2025) Vorlesung mit Übung: Materials and Structure (CEP, Seminar) (2 SWS) (SoSe 2025)	2 ECTS -
3	Lehrende	Prof. Dr. Erdmann Spiecker Prof. Dr. Philipp Pelz Dr. Johannes Will	

4	**Module coordinator**	Prof. Dr. Erdmann Spiecker
5	**Contents**	The content of the module gives an overview of different fields of materials science and engineering. The following topics are included in the module: • Atomic structure and interatomic bonding • Structure of crystalline solids • Structure determination by X-ray diffraction • Imperfections in solids • Microscopic characterization of crystal defects • Mechanical properties of metals • Dislocations and strengthening mechanisms • Phase diagrams of binary alloys • Phase diagrams of metals: development of microstructure • Kinetics of phase transformations • Structure and properties of ceramics The lecture, which includes exercises, is accompanied by a seminar, in which the students prepare contributions about specific aspects in the framework of the above mentioned topics.
6	**Learning objectives and skills**	Students who participate in this course will become familiar with basic, important concepts of materials and their structure. The course enables the students: • • to classify different types of bonding that occur in materials • to understand the relationship between bonding, structure and fundamental materials properties • to describe crystalline materials with basic concepts of crystallography • to classify crystal defects with respect to their dimensionality • to describe the importance of dislocations and interfaces for the mechanical properties of metals • to understand the development of microstructure based on phase diagrams and the kinetics of phase transformation • to describe basic crystal structures of ceramics • to prepare and give a talk in a scientific environment
7	**Prerequisites**	Prerequisites:

		Basics of chemistry and maths
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Material Science Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 50 h Independent study: 100 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• William D. Callister, Jr., "Materials Science and Engineering: An Introduction", John Wiley & Sons, Inc., 7th edition (or later)

1	**Module name** 46274	**Materials Informatics** Materials informatics	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Classical Machine Learning for Materials (2 SWS, WiSe 2025) Vorlesung: Materials Data Engineering in Industrial Practice (2 SWS, SoSe 2025)	- 2,5 ECTS
3	Lehrende	Prof. Dr. Michael Zaiser PD Dr. Paolo Moretti Dr. Johannes Möller	

4	**Module coordinator**	PD Dr. Paolo Moretti
5	**Contents**	1. Data science in materials modeling 2. Correlations and methods of statistical inference 3. Machine learning techniques 4. Elements of high performance computing 5. Data structures in microstructure modeling
6	**Learning objectives and skills**	the students • acquire advanced knowledge of computer-based techniques of data analysis and materials modeling • learn methods of relevance in the treatment of data coming from both simulations and experiments. • become familiar with concepts and tools of machine learning and high performance computing, of relevance in the study of materials properties, through extensive practical sessions
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Material Science Master of Science Data Science 20212
10	**Method of examination**	mündlich currently taking an oral exam (15 min.) *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	2 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 48241	**Mathematical Image Processing**	**5 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt! This module is offered in every second summer term. The next course will be held in the summer semester 2024.	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	Prof. Dr. Daniel Tenbrinck
5	**Contents**	This module covers mathematical image processing techniques based on Fourier domain filters, variational methods, and partial differential equations. In particular, the following content will be introduced to the students: • contrast enhancement • filtering in Fourier and image domain • Bayesian image denoising • image deblurring / deconvolution • pixel-based clustering • region-based segmentation • image inpainting • nonlocal image processing using graphs
6	**Learning objectives and skills**	Students following this course will • learn how image data can be modeled and analyzed mathematically • develop a deeper understanding of mathematical basics and methods for image processing • implement own algorithms for mathematical image processing • discover connections to related mathematical fields, e.g., inverse problems and convex analysis
7	**Prerequisites**	Knowledge in calculus and linear algebra is **recommended** to understand the mathematical foundations of image processing. Knowledge in functional analysis, numerical mathematics, or inverse problems is **helpful** to understand advanced concepts in mathematical image processing.
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	Studienrichtung Mathematische Theorie / Grundlagen der Data Science Master of Science Data Science 20212 Studienrichtung Simulation and Numerics Master of Science Data Science 20212
10	**Method of examination**	schriftlich oder mündlich Oral examination (20 min.) or written examination (60 min.) depending on size of course. *

11	**Grading procedure**	schriftlich oder mündlich (100%) Oral exam (100%) or written exam (100%) depending on size of course.
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 37,5 Independent study: 112,5
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• G. Aubert & P. Kornprobst: Mathematical problems in Image Processing, Springer • K. Bredies & D. Lorenz, Mathematical Image Processing, Springer • S. Osher & R. Fedkiw, Level Set Methods and Dynamic Implicit Surfaces, Springer • A. Elmoataz , O.Lezoray, S. Bougleux: Nonlocal Discrete Regularization on Weighted Graphs: a framework for Image and Manifold Processing, IEEE Transactions On Image Processing, 17 (7), pp: 1047-1060, 2008

1	**Module name** 65785	**Mathematics of Learning** Mathematics of learning	**5 ECTS**
2	Courses / lectures	Vorlesung: Mathematics of Learning (2 SWS) Übung: Übung zu Mathematics of Learning (2 SWS)	3 ECTS 2 ECTS
3	Lehrende	Prof. Dr. Frauke Liers-Bergmann Sebastian Denzler	

4	**Module coordinator**	Prof. Dr. Frauke Liers-Bergmann
5	**Contents**	• Machine learning: empirical risk minimization, kernel methods and variational models • Mathematical aspects of deep learning • Ranking problems • Mathematical models of network interaction
6	**Learning objectives and skills**	Students • develop understanding of modern big data and state of the art methods to analyze them, • apply state of the art algorithms to large data sets, • derive models for network / graph structured data.
7	**Prerequisites**	Prerequisites: Knowledge in linear algebra and analysis is required, e.g., as taught in the first year in BSc Data Science or BSc Computer Science. Basic knowledge in numerical methods and optimization is recommended.
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Pflichtmodul Master of Science Data Science 20212
10	**Method of examination**	Klausur (60 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Goodfellow, Bengio, Courville, Deep Learning, MIT Press, 2015 • Hastie, Tibshirani, Friedman, The Elements of Statistical Learning, 2008

1	**Module name** 65711	**Mathematik für Data Science 1** Mathematics for data science 1	**10 ECTS**
2	Courses / lectures	Vorlesung: Mathematik für Data Science 1 (4 SWS)	-
		Übung: Tafelübung zu Mathematik für Data Science 1 / Physikstudierende A (2 SWS)	-
		Übung: DS-1-Ü (2 SWS)	2 ECTS
		Übung: DS-1 Ü (2 SWS)	2 ECTS
		Vorlesung: Orientierungswoche Data Science/Physik (0 SWS)	-
		Vorlesung: Übungen Orientierungswoche Data Science/ Physik (0 SWS)	-
3	Lehrende	Dr. Manfred Kronz Martin Hannuschka	

4	**Module coordinator**	
5	**Contents**	Analysis I: • Naive Mengenlehre und Logik • Grundeigenschaften der natürlichen, rationalen und reellen Zahlen: Vollständige Induktion, Körper- und Anordnungsaxiome, Vollständigkeit, untere / obere Grenzen, Dichtheit von Q in R, abzählbare und überabzählbare Mengen • Komplexe Zahlen: Rechenregeln und ihre geometrische Interpretation, quadratische Gleichungen • Konvergenz, Cauchy-Folgen, Vollständigkeit • Zahlenfolgen und Reihen: Konvergenzkriterien und Rechenregeln, absolute Konvergenz, Potenzreihen, unendliche Produkte • Elementare Funktionen, rationale Funktionen, Potenzen mit reellen Exponenten, Exponentialfunktion, Hyperbelfunktionen, trigonometrische Funktionen, Monotonie und Umkehrfunktion, Logarithmus • Stetige reellwertige Funktionen: Zwischenwertsatz, Existenz von Minimum und Maximum auf kompakten Mengen, stetige Bilder von Intervallen und Umkehrbarkeit, gleichmäßige Stetigkeit, gleichmäßige Konvergenz • Differential- und Integralrechnung in einer reellen Veränderlichen: Rechenregeln für Differentiation, Mittelwertsatz der Differentialrechnung, Taylorformel, Extremwerte und Kurvendiskussion, Definition des Integrals und Rechenregeln, gliedweise Differentiation, Hauptsatz der Differential- und Integralrechnung, Mittelwertsatz der Integralrechnung Lineare Algebra I: • Lineare Gleichungssysteme • Vektorräume • Euklidische Vektorräume (Orthonormalisierung, Orthogonalprojektion)

		• Lineare Abbildungen • Gruppen und Körper • Lineare Abbildungen, Matrizen, Gauss-Algorithmus, Determinanten, Eigenwerte und Eigenvektoren, • Diagonalisierung Hauptachsentransformation • Elemente der numerischen linearen Algebra (LR und QR-Zerlegung) Die Präsentation des Stoffes erfolgt in Vorlesungsform. Die weitere Aneignung der wesentlichen Begriffe und Techniken erfolgt durch wöchentliche Hausaufgaben.
6	**Learning objectives and skills**	Die Studierenden • definieren und erklären grundlegende Begriffe der Analysis und linearen Algebra; • diskutieren einfache Funktionen; • bewerten Folgen und Reihen; • analysieren lineare Abbildungen und Matrizen; reproduzieren grundlegende Prinzipien und Techniken.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	
10	**Method of examination**	Übungsleistung Klausur (120 Minuten) Übungsleistung Klausur (120 Minuten) *
11	**Grading procedure**	Übungsleistung (bestanden/nicht bestanden) Klausur (bestanden/nicht bestanden)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 120 h Independent study: 180 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	• O. Forster: Analysis 1 • S. Hildebrandt: Analysis I • G. Fischer: Lineare Algebra

1	**Module name** 65712	**Mathematik für Data Science 2** Mathematics for data science 2	**10 ECTS**
2	Courses / lectures	Vorlesung: Mathematik für Data Science 2 / Physikstudierende B (4 SWS) (SoSe 2025) Übung: Tafelübung zu Mathematik für Data Science 2 / Physikstudierende B (2 SWS) (SoSe 2025) Übung: Übungen zu Mathematik für Data Science 2 / Physikstudierende B (2 SWS) (SoSe 2025)	8 ECTS - 2 ECTS
3	Lehrende	apl. Prof. Dr. Jens Habermann	

4	**Module coordinator**	
5	**Contents**	Der Kurs beinhaltet: • Eigenwerte • Euklidische Vektorräume (Orthonormalisierung, Orthogonalprojektion). • Diskrete Fouriertransformation als Beispiel für Orthogonalbasis, Hinführung auf Fourier-Reihen • Normierte Räume, stetige Abbildungen zwischen normierten Räumen, Kompaktheit, Vollständigkeit, Dualraum • Fixpunktsatz von Banach • Satz von Arzela-Ascoli • Bilinearformen, Skalarprodukte • Adjungierte Operatoren • Differentialrechnung in mehreren Veränderlichen: Partielle Ableitung und Jacobi-Matrix, Satz von Schwarz, • Grundlagen Lineare Differentialgleichungen mit konstanten Koeffizienten: Lösung mittels Exponentiation von Matrizen bzw. mit charakteristischem Polynom • Gewöhnliche Differentialgleichungen: Lokale und globale Existenz und Eindeutigkeit der Lösung, Phasenportrait (DGL: insgesamt 2 Wochen) • Extrema, Optimierung mit Nebenbedingungen (kurz, wird im Kernmodul vertieft) • totale Ableitung und Linearisierung, Lipschitz-Stetigkeit und Schrankensatz, Taylorformel
6	**Learning objectives and skills**	Die Studierenden • erweitern ihr Spektrum an Grundbegriffen der Analysis und erklären diese; • wenden das Grundwissen der Analysis an, reproduzieren und vertiefen grundlegende Prinzipien und ordnen diese ein; • wenden Grundtechniken der Analysis an; • sammeln und bewerten relevante Informationen und erkennen Zusammenhänge, erkennen lineare und nichtlineare Zusammenhänge und behandeln sie quantitativ und qualitativ; • verwenden und untersuchen quadratische Formen als die einfachsten nicht-linearen Funktionen; • verwenden Dualräume zur Analyse linearer Abbildungen; • erkennen die Querverbindung zur Analysis;

		• führen exemplarische inner- und außermathematische Anwendungen durch.
7	**Prerequisites**	empfohlen: Mathematik für Data Science 1
8	**Integration in curriculum**	semester: 2
9	**Module compatibility**	
10	**Method of examination**	Klausur (120 Minuten) Übungsleistung Klausur (120 Minuten) Übungsleistung *
11	**Grading procedure**	Klausur (100%) Übungsleistung (bestanden/nicht bestanden)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 120 h Independent study: 180 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	• O. Forster: Analysis 2 • G. Fischer: Lineare Algebra • Jorge Nocedal, Stephen J. Wright: Numerical Optimization

1	**Module name** 65133	**Mathematische Grundlagen zu Künstliche Intelligenz, Neuronale Netze und Data Analytics I** Mathematical foundations of artificial intelligence, neural networks and data analytics	**5 ECTS**
2	Courses / lectures	Vorlesung: Mathematical Basics of Artificial Intelligence, Neural Networks and Data Analytics I (2 SWS)	5 ECTS
3	Lehrende	Jorge Weston Dr. Hans Georg Zimmermann	

4	**Module coordinator**	Dr. Hans Georg Zimmermann
5	**Contents**	Künstliche-Intelligenz Forschung ist der Versuch, menschenähnliche Denkprozesse auf Maschinen zu übertragen. Das betrifft insbesondere Wahrnehmung (nicht nur Sensordaten, sondern auch Bild- und Audio-daten), Modellierung (Untersuchung von Zusammenhängen in Beobachtungen) und Aktionsplanung (für optimale Aktionsplanung ist ein Modell zur Beurteilung vorgeschlagener Aktionen essenziell). Die Mathematik der Neuronalen Netze wurde von Anfang an als adäquate Lösungsmethode gesehen es dauerte aber ein halbes Jahrhundert, bis diese Mathematik und die Computer Hardware soweit entwickelt waren, dass die Vision tatsächlich bearbeitet werden kann. Im Wintersemester zeigen wir, in welchem Sinne Feedforward Neuronale Netze universelle Approximatoren für komplexe (d.h. nichtlineare und hochdimensionale) Systeme sind. Es wird dargestellt, dass sich das Lernen nicht auf die klassische Sichtweise einer nichtlinearen Regression beschränken lässt. Das liegt auch, aber nicht nur an den Weiterführungen zum Thema Deep-Learning. Wir werden auf die Unterschiede zwischen Regression und Klassifikation eingehen. Weiterführende Kapitel beschäftigen sich mit Unüberwachtem Lernen, Bilderkennung, Neuro-Fuzzy und komplexwertigen Systemen. In der Vorlesung wird auch darauf eingegangen, dass unsere Humane Intelligenz noch andere Qualitäten hat wir sollten Künstliche- und Humane-Intelligenz nicht als Verdrängungswettbewerb sehen, sondern nach einer optimalen Ergänzung suchen.
6	**Learning objectives and skills**	Die Studierenden • erkennen selbständig Aufgabenstellungen, in denen Neuronale Netze eine hilfreiche Lösungsmethode sind • sind in der Lage, die richtigen Netzstrukturen für echte Anwendungsprobleme zu konstruieren.
7	**Prerequisites**	mathematische Grundlagen aus dem Bachelor-Studium
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212 Studienrichtung Mathematisch statistische Datenanalyse Master of Science Data Science 20212
10	**Method of examination**	mündlich (15 Minuten)
11	**Grading procedure**	mündlich (100%)

12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german or english english
16	**Bibliography**	

1	**Module name** 65723	**Mathematische Grundlagen zu Künstliche Intelligenz, Neuronale Netze und Data Analytics II** Mathematical foundations of Artificial Intelligence, Neural Networks and Data Analytics II	**5 ECTS**
2	Courses / lectures	Vorlesung: Mathematische Grundlagen zu Künstliche Intelligenz, Neuronale Netze und Data Analytics II (Mathematical Basics of Artificial Intelligence, Neural Networks and Data Analytics II) (2 SWS) (SoSe 2025)	5 ECTS
3	Lehrende	Dr. Hans Georg Zimmermann Jorge Weston	

4	**Module coordinator**	Dr. Hans Georg Zimmermann
5	**Contents**	*The focus of this lecture is on the analysis of dynamical systems, or on data which are generated by dynamical systems. Time is a strong structure in modelling, which allows an in depth structural analysis before we touch data. An example is the following question: in which way influences past the present time?. The answer is a modelling of memory: how can we do this in an efficient way?. Large dynamical system (especially in economics) are only partially observable: how to handle the missing information?. In which way learning is helpful to solve this problem?. In many real world applications the dimensionality of the observables and even more the underlying state space is very large – if the dynamics evolves along a manifold in these large spaces, how can we use the manifold to make the task tractable?. In different coordinate systems the same observed dynamics might look different complicated: what is an optimal coordinate system to do the analysis and forecasting of a dynamical system?. A question which is always popping up in the challenge of forecasting is on the minimal number of observables: which are the relevant ones?. And Last but not least, if you do a prediction, are you able to say something about the uncertainty of the forecast?. In our neural network framework we can define descriptions of uncertainties beyond an expanding normal distribution. In the context of artificial intelligence it is natural, not only to ask for a good modelling but a combined optimal action planning. In which way we merge model building and action planning?. Finally we will touch the discussion between artificial intelligence entities and humans.*
6	**Learning objectives and skills**	The students independently recognize tasks in which neural networks are a helpful solution method and are able to construct the correct network structures for real application problems.
7	**Prerequisites**	*Mathematical basics from the bachelor's degree. It is recommended to have attended the lecture during the winter semester. (Part I).*
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212 Studienrichtung Mathematisch statistische Datenanalyse Master of Science Data Science 20212
10	**Method of examination**	mündlich (15 Minuten)

		The lecture is planned as a block lecture exactly one week before the normal lecture period starts. Details can be found in the StudOn group. *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	*Lecture slides*

1	**Module name** 65969	**Mathematische Statistik** Mathematical statistics	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Mathematische Statistik (3 SWS) (SoSe 2025)	5 ECTS
3	Lehrende	apl. Prof. Dr. Christophorus Richard	

4	**Module coordinator**	apl. Prof. Dr. Christophorus Richard
5	**Contents**	• Parameterschätzung • Konfidenzbereiche • Hypothesentests Die Präsentation des Stoffes erfolgt in Vorlesungsform. In der Übung vertiefen Lösungen typischer Beispiele das Verständnis des Vorlesungsstoffs.
6	**Learning objectives and skills**	Die Studierenden erklären und verwenden mathematische Grundlagen der Statistik. Sie entwickeln Lösungsmethoden für einfache statistische Problemstellungen eigenständig.
7	**Prerequisites**	Stochastische Modellbildung sowie Maßtheorie (Analysis III),Grundkenntnisse in Wahrscheinlichkeitstheorie
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Mathematisch statistische Datenanalyse Master of Science Data Science 20212
10	**Method of examination**	mündlich Dauer der mündlichen Prüfung: 15 Min. *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	• Georgii, Stochastik • Casella, Berger, Statistical Inference

1	**Module name** 95811	**Medizintechnik II (Bildgebende Verfahren)** Medical engineering II (imaging techniques)	**5 ECTS**
2	Courses / lectures	Übung: Medizintechnik II Rechnerübung (2 SWS) (SoSe 2025) Vorlesung: Medizintechnik II (4 SWS) (SoSe 2025) Übung: Medizintechnik II Tafelübung (2 SWS) (SoSe 2025) No. The module is offered in a hybrid format. About 26 students can attend the lecture in the course room, the rest of the participants can attend online (more information in StudOn).	- 3,75 ECTS 1,25 ECTS
3	Lehrende	Annika Hofmann Prof. Dr. Florian Knoll Prof. Dr. Bernhard Kainz Mischa Dombrowski Erik Gösche	

4	**Module coordinator**	Prof. Dr. Bernhard Kainz Prof. Dr. Florian Knoll
5	**Contents**	The MT II module is aimed at students of the medical engineering degree programme and is one of the basic lectures there in the field of informatics. Methods and devices that process and display the anatomy and function of the body for diagnosis and therapy are explained. Emphasis is placed on understanding and applying basic algorithms of medical image processing, such as segmentation, filtering and image reconstruction. Modalities presented include X-ray systems, computed tomography (CT), magnetic resonance imaging (MRI), optical coherence tomography (OCT) and ultrasound (US).
6	**Learning objectives and skills**	The students will • recognise and reproduce essential methods and modalities of medical imaging • understand and explain basic physical principles of medical imaging • independently apply acquired knowledge of methods to interdisciplinary problems in medicine and engineering sciences • implement algorithms of medical imaging in the programming language Java • apply the contents of the lecture in independent but supervised project work to a concrete medical problem • acquire interface competence between engineering sciences and medicine • learn to present subject-related content clearly and in a manner appropriate to the target group
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!

9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	schriftlich Project work: Implementation on the computer and written report (generally about 7 pages) *
11	**Grading procedure**	schriftlich (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 120 h Independent study: 30 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Arnulf Oppelt: Imaging Systems for Medical Diagnostics, Publicis Kommunikations AG, Erlangen, 2005

1	**Module name** 93641	**Methods of Advanced Data Engineering (VUE 5-ECTS)**	**5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Dirk Riehle
5	**Contents**	This module teaches advanced methods of data engineering using software engineering practices that support the development and operation of complex data engineering pipelines. Lecture topics include software development workflows using git/GitHub, automated testing, continuous integration and how to successfully open-source the final data science project. Participants plan, implement, and deploy a self-directed data science project based on open data using Python. Additionally, students complete exercises introducing challenges found in realistic open data sources in an open-source, domain-specific language to model data pipelines, called Jayvee. The course language is English. Previous experience in programming (for example from OSS-ADAP or OSS-AMOS) or the willingness to learn alongside the course is required. Programming in Jayvee will be taught during the course.
6	**Learning objectives and skills**	• Students learn concepts of open data and open-source software engineering • Students learn concepts and tools of data engineering, setting up and operating automated data pipelines • Students learn concepts and tools of automated testing, continuous integration and working with git/GitHub • Students gain experience with data engineering and data science in the context of a development project • Students gain experience dealing with data engineering challenges inherent to open data
7	**Prerequisites**	- OSS-ADAP - OSS-AMOS
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212 See https://bit.ly/3eberfi
10	**Method of examination**	Variabel
11	**Grading procedure**	Variabel (100%)
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h

14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 722831	**Middleware - Cloud Computing (Vorlesung mit erweiterten Übungen)** Lecture and advanced tutorial: Middleware - Cloud computing	**7,5 ECTS**
2	Courses / lectures	Vorlesung: Middleware - Cloud Computing (2 SWS) Übung: MW-Ü (2 SWS) Übung: Middleware - Cloud Computing - Übungen (2 SWS) Übung: MW-EÜ (2 SWS)	- - - 5 ECTS
3	Lehrende	Dr. rer. nat. Christian Berger Paul Bergmann	

4	**Module coordinator**	Dr. rer. nat. Christian Berger
5	**Contents**	• Überblick Cloud Computing • Grundlagen verteilter Programmierung (Web Services/SOAP/ REST) • Virtualisierung als Basis für Cloud Computing • Infrastructure as a Service (IaaS) am Beispiel von Eucalyptus und Amazon EC2 • Skalierbare Verarbeitung von großen Datenmengen • Interoperabilität und Multi-Cloud Computing • Fehlertoleranz im Kontext von Cloud Computing • Aktuelle Forschungstrends
6	**Learning objectives and skills**	Studierende, die das Modul erfolgreich abgeschlossen haben: - nennen unterschiedliche Ausprägungen von Cloud-Computing. - erläutern verschiedene Cloud-Architekturen. - stellen Vor- und Nachteile von Cloud-Computing gegenüber. - unterscheiden die Herangehensweisen bei der Entwicklung von SOAP- im Vergleich zu REST-Anwendungen. - organisieren den Austausch von Informationen in einer verteilten Anwendung unter Verwendung eines Verzeichnisdienstes. - entwickeln eigene auf Web-Services basierende Anwendungen. - bewerten die Vor- und Nachteile der Bündelung von Nachrichten beim Aufruf von Web-Services. - erläutern die Anforderungen an ein virtualisiertes System. - beschreiben die für die Virtualisierung eines Systems erforderlichen Kriterien. - vergleichen zwischen unterschiedlichen Virtualisierungstechniken und -ebenen. - schildern den Aufbau und die Funktionsweise von Xen und Linux-VServer. - erproben das Einrichten eines Abbilds für eine virtuelle Maschine. - skizzieren die Architektur einer Infrastruktur-Cloud sowie die Aufgabenbereiche hierfür zentraler Komponenten am Beispiel von Eucalyptus. - erproben das Bereitstellen von Anwendungen in einer Infrastruktur-Cloud.

		- zeigen die Grundlagen Software-definierter Netzwerke am Beispiel von Onix und B4 auf. - bewerten verschiedene im Bereich Cloud-Computing zum Einsatz kommende Datenspeichersysteme (Google File System, Bigtable, Windows Azure Storage, Amazon Dynamo) hinsichtlich der Kriterien Verfügbarkeit, Konsistenz und Partitionstoleranz. - erläutern eine auf Vektoruhren basierende Methode zur Auflösung im Zusammenhang mit letztendlicher Konsistenz auftretender Konflikte. - entwickeln ein verteiltes, repliziertes Dateisystem nach dem Vorbild von HDFS, das auf die hierarchische Speicherung großer Datenmengen ausgelegt ist. - erkunden das Bereitstellen selbst entwickelter Dienste mittels Docker. - erstellen ein Framework zur parallelen Bearbeitung von Daten nach dem Vorbild von MapReduce. - konzipieren eigene MapReduce-Anwendungen zur Verarbeitung strukturierter bzw. unstrukturierter Rohdaten. - diskutieren die Fehlertoleranzmechanismen in Google MapReduce. - schildern die grundsätzliche Funktionsweise von Systemen zur Kühlung von Datenzentren mittels Umgebungsluft. - beschreiben das Grundkonzept einer temperaturabhängigen Lastverteilung von Prozessen in einem Datenzentrum. - stellen diverse Ansätze zur Erhöhung der Energieeffizienz von MapReduce-Clustern gegenüber. - unterscheiden die Architekturen und Funktionsweisen der Koordinierungsdienste Chubby und ZooKeeper. - entwickeln einen eigenen Koordinierungsdienst nach dem Vorbild von ZooKeeper. - ermitteln die Konsistenzeigenschaften der eigenen Koordinierungsdienstimplementierung. - erläutern unterschiedliche Ansätze zur Reduzierung bzw. Tolerierung von Tail-Latenz. - skizzieren das Grundkonzept von Erasure-Codes. - beschreiben den Aufbau eines auf die Clouds mehrerer Anbieter gestützten Datenspeichersystems. - erläutern den Einsatz passiver Replikation zur Bereitstellung von Fehlertoleranzmechanismen für virtuelle Maschinen am Beispiel von Remus. - schildern die Grundlagen der Migration von virtuellen Maschinen. - bewerten die Qualität einer aktuellen Publikation aus der Fachliteratur. - erschließen sich typische Probleme (Nebenläufigkeit, Konsistenz, Skalierbarkeit) und Fehlerquellen bei der Programmierung verteilter Anwendungen. - können in Kleingruppen kooperativ arbeiten. - können ihre Entwurfs- und Implementierungsentscheidungen kompakt präsentieren und argumentativ vertreten. - können offen und konstruktiv mit Schwachpunkten und Irrwegen umgehen. - reflektieren ihre Entscheidungen kritisch und leiten Alternativen ab.
7	**Prerequisites**	Gute Programmierkenntnisse in Java

8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Data bases and knowledge representation Master of Science Data Science 20212
10	**Method of examination**	Portfolio Das Modul wird bestanden bei erfolgreicher Bearbeitung aller 6 Aufgaben zu den erweiterten Übungen (Bewertung jeweils mit "ausreichend") und dem Bestehen einer 30-minütigen mündlichen Prüfung. *
11	**Grading procedure**	Portfolio (100%) Die Modulnote ergibt sich zu 100% aus der Bewertung der mündlichen Prüfung.
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 135 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	

1	**Module name** 858896	**Modellierung, Optimierung und Simulation von Energiesystemen** Modeling, optimization and simulation of energy systems	**5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	Marco Pruckner
5	**Contents**	In der Vorlesung Modellierung, Optimierung und Simulation von Energiesystemen werden systemtechnische Planungs- und Analysemethoden behandelt, die zur Lösung komplexer und interdisziplinärer Entscheidungsaufgaben in der Energiewirtschaft eingesetzt werden. Dabei werden die wichtigsten Methoden und Verfahren anhand praktischer Fragestellungen (z.B. Ausbau erneuerbarer Energien, Zunahme der Elektromobilität) aus der energiepolitischen Planung vermittelt und die Bewältigung technisch-ökonomischer Probleme verdeutlicht. Zu den eingesetzten Tools zählen die Statistiksoftware R, AnyLogic und lpSolve. Vorkenntnisse im Umgang mit diesen Werkzeugen ist nicht zwingend erforderlich. In den Übungen werden Einführungen in die genannten Softwarepakete gegeben.
6	**Learning objectives and skills**	Die Studierenden • unterscheiden Probleme und Herausforderungen, die mit dem Energieumstieg verbunden sind, • erfassen die Vorteile und die Anwendungsmöglichkeiten computergestützter Planungsmethoden im Energiebereich, • analysieren verschiedene Problemstellungen und setzen Lösungen dafür um, • erlernen verschiedene Methoden der Datenanalyse, Optimierung und Simulation.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Simulation and Numerics Master of Science Data Science 20212
10	**Method of examination**	Portfolio
11	**Grading procedure**	Portfolio (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german german or english
16	**Bibliography**	

1	**Module name** 47674	**Movement Neuroscience: Connections between Brain and Muscles in Humans** Movement Neuroscience: Connections between brain and muscles in humans	**5 ECTS**
2	Courses / lectures	Vorlesung: Movement Neuroscience: Connections between the Brain and Muscles in Humans (3 SWS)	5 ECTS
3	Lehrende	Prof. Dr. Alessandro Del Vecchio Janina Kloos Yannick Finck	

4	**Module coordinator**	Prof. Dr. Alessandro Del Vecchio
5	**Contents**	Module: Principles of Neural control of movement and neuroengineering How the central nervous system controls muscle forces; Neurons, upper and lower motoneurons, Cortical and brainstem function, Interneurons and Motor Units. Neuroengineering applications for studying the neural control of movement; invasive and non-invasive recordings, electrical stimulation of the nervous system. Module: Electrophysiology Generation of an action potential, difference between intracellular and extracellular action potential, sparsity of the action potential in a matrix of electrodes. Module: Generation of EMG signals and analysis Recording electrophysiological data in humans; examples of EMG and EEG recordings. Module: Oscillations in neuronal networks Coherence analysis; Common synaptic input to populations of neurons; Noise in the nervous system; Associations between EEG and EMG signals; Startle responses Module: Simulation of muscle forces from the firing of individual motoneurons Motor unit model, HodgkinHuxley model, Muscle Properties Module: EMG signals in Neural Pathologies Parkinsons and Spinal Cord Injury, Motor unit analysis in neurodegenerative and neurotraumatic diseases. Module: MATLAB / Python practical coursework Extraction of neural information from electrophysiological signals; associations of information between electrophysiological signals and behavioural data; Experiment in humans.
6	**Learning objectives and skills**	Students understand motor function at the brain and muscle level. The students describe how these systems are organized and what information can be extracted from the brain and muscles with the use of EMG signals. Moreover, students explore the acquisition, analysis, and interpretation of electrophysiological data with a specific focus on human recordings in health and pathological conditions (e.g., spinal cord injury, stroke, and Parkinsons disease).
7	**Prerequisites**	No compulsory prerequisites. **Recommended:** Basic biology and neurophysiology, Computer programming (Matlab and/or Python), Biosignal processing.

8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Variabel (60 Minuten) Online exam (60 min.) *
11	**Grading procedure**	Variabel (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 75 h Independent study: 75 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	- Tutorial: Analysis of motor unit discharge characteristics from high-density surface EMG signals, Del Vecchio et al. https://doi.org/10.1016/j.jelekin.2020.102426 -Principles of Neuroscience from Eric R. Kandel, MD -Motor unit from Heckman and Enoka, DOI: 10.1002/cphy.c100087 -Surface Electromyography, Physiology, Engineering, and Applications Edited by Roberto Merletti and Dario Farina -Ibanez et al. 2021 J Neurosci https://doi.org/10.1523/JNEUROSCI.2908-20.2021

1	**Module name** 96890	**Music Processing - Analysis** Music processing - Analysis	**2,5 ECTS**
2	Courses / lectures	Vorlesung: Music Processing Analysis (2 SWS)	2,5 ECTS
3	Lehrende	Prof. Dr. Meinard Müller	

4	**Module coordinator**	Prof. Dr. Meinard Müller
5	**Contents**	Music signals possess specific acoustic and structural characteristics that are not shared by spoken language or audio signals from other domains. In fact, many music analysis tasks only become feasible by exploiting suitable music-specific assumptions. In this course, we study feature design principles that have been applied to music signals to account for the music-specific aspects. In particular, we discuss various musically expressive feature representations that refer to musical dimensions such as harmony, rhythm, timbre, or melody. Furthermore, we highlight the practical and musical relevance of these feature representations in the context of current music analysis and retrieval tasks. Here, our general goal is to show how the development of music-specific signal processing techniques is of fundamental importance for tackling otherwise infeasible music analysis problems.
6	**Learning objectives and skills**	Expertise Understand • The students present central tasks in music processing in their own words and outline possible solutions. • The students understand the properties of different forms of representation of music. Apply • The students apply basic algorithms for the analysis and comparison of music signals. • Students can predict how different musical properties will affect the signal analysis. Analyze • The students observe and discuss the meaning and impact of parameters in music analysis. • The students compare different methods of analyzing periodicities. Evaluate • The students question assumptions that are often implicitly made when using analytical methods. • Students estimate when methods might work when analyzing specific music signals and when they typically fail. Learning and methodological skills • The students prepare for the lecture using selected literature and Jupyter notebooks. • The students question existing approaches regarding their applicability in practice. • The students pay attention to efficiency issues in the algorithms discussed. Self-competence

- The students question their understanding of what they have learned using exercises.
- The students formulate questions and ask them to the lecturer and the audience in the lecture.

Social skills

- The students independently organize learning groups in which the subject is discussed and deepened.
- The students simulate oral exams with their fellow students.

Fachkompetenz

Verstehen

- Die Studierenden stellen zentrale Aufgabenstellungen der Musikverarbeitung in eigenen Worten dar und skizzieren Lösungsansätze.
- Die Studierenden verstehen die Eigenschaften von unterschiedlichen Darstellungsformen von Musik.

Anwenden

- Die Studierenden wenden grundlegende Algorithmen zur Analyse und zum Vergleich von Musiksignalen an.
- Die Studierenden können voraussagen, wie sich unterschiedliche musikalische Eigenschaften bei der Signalanalyse auswirken.

Analysieren

- Die Studierenden beobachten und diskutieren die Bedeutung und Auswirkung von Parametern bei der Musikanalyse.
- Die Studierenden stellen unterschiedliche Verfahren bei der Analyse von Periodizitäten gegenüber.

Evaluieren (Beurteilen)

- Die Studierenden hinterfragen Annahmen, die implizit bei der Verwendung von Analysemethoden gemacht werden.
- Die Studierenden schätzen ein, wann Methoden bei der Analyse von gewissen Musiksignalen funktionieren könnten und wann sie typischerweise versagen.

Lern- bzw. Methodenkompetenz

- Die Studierenden bereiten sich auf die Vorlesung anhand ausgewählter Literatur vor.
- Die Studierenden hinterfragen bestehende Ansätze hinsichtlich ihrer Anwendbarkeit in der Praxis.
- Die Studierenden beachten Fragen der Effizienz bei den diskutierten Algorithmen.

Selbstkompetenz

- Die Studierenden hinterfragen ihr Verständnis von dem Gelernten anhand von Übungsaufgaben.
- Die Studierenden formulieren Fragen und stellen diese in der Vorlesung an den Dozenten und die Zuhörerschaft.

Sozialkompetenz

- Die Studierenden organisieren selbständig Lerngruppen, in denen der Stoff diskutiert und vertieft wird.
- Die Studierenden simulieren mit ihren Kommilitonen mündliche Prüfungen.

7	**Prerequisites**	In this course, we discuss a number of current research problems in music processing or music information retrieval (MIR) covering aspects from information science and digital signal processing. We provide the necessary background information and give numerous motivating examples so that no specialized knowledge is required. However, the students should have a solid mathematical background. The lecture is accompanied by readings from textbooks or the research literature. Furthermore, the students are required to experiment with the presented algorithms using Python.
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	schriftlich oder mündlich Prüfung: mündl. 30min *
11	**Grading procedure**	schriftlich oder mündlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 45 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	http://www.music-processing.de http://www.springer.com/gp/book/9783319219448

1	**Module name** 639119	**Music Processing Analysis - Lecture and Exercise** Music processing analysis - Lecture and exercise	**5 ECTS**
2	Courses / lectures	Übung: Music Processing Analysis - Exercise (2 SWS) Vorlesung: Music Processing Analysis (2 SWS)	2,5 ECTS 2,5 ECTS
3	Lehrende	Prof. Dr. Meinard Müller	

4	**Module coordinator**	Prof. Dr. Meinard Müller
5	**Contents**	Music signals possess specific acoustic and structural characteristics that are not shared by spoken language or audio signals from other domains. In fact, many music analysis tasks only become feasible by exploiting suitable music-specific assumptions. In this course, we study feature design principles that have been applied to music signals to account for the music-specific aspects. In particular, we discuss various musically expressive feature representations that refer to musical dimensions such as harmony, rhythm, timbre, or melody. Furthermore, we highlight the practical and musical relevance of these feature representations in the context of current music analysis and retrieval tasks. Here, our general goal is to show how the development of music-specific signal processing techniques is of fundamental importance for tackling otherwise infeasible music analysis problems.
6	**Learning objectives and skills**	Fachkompetenz Verstehen • Die Studierenden stellen zentrale Aufgabenstellungen der Musikverarbeitung in eigenen Worten dar und skizzieren Lösungsansätze. • Die Studierenden verstehen die Eigenschaften von unterschiedlichen Darstellungsformen von Musik. • Die Studierenden interpretieren Signaleigenschaften anhand von Visualisierungen (Exercise). Anwenden • Die Studierenden wenden grundlegende Algorithmen zur Analyse und zum Vergleich von Musiksignalen an. • Die Studierenden können voraussagen, wie sich unterschiedliche musikalische Eigenschaften bei der Signalanalyse auswirken. • Die Studierenden implementieren Algorithmen zur Analyse, zum Vergleich und zur inhaltsbasierten Suche von Musiksignalen (Exercise). Analysieren • Die Studierenden beobachten und diskutieren die Bedeutung und Auswirkung von Parametern bei der Musikanalyse. • Die Studierenden stellen unterschiedliche Verfahren bei der Analyse von Periodizitäten gegenüber. • Die Studierenden analysieren und erforschen Eigenschaften von Musiksignalen mittels automatisierter Methoden (Exercise). • Die Studierenden klassifizieren und strukturieren Musikdaten mittels Lernverfahren (Exercise).

		Evaluieren (Beurteilen) • Die Studierenden hinterfragen Annahmen, die implizit bei der Verwendung von Analysemethoden gemacht werden. • Die Studierenden schätzen ein, wann Methoden bei der Analyse von gewissen Musiksignalen funktionieren könnten und wann sie typischerweise versagen. • Die Studierenden evaluieren automatisierte Methoden mittels geeigneter Evaluationsmaße unter Verwendung von manuell erstellten Annotationen (Exercise). Erschaffen • o Die Studierenden bereiten sich auf die Vorlesung anhand ausgewählter Literatur vor. o Die Studierenden hinterfragen bestehende Ansätze hinsichtlich ihrer Anwendbarkeit in der Praxis. o Die Studierenden beachten Fragen der Effizienz bei den diskutierten Algorithmen. o Die Studierenden entwickeln praktische Lösungswege für Problem in der Musikverarbeitung (Exercise) o Die Studierenden hinterfragen ihr Verständnis von dem Gelernten anhand von Übungsaufgaben. o Die Studierenden formulieren Fragen und stellen diese in der Vorlesung an den Dozenten und die Zuhörerschaft. o Die Studierenden nutzen Verbesserungshinweise des Betreuers und der Tutoren zur Verbesserung ihrer Lernstrategien (Exercise). o Die Studierenden organisieren selbständig Lerngruppen, in denen der Stoff diskutiert und vertieft wird. o Die Studierenden simulieren mit ihren Kommilitonen mündliche Prüfungen. o Die Studierenden entwickeln und implementieren Software im Team (Exercise). o Die Studierenden geben Kommilitonen im Rahmen ihrer Zusammenarbeit wertschätzendes Feedback (Exercise).
7	**Prerequisites**	In this course, we discuss a number of current research problems in music processing or music information retrieval (MIR) covering aspects from information science and digital signal processing. We provide the necessary background information and give numerous motivating examples so that no specialized knowledge is required. However, the students should have a solid mathematical background. The lecture is accompanied by readings from textbooks or the research literature. Furthermore, the students are required to experiment with the presented algorithms using Python.
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	mündlich (30 Minuten) Die Prüfung ist eine mündliche Prüfung mit einer Dauer von 30 Minuten. / The form of examination is an oral exam of 30 minutes.

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11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Meinard Müller Fundamentals of Music Processing Using Python and Jupyter Notebooks 2nd edition, 495 p., hardcover ISBN: 978-3-030-69807-2 Springer, 2021 http://www.music-processing.de/ https://www.audiolabs-erlangen.de/FMP

1	**Module name** 96895	**Music Processing - Synthesis** Music processing - synthesis	**2,5 ECTS**
2	Courses / lectures	Vorlesung: Musikverarbeitung - Synthese (2 SWS)	-
3	Lehrende	Dr.-Ing. Maximilian Schäfer	

4	**Module coordinator**	Dr.-Ing. Maximilian Schäfer
5	**Contents**	• Verarbeitung von Audiosignalen durch parametrische Filter und Effekte • Erzeugung von künstlichen Klängen mit Mitteln der digitalen Klangsynthese • Klangwiedergabe in echten und virtuellen Räumen • Klangbeispiele und Demonstrationen • Programmiersprachen für Audio-Echtzeit-Verarbeitung *Content*: • a short history of electrical and electronic music • processing of audio signals by parametric filters and effects • digital sound synthesis • sound reproduction in real and in virtual environments • sound examples and demonstrations • programming languages for audio real-time processing
6	**Learning objectives and skills**	Die Studierenden • beschreiben die speziellen Anforderungen für Audio-Echtzeit-Verarbeitung, • wenden ihre theoretischen Kenntnisse zeitdiskreter Signale und Systeme für die Verarbeitung und Erzeugung musikalischer Klänge an, • gestalten eigene Software-Realisierungen zur Klangsynthese, • entwerfen technische Systeme für musikalisch motivierte Aufgabenstellungen. The students • specify the special requirements for audio realtime processing, • apply their theoretical knowledge about discrete-time signals and systems to processing and synthesis of musical sounds, • design their own software realizations for sound synthesis • implement technical systems for digital music.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	schriftlich oder mündlich The examination is a 30-minute oral exam. The examination language is English. *
11	**Grading procedure**	schriftlich oder mündlich (100%)
12	**Module frequency**	Only in winter semester

13	**Workload in clock hours**	Contact hours: 30 h Independent study: 45 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Das Vorlesungsskript und weitere Zusatzmaterialien zur Vorlesung werden via StudOn zur Verfügung gestellt.

1	**Module name** 480491	**Nailing your Thesis (VUE 5-ECTS)** Nailing your thesis (VUE 5-ECTS)	**5 ECTS**
2	Courses / lectures	Übung: Nailing your Thesis (UE) (2 SWS) (SoSe 2025) Vorlesung: Nailing your Thesis (VL) (SoSe 2025)	2,5 ECTS -
3	Lehrende	Prof. Dr. Dirk Riehle	

4	**Module coordinator**	Prof. Dr. Dirk Riehle
5	**Contents**	This course teaches students how to perform scientific research for their final thesis or a research paper. The goal is to prepare students for a Bachelor or Master research thesis. The course covers the following topics: • Science and society • The research process • Theory building research • Theory validation research • Writing a research thesis/paper • The scientific community Students can choose one or both of two components: • VUE (VL + UE or seminar), 4 SWS, 5 ECTS. VUE combines lectures with homework and exercises. VUE is run as a 3h block. • PROJ (small research project), 2 SWS, 5 ECTS. In PROJ, students perform a small research project, either individually or in teams. The available projects will be presented at the beginning of the course. Students perform the research, write a paper, and hold a presentation about their work. Sign-up and further course information are available at https://nyt.uni1.de - please sign up for the course on StudOn (available through previous link) as soon as possible. The course information will also tell you how the course will be held (online or in person).
6	**Learning objectives and skills**	• Students gain an understanding of how science works • Students learn how to perform research work • Students learn how to write a research thesis
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Portfolio
11	**Grading procedure**	Portfolio (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	english
16	**Bibliography**	See https://nyt.uni1.de

1	**Module name** 47673	**Network medicine**	**5 ECTS**
2	Courses / lectures	Hauptseminar: Network Medicine (2 SWS)	5 ECTS
3	Lehrende	Prof. Dr. David Blumenthal	

4	**Module coordinator**	Prof. Dr. David Blumenthal
5	**Contents**	Network medicine is an emerging research field which leverages techniques from molecular biology, bioinformatics, combinatorial optimization, and artificial intelligence to uncover potential disease mechanisms and candidates for causally effective treatments in heterogeneous molecular networks. In this seminar, students will dive into selected hot topics in network medicine.
6	**Learning objectives and skills**	Students will • be able to explain hot topics in the field of network medicine, • be able to identify, understand, and contextualize relevant research literature, • be able to give a presentation for a scientific audience, • be able to write an academic report.
7	**Prerequisites**	Some prior knowledge in graph theory and/or network science is recommended.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung Written mini-survey (4 pages double column) + oral presentation of mini-survey (20 min + 10 min Q & A) + lead of discussion following oral presentation of another seminar participant (10 min). *
11	**Grading procedure**	Seminarleistung (100%) Written mini-survey (40%), oral presentation of mini-survey (40%), lead of discussion following oral presentation of another seminar participant (20%).
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	All relevant literature will be made available in StudOn. For background reading, students can consult the following textbook: • Loscalzo, Joseph, Albert-László Barabási, and Edwin K. Silverman (eds.): Network Medicine: Complex Systems in Human Disease and Therapeutics. Harvard University Press, 2017.

1	**Module name** 407487	**Numerical Aspects of Linear and Integer Programming** Numerical aspects of linear and integer programming	**5 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the summer semester.	
3	Lehrende	-	

4	**Module coordinator**	Prof. Dr. Frauke Liers-Bergmann
5	**Contents**	• Revidiertes Simplexverfahren (mit Schranken) • Phase I des Verfahrens • Duales Simplexverfahren • LP Presolve/Postsolve • Skalierung • MIP Solution Techniques Die Präsentation des Stoffes erfolgt in Vorlesungsform. In den Übungen werden die Studierenden von einem Übungsgruppenleiter betreut.
6	**Learning objectives and skills**	Die Studierenden erklären und verwenden im Rahmen der Vorlesung Methoden und numerische Verfahren, die zur Lösung von Linearen und Gemischt-ganzzahligen Programmen in der Praxis Anwendung finden.
7	**Prerequisites**	empfohlen: Lineare Algebra, Lineare und Kombinatorische Optimierung
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Databased optimization Master of Science Data Science 20212
10	**Method of examination**	mündlich
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 36 h Independent study: 114 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	• V. Chvátal: Linear Programming, W. H. Freeman and Company, New York, 1983 • L.A. Wolsey: Integer Programming, John Wiley and Sons, Inc., 1998

1	**Module name** 65923	**Optimization in industry and economy**	**5 ECTS**
2	Courses / lectures	Vorlesung: Optimization in Industry and Economy (2 SWS)	5 ECTS
3	Lehrende	Prof. Dr. Frauke Liers-Bergmann Sebastian Denzler	

4	**Module coordinator**	Prof. Dr. Frauke Liers-Bergmann
5	**Contents**	This course focuses on modeling and solving real-world optimization problems occurring in industry and economics. Advantages and disadvantages of different modeling techniques will be outlined. In order to achieve efficient solution approaches, different reformulations and their numerical results will be discussed. Students will learn how to present optimization results properly as well as how to interpret and evaluate these results for practical applications. The latter may include but is not limited to the optimization of transport networks (gas, water, energy), air traffic management and mathematical modeling/optimization of market mechanisms in the energy sector.
6	**Learning objectives and skills**	Students • model complex real-world optimization problems with respect to efficient • solvability, • classify the models and use appropriate solution strategies, • evaluate the achieved computational results.
7	**Prerequisites**	Recommended: Modul LKOpt: Linear and combinatorial optimization
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Studienrichtung Databased optimization Master of Science Data Science 20212
10	**Method of examination**	mündlich (15 min) *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english

16	**Bibliography**	• Lecture notes (will be published on StudOn at the beginning of the semester) • Up-to-date research literature (will be published on StudOn at the beginning of the semester)

1	**Module name** 93040	**Parallele und Funktionale Programmierung** Parallel and functional programming	**5 ECTS**
2	Courses / lectures	Übung: PFP-T06 (2 SWS)	2,5 ECTS
		Übung: PFP-T03 (2 SWS)	2,5 ECTS
		Übung: PFP-R05 (2 SWS)	2,5 ECTS
		Übung: PFP-T01 (2 SWS)	2,5 ECTS
		Übung: PFP-R04 (2 SWS)	2,5 ECTS
		Übung: PFP-R02 (2 SWS)	2,5 ECTS
		Übung: PFP-R01 (2 SWS)	2,5 ECTS
		Übung: PFP-T04 (2 SWS)	2,5 ECTS
		Übung: PFP-R06 (2 SWS)	2,5 ECTS
		Übung: PFP-T07 (2 SWS)	2,5 ECTS
		Übung: PFP-R03 (2 SWS)	2,5 ECTS
		Übung: PFP-T02 (2 SWS)	2,5 ECTS
		Übung: PFP-T05 (2 SWS)	2,5 ECTS
		Vorlesung: Parallele und Funktionale Programmierung (2 SWS)	2,5 ECTS
3	Lehrende	David Schwarzbeck Dr.-Ing. Norbert Oster Lukas Rotsching Prof. Dr. Michael Philippsen Ludwig Schmotzer	

4	**Module coordinator**	Dr.-Ing. Norbert Oster Prof. Dr. Michael Philippsen
5	**Contents**	• Grundlagen der funktionale Programmierung • Grundlagen der parallelen Programmierung • Datenstrukturen • Objektorientierung • Scala-Kenntnisse • Erweiterte JAVA-Kenntnisse • Aufwandsabschätzungen • Grundlegende Algorithmen
6	**Learning objectives and skills**	Die Studierenden • erlernen die Grundlagen der funktionalen Programmierung anhand der Programmiersprache Scala • verstehen paralleles Programmieren mit Java • kennen fundamentale Datenstrukturen und Algorithmen • können funktionale und parallele Algorithmen entwickeln und analysieren
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 3

9	**Module compatibility**	
10	**Method of examination**	Klausur (60 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	

1	**Module name** 65123	**Partielle Differentialgleichungen I** Partial differential equations I	**10 ECTS**
2	Courses / lectures	Übung: Übungen zu Partielle Differentialgleichungen I (2 SWS) Vorlesung: Partielle Differentialgleichungen I (4 SWS)	- 10 ECTS
3	Lehrende	Prof. Dr. Aaron Brunk	

4	**Module coordinator**	Prof. Dr. Günther Grün
5	**Contents**	• schwache Existenztheorie elliptischer Gleichungen zweiter Ordnung • Regularität schwacher Lösungen (Differenzenquotientenmethode, Moser, Harnack) • Wärmeleitungsgleichung in Hölderräumen, Vergleichssätze Die Präsentation des Stoffes erfolgt in Vorlesungsform. Die weitere Aneignung der wesentlichen Begriffe und Techniken erfolgt durch wöchentliche Hausaufgaben.
6	**Learning objectives and skills**	Die Studierenden erarbeiten sich einen Überblick über Anwendungsbereiche von PDGen. Sie verwenden einfache explizite Lösungsmethoden und nutzen klassische und schwache Zugänge zu Existenzresultaten
7	**Prerequisites**	empfohlen: Analysis-Module des Bachelorstudiums
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Mathematische Theorie / Grundlagen der Data Science Master of Science Data Science 20212 Studienrichtung Simulation and Numerics Master of Science Data Science 20212
10	**Method of examination**	mündlich Dauer der mündlichen Prüfung: 20 Min. *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 210 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	• E. DiBenedetto: Partial Differential Equations, Birkhäuser 2001 • L. C. Evans: Partial Differential Equations, AMS 1997 • D. Gilbarg, N. S. Trudinger: Elliptic Partial Differential Equations, Springer 1983 • Vorlesungsskriptum

1	**Module name** 409733	**Partielle Differentialgleichungen II** Partial differential equations II	**10 ECTS**
2	Courses / lectures	Vorlesung: Partielle Differentialgleichungen II (4 SWS) (SoSe 2025) Übung: Übungen zu Partielle Differentialgleichungen II (2 SWS) (SoSe 2025)	10 ECTS -
3	Lehrende	Prof. Dr. Emil Wiedemann	

4	**Module coordinator**	Prof. Dr. Günther Grün
5	**Contents**	• direkte Methoden der Variationsrechnung, Existenz im konvexen Fall, Hölder-Regularität • Die Wärmeleitungsgleichung und andere parabolische Gleichungen • Die Wellengleichung und andere hyperbolische Gleichungen • Weitere ausgewählte Themen, z.B.: • Energiemethoden • Viskositätslösungen • skalare Erhaltungsgleichungen • parabolische p-Laplace und poröse Mediengleichung (Regularität, qualitative Eigenschaften, usw.) • Gleichungen vierter Ordnung Die Präsentation des Stoffes erfolgt in Vorlesungsform. Die weitere Aneignung der wesentlichen Begriffe und Techniken erfolgt durch wöchentliche Hausaufgaben
6	**Learning objectives and skills**	Die Studierenden wenden Methoden für Existenzbeweise bei nichtlinearen Gleichungen an, und erweitern ihr Methodenspektrum für Lösungskonzepte und Eindeutigkeitsresultate.
7	**Prerequisites**	Partielle Differentialgleichungen I als dringende Empfehlung
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Mathematische Theorie / Grundlagen der Data Science Master of Science Data Science 20212
10	**Method of examination**	mündlich Dauer der mündlichen Prüfung: 20 Min. *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 210 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german or english
16	**Bibliography**	• L. C. Evans, Partial Differential Equations, AMS 1997 • D. Gilbarg, N. S. Trudinger, Elliptic Partial Differential Equations, Springer 1983

		• E. DiBenedetto, Partial Differential Equations, Birkhäuser 2001 • E. Giusti, Direct methods in the calculus of variations. World Scientific Publishing 2003 • Vorlesungsskriptum

1	**Module name** 57172	**Patenting for innovation**	**5 ECTS**
2	Courses / lectures	Vorlesung: Patenting for Innovation (4 SWS)	5 ECTS
3	Lehrende	Layla Hajjam-Demir Prof. Dr. Bernhard Grill Prof. Dr. Kathrin Möslein	

4	**Module coordinator**	Prof. Dr. Kathrin Möslein
5	**Contents**	Intellectual Properties (Ips) in general and especially patents play an important role in innovation in any Hightech society. This topic is multi-faceted and can be accessed from different viewpoints: business, politics, legal framework, organization, etc. In this course, we will focus on: • the introduction to Ips and patents in general, • the role of Ips and patents in research, development and (open) innovation, • the patent exploitation through licensing contracts and patent pools, the patent policies in the European Union, China and USA.
6	**Learning objectives and skills**	The students: • learn to understand the role of patenting in the innovation process, • gain deeper insights into the roles of IP in various types of businesses, study the role of IP and patents in different regions and contexts (Asia, United States, Europe).
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	International Information Systems Master of Science Data Science 20212
10	**Method of examination**	Seminararbeit
11	**Grading procedure**	Seminararbeit (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Literature will be announced and distributed in the first sessions.

1	**Module name** 44120	**Pattern Analysis** Pattern analysis	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Pattern Analysis (4 SWS) (SoSe 2025)	5 ECTS
3	Lehrende	PD Dr.-Ing. Christian Riess	

4	**Module coordinator**	PD Dr.-Ing. Christian Riess
5	**Contents**	This lecture is the sequel to the lecture *"Pattern Recognition"*. As such, it covers topics from the chapters 8-14 from the book *"Pattern Recognition and Machine Learning"* by Christopher Bishop. These topics include various aspects of Bayesian modeling, including (but not limited to) • probabilistic graphical models • mixture modeling • variational inference • sampling methods • manifold learning • Markov random fields • hidden Markov models • tree-based methods • ensembling
6	**Learning objectives and skills**	The students • explain the discussed methods for classification, prediction, and analysis of patterns, • compare and analyze methods for manifold learning and select a suited method for a given set of features and a given problem, • compare and analyze methods for probability density estimation and select a suited method for a given set of features and a given problem, • apply non-parametric probability density estimation to pattern analysis problems, • apply dimensionality reduction techniques to high-dimensional feature spaces, • explain statistic modeling of feature sets and sequences of features, • explain statistic modeling of statistical dependencies
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212
10	**Method of examination**	Variabel (60 Minuten) Die Prüfung ist eine schriftliche Klausur mit Multiple Choice mit einer Dauer von 60 Minuten. --- The form of examination is a written exam with multiple choice with a duration of 60 minutes.

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11	**Grading procedure**	Variabel (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Begleitende Literatur / Accompanying literature: • C. Bishop: Pattern Recognition and Machine Learning, Springer Verlag, Heidelberg, 2006 • T. Hastie, R. Tibshirani und J. Friedman: The Elements of Statistical Learning, 2nd Edition, Springer Verlag, 2009 • A. Criminisi and J. Shotton: Decision Forests for Computer Vision and Medical Image Analysis, Springer, 2013

1	**Module name** 44130	**Pattern Recognition** Pattern recognition	**5 ECTS**
2	Courses / lectures	Übung: PR Exercise (1 SWS) Vorlesung: Pattern Recognition (3 SWS)	1,25 ECTS 3,75 ECTS
3	Lehrende	Linda-Sophie Schneider Dr.-Ing. Siming Bayer Prof. Dr.-Ing. Andreas Maier	

4	**Module coordinator**	Prof. Dr.-Ing. Andreas Maier
5	**Contents**	Mathematical foundations of machine learning based on the following classification methods: • Bayesian classifier • Logistic Regression • Naive Bayes classifier • Discriminant Analysis • norms and norm dependent linear regression • Rosenblatt's Perceptron • unconstraint and constraint optimization • Support Vector Machines (SVM) • kernel methods • Expectation Maximization (EM) Algorithm and Gaussian Mixture Models (GMMs) • Independent Component Analysis (ICA) • Model Assessment • AdaBoost Mathematische Grundlagen der maschinellen Klassifikation am Beispiel folgender Klassifikatoren: • Bayes-Klassifikator • Logistische Regression • Naiver Bayes-Klassifikator • Diskriminanzanalyse • Normen und normabhängige Regression • Rosenblatts Perzeptron • Optimierung ohne und mit Nebenbedingungen • Support Vector Maschines (SVM) • Kernelmethoden • Expectation Maximization (EM)-Algorithmus und Gaußsche Mischverteilungen (GMMs) • Analyse durch unabhängige Komponenten • Modellbewertung • AdaBoost
6	**Learning objectives and skills**	Die Studierenden • verstehen die Struktur von Systemen zur maschinellen Klassifikation einfacher Muster • erläutern die mathematischen Grundlagen ausgewählter maschineller Klassifikatoren • wenden Klassifikatoren zur Lösung konkreter Klassifikationsproblem an

		- beurteilen unterschiedliche Klassifikatoren in Bezug auf ihre Eignung - verstehen in der Programmiersprache Python geschriebene Lösungen von Klassifikationsproblemen und Implementierungen von Klassifikatoren Students - understand the structure of machine learning systems for simple patterns - explain the mathematical foundations of selected machine learning techniques - apply classification techniques in order to solve given classification tasks - evaluate various classifiers with respect to their suitability to solve the given problem - understand solutions of classification problems and implementations of classifiers written in the programming language Python
7	**Prerequisites**	- Well grounded in probability calculus, linear algebra/matrix calculus - The attendance of our bachelor course 'Introduction to Pattern Recognition' is not required but certainly helpful. - Gute Kenntnisse in Wahrscheinlichkeitsrechnung und Linearer Algebra/Matrizenrechnung - Der Besuch der Bachelor-Vorlesung 'Introduction to Pattern Recognition' ist zwar keine Voraussetzung, aber sicherlich von Vorteil.
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german or english english
16	**Bibliography**	- Richard O. Duda, Peter E. Hart, David G. Stock: Pattern Classification, 2nd edition, John Wiley&Sons, New York, 2001 - Trevor Hastie, Robert Tobshirani, Jerome Friedman: The Elements of Statistical Learning - Data Mining, Inference, and Prediction, 2nd edition, Springer, New York, 2009 - Christopher M. Bishop: Pattern Recognition and Machine Learning, Springer, New York, 2006

1	**Module name** 878210	**Praktikum Machine Learning in der Signalverarbeitung** Lab course machine learning in signal processing	**2,5 ECTS**
2	Courses / lectures	Praktikum: Lab Course Machine Learning in Signal Processing (4 SWS) (SoSe 2025)	2,5 ECTS
3	Lehrende	Prof. Dr. Vasileios Belagiannis Rohan Asthana Marc Hölle Michele De Vita	

4	**Module coordinator**	Prof. Dr. Vasileios Belagiannis
5	**Contents**	This is an advanced level lab course in machine learning. Imagine a car driving on an autobahn in an automatic mode. Among other things, the car needs to steer itself to keep driving in it's own lane. To accomplish this, the central problem is to detect the road-lane markings. These are the white solid or dashed lines that are drawn on each side of the lane. The standard modern approach to solve this type of problems is to take a large dataset of labeled examples and train a deep neural network model to accomplish the task. This is how car and pedestrian detection algorithms are developed. The difficulty with the road-lane markings is that there is no labeled dataset of them and creating such dataset would cost millions of dollars. In this lab course we will solve this problem using transfer learning and mathematical modeling: • Create cartoon-like artificial images of a road with known locations for the lane markings. • Train deep neural network on these artificial images with heavy data augmentations that mimic real-world images. • Create a dataset of unlabeled real-life videos by downloading and organizing examples from youtube. • Create a machine learning pipeline for working with these videos efficiently. • Apply the neural network that has been trained on artificial data to the real world videos. • Analyze the quality of results produced by the network. • Use mathematical modeling to correct the outputs of the network. • Retrain the network on the dataset composed of the corrected outputs. • Measure and analyze the quality of the results. The software will be written in Python using JupyterLab development framework. Access to modern GPU server will be provided. The best students will have the opportunity to contribute to the creation of state-of-the-art lane detection system for self-driving cars during or after the corse.
6	**Learning objectives and skills**	Students are able to:

		• Independently design machine learning pipelines to solve complex problems in artificial intelligence. • Choose appropriate algorithms for the problem at hand. • Use standard packages for machine learning in Python: numpy, cvxpy, scikit-learn, pywavelets, pytorch. • Debug and calibrate machine learning algorithms. Develop modification to the standard algorithms as appropriate to the problem at hand. • Explain the theoretical aspects of deep learning.
7	**Prerequisites**	Knowledge of Python programming language is required. Basic theoretical knowledge in machine learning is assumed: consider taking the Machine Learning in Signal Processing (MLSIP) course in the same semester.
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Mathematisch statistische Datenanalyse Master of Science Data Science 20212
10	**Method of examination**	Praktikumsleistung To pass the lab course, the programming tasks of each of the 5 session must be successfully completed.
11	**Grading procedure**	Praktikumsleistung (bestanden/nicht bestanden)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 15 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	1) Goodfellow, I., Bengio, Y., Courville, A., & Bengio, Y. (2016). Deep learning. 2) Friedman, J., Hastie, T., & Tibshirani, R. (2001). The elements of statistical learning. 3) Raschka, S., Liu, Y. H., Mirjalili, V., & Dzhulgakov, D. (2022). Machine Learning with PyTorch and Scikit-Learn: Develop machine learning and deep learning models with Python.

1	**Module name** 54760	**Process Analytics (PA)** Process analytics (PA)	**5 ECTS**
2	Courses / lectures	Vorlesung: V: Process Analytics (2 SWS) Tutorium: T: Process Analytics (0 SWS)	- -
3	Lehrende	Annina Ließmann Willi Tang Prof. Dr. Martin Matzner	

4	**Module coordinator**	Annina Ließmann Prof. Dr. Martin Matzner
5	**Contents**	The course focuses on the data-driven analysis of business processes. It covers various technical, organizational, and business aspects of process improvement, with Process Mining being the central focus. The module emphasizes practical application and encourages students to apply the methods and concepts learned during the lectures. In the group project, students will utilize their knowledge by working with state-of-the-art process mining tools, such as Celonis.
6	**Learning objectives and skills**	The students • capture the concepts around process improvement and recognize the potential for organizations • understand technical aspects of data-driven process analysis • know about state-of-the art technologies for process mining • apply technologies for process analysis in a practical setting • analyze a business process and develop a business case for process improvements • work in groups and present their results together
7	**Prerequisites**	Beneficial: • Basic understanding of business processes and process notations / modelling
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	International Information Systems Master of Science Data Science 20212
10	**Method of examination**	Präsentation Klausur (60 Minuten)
11	**Grading procedure**	Präsentation (70%) Klausur (30%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	None

1	**Module name** 93164	**Project Music and Audio Processing** Project music and audio processing	**10 ECTS**
2	Courses / lectures	Praktikum/Projekt: Project Music and Audio Processing (0 SWS)	10 ECTS
3	Lehrende	Prof. Dr. Meinard Müller	

4	**Module coordinator**	Prof. Dr. Meinard Müller
5	**Contents**	At the International Audio Laboratories Erlangen we offer project topics that are connected to our current research in the field of semantic audio processing with a focus on music analysis, retrieval, and classification applications. Project topics are defined individually. The 10 ECTS project is directed towards students of computer science. Please directly contact Meinard Müller for further details and possible project topics.
6	**Learning objectives and skills**	The students • familiarize themselves with complex software systems and expand them • learn to develope and implement solutions independently • conduct systematic experiments and evaluate results • document the software they develop
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	Praktikumsleistung
11	**Grading procedure**	Praktikumsleistung (100%) The grade is formed by the quality of the deliverables, weighted according to: • 50% implementation of software to solve the given task; • 25% demonstration of the functionality to the supervisor; • 25% description of the software in the form of a scientific elaboration or as conventional software documentation. The length of the scientific elaboration is a maximum of 10 pages.
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 240 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english
16	**Bibliography**	

1	**Module name** 93112	**Project Representation Learning** Project: Representation learning	**10 ECTS**
2	Courses / lectures	Projekt: Project Representation Learning (8 SWS) yes for final presentations and meetings	10 ECTS
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Bernhard Kainz
5	**Contents**	At the Image Data Exploration and Analysis Lab we offer project topics that are connected to our current research in the fields of medical image processing, machine learning, human-in-the-loop computing, and computer vision. Other than a course with fixed topic, project topics are defined individually. The 10 ECTS project is directed towards students of computer science and medical engineering. Please have a look at our website for an overview. https://www.idea.tf.fau.eu/teaching/open-projects/ Different projects in the area of (deep) representation learning are on offer. These reach from theoretical exploration of new data representation methods to practical evaluation of applications in, e.g., medical image analysis. Furhter example projects will be made available on the website of the Image Data Exploration and Analysis Lab. Students may also propose their own projects, which will be coordinated and refined with the module lead during preliminary discussions.
6	**Learning objectives and skills**	The students work their way into complex software systems and expand them learn to develop and implement solutions independently document the software they have written. We'll start with a project definition phase, followed by literature research, idea outline and implementation phase. Final results will be presented in a mini-symposium and further explained in a short 10-page scientific report. **Module aims** In this module you will have the opportunity to demonstrate independence and originality, to plan and organise a large project over a long period, and to put into practice the knowledge, skills and research methods that you have learnt throughout the course. **Learning outcomes** Upon successful completion of this module, you will have demonstrated your ability to: - apply previously taught knowledge and skills to a substantial problem in Computing or Data Science, as an individual - conduct an independent investigation and apply cutting-edge research, methods and thinking appropriate to the problem - present complex technical material orally to a mixed audience

		- exercise scientific writing skills by way of a substantial written report, summarising your findings **Module syllabus** There will be a small number of supporting meetings that will 1. describe the structure of the project, including expectations, milestones and deliverables, 2. give guidance on writing and presentation skills targeted specifically at individual projects, 3. explain the assessment procedures. The rest of the project involves an independent investigation under the supervision of an academic advisor.
7	**Prerequisites**	You should have very solid programming skills and have knowlege in machine learning, deep learning and computer vision methods.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212 Studienrichtung Data bases and knowledge representation Master of Science Data Science 20212
10	**Method of examination**	Variabel The deliverables include a written report (10 pages) and a presentation (20 minutes) *
11	**Grading procedure**	Variabel (100%) The grade consists of the written report (80%) and the presentation (20%).
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 240 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 47676	**Projekt Biomedical Network Science** Project: Biomedical network science	**10 ECTS**
2	Courses / lectures	Projekt: Projekt Biomedical Network Science (4 SWS)	10 ECTS
3	Lehrende	Dr. Anne Hartebrodt Prof. Dr. David Blumenthal	

4	**Module coordinator**	Prof. Dr. David Blumenthal
5	**Contents**	The Biomedical Network Science (BIONETS) lab investigates molecular disease mechanisms using techniques from combinatorial optimization, network science, and artificial intelligence. We also develop privacy-preserving decentralized biomedical AI solutions, which enable cross-institutional studies on sensitive data. Students will work on individual research topics within these field and develop prototypes of software tools to solve the addressed problems.
6	**Learning objectives and skills**	Students will be able to • develop and implement an algorithm for a problem within the field of biomedical networks science which, in certain respects, improves upon the state-of-the-art, • apply best practices in software development and documentation, • write an academic report.
7	**Prerequisites**	Strong programming skills in any programming language.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Variabel Practical Achievement: Fully functional software prototype submitted as persistent source code repository + written report (4 pages double column) + oral presentation of software prototype. *
11	**Grading procedure**	Variabel (100%) Fully functional software prototype submitted as persistent source code repository (40%), written report (40%), oral presentation of software prototype (20%).
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 240 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	All relevant research literature will be made available in StudOn.

1	**Module name** 924553	**Projekt Maschinelles Lernen und Datenanalytik** Project machine learning and data analytics	**10 ECTS**
2	Courses / lectures	Sonstige Lehrveranstaltung: Projekt Maschinelles Lernen und Datenanalytik (2 SWS)	10 ECTS
3	Lehrende	Prof. Dr. Björn Eskofier Dr. Dario Zanca	

4	**Module coordinator**	Prof. Dr. Björn Eskofier An Nguyen Dr. Dario Zanca
5	**Contents**	At the Machine Learning and Data Analytics Lab we offer project topics that are related to our current research in the fields of Machine Learning, Human Computer Interaction, Modeling and Simulation and Wearable Computing. Other than a course with fixed topic, project topics are defined individually. The 10 ECTS project addresses students of computer science and medical engineering. However, most projects can also be offered as 5 ECTS medical engineering internship/praktikum. There will be a kick-off meeting the first Thursday 16:15-18:00 of each semester where topics in the field of machine learning and data analytics will be presented. Most topics will be related to the diverse research fields of the Machine Learning and Data Analytics Lab. Students also have the possibility to discuss their own project ideas with the supervisors. The distribution of topics will be based on prerequisites and first come, first serve in terms of time of registration until all topics are distributed. Students will have to contact the corresponding supervisor for the topic of interest. Additional topics are also presented on our website.
6	**Learning objectives and skills**	The students • work on a machine learning algorithm and implement it • work on complex software systems and expand them • learn to independently develop and implement proposed solutions • document the software they have written
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212 Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212 No prerequisites for this course.
10	**Method of examination**	Portfolio The evaluation for projects includes a code repository with the implementation of the work (including proper code documentation), a 15-minute presentation, and a term paper of approximately 10 pages. *
11	**Grading procedure**	Portfolio (100%)

		The overall grade consists of these parts: • 50% graded implementation • 25% graded presentation • 25% graded documentation/report
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 240 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english
16	**Bibliography**	

1	**Module name** 628205	**Projekt Mustererkennung** Project: Pattern recognition	**10 ECTS**
2	Courses / lectures	Praktikum/Projekt: Projekt Computer Vision (0 SWS) Praktikum/Projekt: Projekt Mustererkennung (0 SWS) Praktikum/Projekt: Project Remote Sensing (2 SWS) Praktikum/Projekt: Project Time Series Praktikum/Projekt: Project Medical Imaging	10 ECTS 10 ECTS 10 ECTS - 10 ECTS
3	Lehrende	Thomas Gorges Dr.-Ing. Vincent Christlein Nora Gourmelon Marcel Nicolas Dreier Tomas Arias Vergara Linda-Sophie Schneider	

4	**Module coordinator**	Prof. Dr.-Ing. Andreas Maier
5	**Contents**	At the Pattern Recognition Lab we offer project topics that are connected to our current research in the fields of medical image processing, speech processing and understanding, computer vision and digital sports. Other than a course with fixed topic, project topics are defined individually. The 10 ECTS project is directed towards students of computer science. However, most projects can also be offered as 5 ECTS medical engineering practical modules (academic laboratory or research laboratory). Please have a look at our website for an overview.
6	**Learning objectives and skills**	Die Studierenden • arbeiten sich in komplexe Softwaresysteme ein und erweitern diese • lernen, eigenständig Lösungsvorschläge auszuarbeiten und umzusetzen • dokumentieren die von ihnen geschriebene Software
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212
10	**Method of examination**	Portfolio
11	**Grading procedure**	Portfolio (100%)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 240 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english

1	**Module name** 562819	**Projektseminar Optimierung (Master)** Optimisation project with computer exercises (Master)	**5 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt!	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	Prof. Dr. Frauke Liers-Bergmann
5	**Contents**	Anhand einer konkreten Anwendung sollen die im Studium bis dahin erworbenen Kenntnisse zu mathematischen Optimierungsmodellen und -methoden umgesetzt werden. Der Inhalt ergibt sich aus einer aktuellen Problemstellung häufig in enger Zusammenarbeit mit einem Industriepartner. Als Beispiele seien genannt die Wasserversorgung einer Stadt, die Gestaltung einer energieeffizienten Fassade eines Bürogebäudes oder das Baustellenmanagement im Schienenverkehr. Das Seminar wird als Projekt durchgeführt. Das heißt, Studierende werden in Teams von bis zu 4 Personen, die in der ersten Woche ausgehändigte Aufgabenstellung im Laufe des Semesters bearbeiten. Am Ende des Semesters werden die Teams ihre Lösungsvorschläge vorstellen und vergleichen.
6	**Learning objectives and skills**	Die Studierenden • führen selbständig in Teams ein größeres Projekt durch, in dem sie eine reale Fragestellung modellieren, Lösungsverfahren entwickeln und implementieren und ihre Ergebnisse auf die Praxis anwenden; • präsentieren die Ergebnisse der Projektarbeit und diskutieren diese; • tauschen sich untereinander und mit den Dozenten über Informationen, Ideen, Probleme und Lösungen auf wissenschaftlichem Niveau aus.
7	**Prerequisites**	empfohlen: • Lineare Algebra • Lineare und Kombinatorische Optimierung
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	mündlich Vortrag 45 Minuten und schriftliche Ausarbeitung 5-10 Seiten *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	german
16	**Bibliography**	werden zu Beginn der Veranstaltung bekannt gegeben

1	**Module name** 675090	**Prozessorientierte Informationssysteme** Process-oriented information systems	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Prozessorientierte Informationssysteme (2 SWS) (SoSe 2025) Übung: Übungen zu Prozessorientierte Informationssysteme (2 SWS) (SoSe 2025)	- -
3	Lehrende	Dr.-Ing. Peter Schwab	

4	**Module coordinator**	Dr.-Ing. Peter Schwab
5	**Contents**	In a globalized world, companies face the challenge of managing constant change. As a result, companies must adapt their business processes, especially those that differentiate them, in ever shorter time frames. If they fail to respond to change, their very existence is threatened. Ideally, an organization's IT department can help meet these challenges by doing its part - implementing the business strategy - as quickly as possible. Unfortunately, the fundamental question remains: How can IT ensure the rapid implementation of new strategic processes so that they become an essential pillar of the organization? This module approaches this question from different angles and discusses solutions based on the following three pillars: 1) A business process-driven methodology to derive the essential parts/artifacts of the resulting business application. 2) A future-proof and flexible architecture for process-driven applications that separates their main functionality into different layers. 3) The general use of BPMN (Business Process Model and Notation) for both modeling and implementation of all processes (business processes as well as technical integration processes) of a process-driven application.
6	**Learning objectives and skills**	Students will... • Define Business Process Management (BPM) and explain its key issues. • Illustrate the BPM lifecycle and BPM framework. • Evaluate the importance of process automation in BPM. • Evaluate the importance of process engines in process automation. • Explain all notational elements of the BPMN specification. • Describe the process flow in given BPMN diagrams and understand the difference between orchestration and collaboration. • Demonstrate the conditions for using the various BPMN activities, events, and gateways. • Define the basic components of a process-driven application. • Model, implement, and evaluate all types of processes within a process-driven application using the BPMN standard. • Design transactions and error and timeout handling in BPMN. • Evaluate different BPMN modeling variants for the same process.

		• Recognize the differences between BPMN and other modeling notations presented in the module and evaluate their advantages and disadvantages compared to each other. • Apply the "Separation of Concerns" principle correctly and know all the development steps that lead to an executable processdriven application. • Recognize and differentiate important style rules (best practices) in BPMN modeling that go beyond the BPMN specification. • Illustrate the different BPMN levels for process modeling and their granularity depending on the consumer of the process model. • Identify the use case for process-driven applications. • Understand the complexity and challenges of process-driven applications. • Understand the need for a sustainable methodology and architecture in the design of process-driven applications to address the challenges that arise. • Validate the (layered) architecture and interfaces of a process-driven application and its business domain. • Understand the heterogeneous IT landscape in companies that has evolved over several years. • Differentiate between a 2-layer and a 3-layer architecture and explain their advantages and disadvantages. • Evaluate the importance of SOA, integration, patterns, eventing and controlling in the context of process-driven applications. • Decompose functionality into different layers and implement them in a way that preserves the flexibility required by the business. • Demonstrate and evaluate the functionality of an Enterprise Service Bus (ESB) in the context of process-driven applications. • Specify and implement process-driven applications. • Explain the basic functionality of rules engines. • Increase the flexibility of process-driven applications by using business rule management systems (BRMS) and analysis applications. • Work cooperatively and independently in small groups.
7	**Prerequisites**	Recommended skills: • Knowledge of Petri nets, in particular with regard to the flow of tokens. • An understanding of microservices. • Knowledge of basic SOA (Service-Oriented Architecture) technologies and concepts, including XML, Web Services, SOAP, UDDI registration, repositories, WSDL, e.g. by attending the eBusiness Technologies (EBT) course.
8	**Integration in curriculum**	no Integration in curriculum available!

9	**Module compatibility**	Studienrichtung Data bases and knowledge representation Master of Science Data Science 20212
10	**Method of examination**	Klausur mit MultipleChoice (60 Minuten)
11	**Grading procedure**	Klausur mit MultipleChoice (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Freund, Jakob; Rücker, Bernd (German version): Praxishandbuch BPMN 2.0. 4., aktualisierte Auflage. München: Hanser, 2014. • Freund, Jakob; Rücker, Bernd (English Version): Real-Life BPMN: Using BPMN 2.0 to Analyze, Improve, and Automate Processes in Your Company. 2nd Edition. CreateSpace Independent Publishing Platform, 2014. • Göpfert, Jochen; Lindenbach, Heidi: Geschäftsprozessmodellierung mit BPMN 2.0: Business Process Model and Notation. Oldenbourg Verlag, 2013. • Josuttis, Nicolai: SOA in Practice: The Art of Distributed System Design. O'Reilly, 2007. • Hohpe, Gregor; Woolf, Bobby: Enterprise Integration Patterns: Designing, Building, and Deploying Messaging Solutions. Addison-Wesley, 2010. • Silver, Bruce: BPMN Method and Style: with BPMN implementer's guide. 2nd Edition. Cody-Cassidy Press, 2011. • Stiehl, Volker (German version): Prozessgesteuerte Anwendungen entwickeln und ausführen mit BPMN: Wie flexible Anwendungsarchitekturen wirklich erreicht werden können. Heidelberg: dpunkt.verlag, 2013. • Stiehl, Volker (English version): Process-Driven Applications with BPMN. Springer, 2014.

1	**Module name** 46559	**Quantum Chemistry 1** Quantum chemistry 1	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Quantum Chemistry 1 (3 SWS)	-
3	Lehrende	Prof. Dr. Andreas Görling	
4	**Module coordinator**	Prof. Dr. Andreas Görling	
5	**Contents**	• Mathematical concepts and current research issues in the field of quantum and computer chemistry • Hartree-Fock, DFT	
6	**Learning objectives and skills**	Students ... • obtain sound knowledge in basic methods of quantum chemistry • are able to solve mathematical problems occurring in quantum chemistry • are able to understand and assess scientific reports in the field of quantum chemistry	
7	**Prerequisites**	Strongly recommended Qualifications: • good knowledge of basic quantum mechanics: axioms of QM, application to simple systems (particle in a box, harmonic oscillator, rigid rotator) • good knowledge in mathematics: differential calculus of functions of several variables, linear algebra	
8	**Integration in curriculum**	semester: 1;3	
9	**Module compatibility**	Chemistry Master of Science Data Science 20212 • as Elective Module in M.Sc. Chemistry or M. Sc. Molecular Science (5 ECTS, not graded)	
10	**Method of examination**	mündlich (20 Minuten) O20 (PL): Oral Examination (20 minutes, not graded: pass/fail) *	
11	**Grading procedure**	mündlich (bestanden/nicht bestanden) not graded: pass/fail	
12	**Module frequency**	Only in winter semester	
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h	
14	**Module duration**	1 semester	
15	**Teaching and examination language**	english	
16	**Bibliography**	• Attila Szabo, Neil S. Ostlund: Modern Quantum Chemistry, Dover 1996 • Frank Jensen: Introduction to Computational Chemistry, Wiley 2017 (3rd ed.) • Ira N. Levine: Quantum Chemistry, Pearson 2016 (7th ed.)	

1	**Module name** 46561	**Quantum Chemistry 2** Quantum chemistry 2	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Quantum Chemistry 2 (3 SWS) (SoSe 2025)	-
3	Lehrende	Prof. Dr. Andreas Görling	

4	**Module coordinator**	Prof. Dr. Andreas Görling
5	**Contents**	• Many-Body Perturbation Theory • Configuration Interaction, Second Quantization, Coupled Cluster • TD-HF, TD-DFT, RPA
6	**Learning objectives and skills**	Students ... • obtain sound knowledge in advanced methods of quantum chemistry • are able to solve mathematical problems occurring in quantum chemistry • are able to understand and assess scientific reports in the field of quantum chemistry
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 2;4
9	**Module compatibility**	Chemistry Master of Science Data Science 20212 • as Elective Module in M.Sc. Chemistry or M. Sc. Molecular Science (5 ECTS, not graded) if Quantum Chemistry I was already chosen as Elective Module!
10	**Method of examination**	mündlich (20 Minuten) O20 (PL): Oral Examination (20 minutes, not graded: pass/fail) *
11	**Grading procedure**	mündlich (bestanden/nicht bestanden) not graded: pass/fail
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Attila Szabo, Neil S. Ostlund: Modern Quantum Chemistry, Dover 1996 • Frank Jensen: Introduction to Computational Chemistry, Wiley 2017 (3rd ed.) • Ira N. Levine: Quantum Chemistry, Pearson 2016 (7th ed.)

1	**Module name** 67156	**Quantum Computing** Quantum computing	**5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Michael Hartmann
5	**Contents**	*Contents:* The course provides an introduction to quantum computing. The development of quantum hardware has progressed substantially in recent years and has now reached a level of maturity where first industrial applications are being explored. This course will introduce the fundamental ingredients of quantum algorithms, quantum bits and quantum gates, the most important hardware implementations and in particular algorithms that can run on near term hardware implementations of so called Noisy Intermediate Scale Quantum (NISQ) devices. The course will be completed with introductions to the basic concepts of error correction, which is needed in the next stage of development to fully exploit the potential of this emerging computing technology. Prerequisites: the main concepts of quantum theory, including quantum states, the Schrödinger equation, unitary evolution and measurements.
6	**Learning objectives and skills**	*Learning goals and competences:* Students • understand the origin of the computation potential of quantum computers • understand key quantum algorithms, such as Deutsch algorithm, quantum phase estimation and Shor's algorithm • understand the working principle of quantum error correction and key error correcting codes • code quantum algorithms in a modern quantum programming language • are able to apply the learned methodology to example problems
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Physics Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	english
16	**Bibliography**	The course will present all the relevant material. Useful additional reading contains "Quantum Computation and Quantum Information by Nielsen and Chuang (Cambridge Univ. Press), "Quantum Computating: A Gentle Introduction by Rieffel and Polak (MIT Press) as well as lecture notes by John Preskill available at http://theory.caltech.edu/~preskill/ph229/ and Ronald de Wolf available at https://homepages.cwi.nl/~rdewolf/qc19.html .

1	**Module name** 451971	**Random Matrices in Communications and Signal Processing** Random matrices in communications and signal processing	**5 ECTS**
2	Courses / lectures	Vorlesung: Random Matrices in Communications and Signal Processing (2 SWS) Übung: Tutorial for Random Matrices in Communications and Signal Processing (2 SWS)	5 ECTS -
3	Lehrende	Prof. Dr.-Ing. Ralf Müller Levi-Pascal Bohnacker	

4	**Module coordinator**	Prof. Dr.-Ing. Ralf Müller
5	**Contents**	Dual antenna arrays, compressive sensing, Wishart distribution, factor iid model, Kronecker model, convergence of random variables, semi-circle law, quarter circle law, full circle law, Haar distribution, Marchenko-Pastur distribution, Stieltjes transform, Girkos law, unitary invariance, freeness, free convolution, R-transform, free central limit theorem, free Poisson limit theorem, subordination, S-transform, R-diagonal random matrices, R-diagonal free convolution, Haagerup-Larsen law, operator-valued freeness, linearization of noncommutative polynomials, free Fourier transform, self-averaging properties, microscopic vs. macroscopic random variables, quenched random variable, a statistical physics point of view of digital systems, spin glasses, frozen disorder, replica method, replica continuity, replica symmetry, replica symmetry breaking, approximate message passing, classification of np-complete problems
6	**Learning objectives and skills**	The students find the limiting eigenvalue distributions of various types of random matrices. The students explain Stieltjes, R- and S-transforms. The students explain the limits of various types of fading channels. The students design coding and decoding methods for a given type of multiuser channel. The students perform additive and multiplicative free convolution. The students calculate the asymptotic eigenvalues distributions of given random matrix ensembles. The students construct random matrix ensembles with a given eigenvalue distribution. The students linearize matrix polynomials. The students derive the Boltzmann distribution. The students utilize saddle point integration. The students perform replica calculations. The students explain the meaning of replica symmetry breaking. The students collaborate on solving exercise problems.
7	**Prerequisites**	Recommended: Good skills in linear algebra, probability theory and complex analysis
8	**Integration in curriculum**	no Integration in curriculum available!

9	**Module compatibility**	Studienrichtung Mathematisch statistische Datenanalyse Master of Science Data Science 20212
10	**Method of examination**	mündlich The examination is a 30-minute oral exam. *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Mingo, J., Speicher, R.: Free Probability and Random Matrices, Springer, 2017 • Couillet, R., Debbah, M.: Random Matrix Methods for Wireless Communications, Cambridge Univ. Press, Cambridge, 2011. • Mezard, M., Montanari, A.: Information, Physics, and Computation, Oxford Graduate Texts, 2009.

1	**Module name** 798810	**Rechnerarchitektur** Computer architecture	**5 ECTS**
2	Courses / lectures	Vorlesung: Rechnerarchitektur (2 SWS) Übung: Übung zu Rechnerarchitektur (2 SWS) Übung: RÜ RA (2 SWS)	2,5 ECTS 2,5 ECTS 2,5 ECTS
3	Lehrende	Prof. Dr.-Ing. Dietmar Fey Tobias Baumeister Kenan Gündogan Philipp Gündisch	

4	**Module coordinator**	Prof. Dr.-Ing. Dietmar Fey
5	**Contents**	Die Vorlesung baut auf die in den Grundlagen der Rechnerarchitektur und -organisation vermittelten Inhalte auf und setzt diese mit weiterführenden Themen fort. Es werden zunächst grundlegende fortgeschrittene Techniken bei Pipelineverarbeitung und Cachezugriffen in modernen Prozessoren und Parallelrechnern behandelt. Ferner wird die Architektur von Spezialprozessoren, z.B. DSPs und Embedded Prozessoren behandelt. Es wird aufgezeigt, wie diese Techniken in konkreten Architekturen (Intel Nehalem, GPGPU, Cell BE, TMS320 DSP, Embedded Prozessor ZPU) verwendet werden. Zur Vorlesung wird eine Tafelübung angeboten. Mit erfolgreicher mündlicher Prüfung können 5 ECTS erworben werden. In den Tafelübungen werden die in der Vorlesung vermittelten Techniken durch zu lösende Aufgaben vertieft. In der Rechnerübung soll u.a. ein einfacher Vielkern-Prozessor auf Basis des ZPU-Prozessors mit Simulationswerkzeugen aufgebaut werden. Im Einzelnen werden folgende Themen behandelt: • Organisationsaspekte von CISC und RISC-Prozessoren • Behandlung von Hazards in Pipelines • Fortgeschrittene Techniken der dynamischen Sprungvorhersage • Fortgeschritten Cachetechniken, Cache-Kohärenz • Ausnutzen von Cacheeffekten • Architekturen von Digitalen Signalprozessoren • Architekturen homogener und heterogener Multikern-Prozessoren (Intel Corei7, Nvidia GPUs, RISC-V) • Architektur von Parallelrechnern (Clusterrechner, Superrechner) • Effiziente Hardware-nahe Programmierung von Mulitkern-Prozessoren (OpenMP, SSE, CUDA) • Leistungsmodellierung und -analyse von Multikern-Prozessoren (Roofline-Modell)
6	**Learning objectives and skills**	Fachkompetenz Wissen Lernende können Wissen abrufen und wiedergeben. Sie kennen konkrete Einzelheiten wie Begriffe, Definitionen, Fakten, und Abläufe in einem Prozessor darlegen. Verstehen

		Lernende können Beispiele für Rechnerarchitekturen anführen, sie sind in der Lage, Schaubilder von Prozessoren zu interpretieren und die Abläufe in eigenen Worten zu beschreiben. Anwenden Lernende können beim Erstellen eigener Programme durch Transfer des Wissens über Interna von Prozesorarchitekturen Optimierungen hinsichtlich des Laufzeitverhaltens vornehmen. Analysieren Lernende können zwischen verschiedenen Varianten von Lösungen einer Prozessorarchitektur klassifizieren, die Gründe für durchgeführte Entwurfsentscheidungen erschließen, Unterscheide gegenüberstellen und gegeneinander bewerten. Lern- bzw. Methodenkompetenz Lernende erwerben die Fähigkeit selbstständig Testprogramme zum Bewerten der Leistungsfähigkeit eines Prozessors zu erstellen.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Variabel
11	**Grading procedure**	Variabel (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english
16	**Bibliography**	• Patterson/Hennessy: Computer Organization und Design • Hennessy/Patterson: Computer Architecture - A Quantitative Approach • Stallings: Computer Organization and Architecture • Märtin: Rechnerarchitekturen

1	**Module name** 93111	**Rechnerarchitekturen für Deep-Learning Anwendungen** Computer architectures for deep-learning applications	**10 ECTS**
2	Courses / lectures	Praktikum: Rechnerarchitekturen für Deep-Learning Anwendungen (8 SWS)	10 ECTS
3	Lehrende	Philipp Gündisch Philipp Holzinger Prof. Dr.-Ing. Dietmar Fey	

4	**Module coordinator**	Prof. Dr.-Ing. Dietmar Fey Dr.-Ing. Marc Reichenbach
5	**Contents**	Maschinelles Lernen, im speziellen Deep-Learning Netzwerke haben in den letzten Jahren stark an Bedeutung gewonnen. Anwendungsfelder umfassen beispielsweise für die Klassifikation von Bildern, das Verstehen von menschlicher Sprache oder die Überwachung von Rechentechnik bzgl. IT-Angriffen. Während die Grundlagen von Deep-Learning (Neuronale Netze) schon über einen langen Zeitraum erforscht wurden, ist eine flächendeckende Anwendung von Deep-Learning Netzwerken erst seit jüngster Zeit möglich, da nun entsprechende leistungsfähige Rechnerarchitekturen zur Verfügung stehen um die aufwendigen Berechnungen durchzuführen. Das genannte Praktikum beschäftigt sich mit der Evaluierung verschiedener Rechnerarchitekturen (mit entsprechenden Architektureigenschaften) bzgl. der performanten Auswertung von Deep-Learning Netzwerken. Dabei werden die Architekturen CPU, GPU und FPGA genauer untersucht und bewertet. Für eine schnelle Auswertung von Deep-Learning Netzwerken spielt Parallelrechentechnik eine wichtige Rolle, deswegen werden unter anderem folgende Fragen im Praktikum genauer beantwortet: • Wie kann ich Multi-Core CPUs effizient nutzen? • Kann ich mit der Verwendung der SIMD-Extensions (SSE, AVX) ein Beschleunigung der Auswertegeschwindigkeit erzielen? • Was sind GPUs und wie kann ich die massive Parallelität für die Auswertung von Deep-Learning Netzwerken nutzen? • Welche Rolle spielen Caches bzw. die Speicherhierachie eines Rechensystems für die schnelle Auswertung von Deep-Learning Netzwerken? • Wie können FPGAs genutzt werden um Deep-Learning Netzwerke applikationsspezifisch zu implementieren? Für einen einfachen Einstieg wird das Deep-Learning Framework Tensorflow verwendet. Anhand einfacher Besipiele können o.g. Fragen beantwortet werden. Ein größeres Beispiel, gerechnet auf unseren eigenen Servern mit Hardware von AMD, Intel und Nvidia zeigt wie sich reale Anwendungen effizient mit "Customer-Hardware" umsetzen lassen. Hardware in verschiedenen Leistungsklassen (von wenigen Milliwatt bis mehrere Kilowatt) steht dabei zur Verfügung. Die Experimente werden in unserem Parallelrechenlabor durchgeführt.

		Die Studierenden erhalten eine Einführung in Form von Vorträgen. Hauptbestandteil ist die praktische Arbeit mit genannten Rechnerarchitekturen durch effiziente Programmierung mittels C(++), Cuda, OpenCL. Für den erfolgreichen Abschluss des Praktikums ist Kolloquium (ca. 15 Minuten) zu bestehen und ein Bericht (ca. 10 Seiten) anzufertigen.
6	**Learning objectives and skills**	Verstehen Die Studierenden verstehen die elementaren Grundfunktion neuronaler Netze und wie sich diese auf Hardware abbilden lassen. Die Studierenden lernen die Architekturen CPU, GPU und FPGA kennen, verstehen den internen Aufbau und können die wesentlichen Architektureigenschaften wiedergeben. Analysieren Die Studierenden nutzen CPUs, GPUs und FPGAs für die Auswertung von DL-Netzwerken. Dabei können sie Performancemetriken (Laufzeit, Energieverbrauch) anwenden. Evaluieren Die Studierenden können die Architekturen CPU, GPU und FPGA hinsichtlich ihrer Eignung für die Auswertung von DL-Netzwerken vergleichen.
7	**Prerequisites**	• Grundlegende Programmierkenntnisse in C • Freude an der Hardware • Detaillierte Kenntnisse in FPGAs, VHDL oder Assembler sind nicht erforderlich • Wissen im Bereich Deep-Learning / Tensorflow ist nicht erforderlich
8	**Integration in curriculum**	semester: 5
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212
10	**Method of examination**	Praktikumsleistung
11	**Grading procedure**	Praktikumsleistung (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 100 h Independent study: 200 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german or english
16	**Bibliography**	Hands-On Machine Learning with Scikit-Learn and TensorFlow: Concepts, Tools, and Techniques for Building Intelligent Systems; Aurélien Géron

1	**Module name** 93150	**Rechnerkommunikation** Computer communications	**5 ECTS**
2	Courses / lectures	Vorlesung: Rechnerkommunikation (2 SWS) (SoSe 2025) Übung: Übungen Rechnerkommunikation (2 SWS) (SoSe 2025)	2,5 ECTS 2,5 ECTS
3	Lehrende	Prof. Dr. Reinhard German Lukas Bayer Mamdouh Muhammad Tarek Suft Dr.-Ing. Peter Bazan Paul Döring	

4	**Module coordinator**	Prof. Dr. Reinhard German
5	**Contents**	Die Vorlesung vermittelt die Grundlagen der Rechnerkommunikation und durchläuft von oben nach unten die Schichten des Internets: • Anwendungsschicht • Transportschicht • Netzwerkschicht • Sicherungsschicht • Physikalische Schicht Sicherheit wird als übergreifender Aspekt behandelt. An verschiedenen Stellen werden analytische Modelle eingesetzt, um Wege für eine quantitative Auslegung von Kommunikationsnetzen aufzuzeigen. Die Übung beinhaltet praktische und theoretische Aufgaben zum Verständnis der einzelnen Schichten.
6	**Learning objectives and skills**	Die Studierenden erwerben • Kenntnisse über zentrale Mechanismen, Protokolle und Architekturen der Rechnerkommunikation (Topologie, Schicht, Adressierung, Wegsuche, Weiterleitung, Flusskontrolle, Überlastkontrolle, Fehlersicherung, Medienzugriff, Bitübertragung) am Beispiel des Internets und mit Ausblicken auf andere Netztechnologien • Kenntnisse über Sicherheit, Leistung und Zuverlässigkeit bei der Rechnerkommunikation • praktische Erfahrung in der Benutzung und Programmierung von Rechnernetzen
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Übungsleistung Klausur (90 Minuten) Hausaufgaben zu Rechnerkommunikation (Übungsleistung): • Studienleistung, Übungsleistung, unbenotet, 2.5 ECTS • weitere Erläuterungen: Bearbeitung (zwei)wöchentlicher Aufgabenblätter in Gruppenarbeit. Für den unbenoteten

		Übungsschein sind 60% der Punkte je Aufgabenblatt zu erreichen Rechnerkommunikation (Klausur): • Prüfungsleistung, Klausur, Dauer (in Minuten): 90, benotet, 2.5 ECTS • Anteil an der Berechnung der Modulnote: 100.0 % *
11	**Grading procedure**	Übungsleistung (bestanden/nicht bestanden) Klausur (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	Lehrbuch: Kurose, Ross. Computer Networking. 8th Ed., Pearson, 2021.

1	**Module name** 93185	**Reinforcement Learning** Reinforcement learning	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Reinforcement Learning (4 SWS) (SoSe 2025)	-
3	Lehrende	Dr.-Ing. Christopher Mutschler	

4	**Module coordinator**	Dr.-Ing. Christopher Mutschler
5	**Contents**	The lecture aims at teachin Reinforcement Learning (RL) and will cover the following topics: • Introduction to Reinforcement Learning (Agent-Environment-Interface, Markov Decision Processes) • Dynamic Programming (Bellman Equations, Value Iteration, Policy Iteration) • Model-Free Prediction • Model-Free Control • Value Function Approximation (Linear VFA and DQNs) • Policy-based Reinforcement Learning (Monte-Carlo Policy Gradient, Advantage Estimators, TRPO, PPO) • Model-based RL • Offline RL • Explainable RL • Exploration-Exploitation • Simulation to Reality Transfer • Research frontiers & hot topics, Sim2Real & Real-World Applications
6	**Learning objectives and skills**	The students will learn to • understand the basic principle behind sequestration decision making problems and how to translate them into a formal model • compare and analyze methods different agents to search for policies • implement the presented methods in PyTorch, • discuss the social impact of applications that automate decision making
7	**Prerequisites**	Es handelt sich hier um eine Spezialisierungsvorlesung, eine erfolgreiche Absolvierung der Vorlesungen IntroPR" und/oder Pattern Recognition"/"Pattern Analysis" wird empfohlen. Konzepte, die in IntroPR" vermittelt werden, werden hier als Grundwissen vorausgesetzt.
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212
10	**Method of examination**	Variabel (90 Minuten) • The examiniation will include a written exam of 90 minutes at the end of the semester • The exam will cover the content of the lecture as well as that of the exercises (the exam will hence contain a mixture of theoretical questions and practical coding tasks)

		Please note that the exam will only take place in summer terms. *
11	**Grading procedure**	Variabel (100%) Written Exam (100 %)
12	**Module frequency**	Only in summer semester The lecture and exam will only be able during summer terms.
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Richard S. Sutton and Andrew G. Barto. 2018. Reinforcement Learning: An Introduction. A Bradford Book, Cambridge, MA, USA. • Bellman, R.E. 1957. Dynamic Programming. Princeton University Press, Princeton, NJ. Republished 2003: Dover, ISBN 0-486-42809-5. • Csaba Szepesvari and Ronald Brachman and Thomas Dietterich. 2010. Algorithms for Reinforcement Learning. Morgan and Claypool Publishers. • Warren B. Powell. 2011. Approximate Dynamic Programming. Wiley. • Maxim Lapan. 2020. Deep Reinforcement Learning Hands-On: Apply modern RL methods to practical problems of chatbots, robotics, discrete optimization, web automation, and more, 2nd Edition. Packt Publishing. • Dimitri P. Bertsekas. 2017. Dynamic Programming and Optimal Control. Athena Scientific. • Miguel Morales. 2020. grokking Deep Reinforcement Learning. Manning. • Laura Graesser and Keng Wah Loon. 2019. Foundations of Deep Reinforcement Learning: Theory and Practice in Python. Addison-Wesley Data & Analytics.

1	**Module name** 47708	**Robotics in Surgery and Diagnostics** Robotics in surgery and diagnostics	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Robotics in Surgery and Diagnostics (4 SWS) (SoSe 2025)	5 ECTS
3	Lehrende	Prof. Dr. Franziska Mathis-Ullrich Steffen Peikert	

4	**Module coordinator**	Prof. Dr. Franziska Mathis-Ullrich
5	**Contents**	To provide motivation, the various scenarios of robot use in the surgical environment are explained and classified using examples. The fundamentals of robotics are addressed, including different kinematic forms, and key parameters such as degrees of freedom, kinematic chains, workspace, and payload are introduced. This includes the presentation of medically used robots in different size scales, ranging from micro- and nanorobotics to minimally invasive continuum robotics and larger systems for robot-assisted surgery. Next, the different modules of the process chain for robot-assisted surgery are presented. It begins with medical imaging and the various tomographic techniques, explaining their physical principles and their diagnostic information about anatomy and pathology. Medical image processing, with a focus on segmentation, follows. This leads to the geometric 3D reconstruction of anatomical structures, forming the basis for an attributed patient model. The methods for registering preprocessed measurement data from different tomographic modalities are described. The various approaches for modeling tissue parameters complement the discussions, forming a complete patient model. The applications of the patient model in visualization and surgical planning are the next topic. The intraoperative part of the process chain includes registration, navigation, augmented reality, and surgical robotic systems. These are explained with fundamentals and application examples. Key points here include techniques for robot-assisted tissue cutting and approaches to micro- and nanosurgery. Finally, applications of machine learning in medical robotics are discussed. The lecture concludes with a brief discourse on specific safety issues and the legal aspects of medical products.
6	**Learning objectives and skills**	Students • have a good overview of existing surgical and medical robotic systems in research and practical applications. • understand the specific requirements of surgery for automation with robots. • can recognize basic kinematics and their relevance to medical requirements and applications. • are familiar with basic techniques for processing and using image data from different modalities and can apply them. • can design the complete workflow for a robot-assisted procedure.

7	**Prerequisites**	Recommended by the lecturer(s): Knowledge on robotics design, robot kinematics
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Variabel Written examination; duration 60 minutes *
11	**Grading procedure**	Variabel (100%) Written examination 100%
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 65918	**Robust optimization II**	**5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Frauke Liers-Bergmann
5	**Contents**	• In practice, provided data for mathematical optimization problems is often not fully known. Robust optimization aims at finding the best solution which is feasible for input data varying within certain tolerances. The lecture covers advanced methods of robust optimization in theory and modeling. In particular, robust network flows, robust integer optimization and robust approximation are included. Further, state-of-the-art concepts, e.g., "light robustness" or "adjustable robustness" will be discussed by means of real-world applications.
6	**Learning objectives and skills**	Students • will be able to identify complex optimization problems under uncertainties as well as suitably model and analyze the corresponding robust optimization problem with the help of advanced techniques of robust optimization, • learn the handling of appropriate solving techniques and how to analyze the corresponding results.
7	**Prerequisites**	• Recommended: Robust Optimization I
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Databased optimization Master of Science Data Science 20212
10	**Method of examination**	mündlich (15 min) *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Lecture notes, will be published on StudOn at the beginning of the semester.

1	**Module name** 46556	**Scientific Programming** Scientific programming	**5 ECTS**
2	Courses / lectures	Praktikum: Quantum Chemistry - Lab / Scientific Programming (10 SWS, SoSe 2025) Please note: • Attendance in the lab course is mandatory! • Module starts only in winter term (duration: 2 semesters)	-
3	Lehrende	Prof. Dr. Andreas Görling Dr. Christian Neiß	

4	**Module coordinator**	Prof. Dr. Andreas Görling
5	**Contents**	• Operating system Linux for high-performance computing (HPC) • Scientific programming in Fortran and Python • Using numerical and mathematical libraries/modules • Introduction to parallel computing • Exercises • Programming project
6	**Learning objectives and skills**	Students .... • get familiar with Linux as operating system for HPC • are able to create computer programs for scientific purposes • can use numerical and mathematical libraries/modules in home-made programs • obtain knowledge about basic parallelization paradigms
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212 • as Elective Module in M.Sc. Chemistry or M. Sc. Molecular Science (5 ECTS, not graded) - please note: the module cannot be combined with the module Quantum Chemistry - Lab
10	**Method of examination**	Praktikumsleistung PL: Successful implementation of the programming project (working program), ungraded - module has to be passed *
11	**Grading procedure**	Praktikumsleistung (bestanden/nicht bestanden) not graded: pass/fail
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 150 h Independent study: 0 h
14	**Module duration**	2 semester
15	**Teaching and examination language**	english

16	**Bibliography**	• Stephen J. Chapman: Fortran for Scientists and Engineers, McGraw Hill 2017 (4th ed.) • Bernd Klein: Einführung in Python 3, Hanser 2017 (3rd ed.) • Stefan Gerlach: Computerphysik, Springer Spektrum 2019 (2nd ed.)

1	**Module name** 65789	**Selected Topics in Mathematics of Learning** Selected topics in mathematics of learning	**5 ECTS**
2	Courses / lectures	Vorlesung: Selected Topics in Mathematics of Learning (2 SWS) Übung: Übung Selected Topics in Mathematics of Learning (2 SWS)	3 ECTS 2 ECTS
3	Lehrende	Prof. Dr. Marie-Christine Düker	

4	**Module coordinator**	Prof. Dr. Frauke Liers-Bergmann
5	**Contents**	Advanced methods of mathematical data science, with a focus on teaching mathematical principles of learning processes.
6	**Learning objectives and skills**	Students gain fundamental theoretical knowledge of learning algorithms in Data Science and will be able to apply the methodologies in a Data Science context.
7	**Prerequisites**	Basic knowledge in numerical methods and optimization are recommended.
8	**Integration in curriculum**	semester: 3
9	**Module compatibility**	Pflichtmodul Master of Science Data Science 20212
10	**Method of examination**	Klausur (60 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	S. Wright, B. Recht: Optimization for Data Analysis (2022).

1	**Module name** 47626	**Seminar AI and Digitalization in Healthcare** Seminar AI and digitalization in healthcare	**5 ECTS**
2	Courses / lectures	Hauptseminar: AI and Digitalization in Healthcare (2 SWS)	5 ECTS
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Janina Beilner Michael Nissen
5	**Contents**	• Projected Newton-Euler equations (Kanes equations) • Numerical methods for ordinary differential equations • Recursive kinematics • Parametrization of rotations • One-dimensional force laws • Ideal constraints • Numerical methods for differential algebraic equations • Inverse kinematics and inverse dynamics
6	**Learning objectives and skills**	**Fachkompetenz** **Wissen** The students should: • learn how to derive the equations of motions of a multibody system using the projected Newton-Euler equations, • familiarize themselves with basic numerical methods for solving ODEs, • understand how kinematic and dynamic quantities of a multibody system can be computed recursively, • know different possible parametrizations of rotation matrices and how to transform one into the other, • understand the concept of one-dimensional force law, • know Lagranges equations of the first kind and how to solve these using appropriate numerical schemes, • know different approaches to inverse kinematics and inverse dynamics based on optimization, • understand the object-oriented code structure for the implementation of a simulation software for multibody systems **Anwenden** The students will: • implement a simulation software for multibody systems in Python.
7	**Prerequisites**	• basic knowledge of dynamics • linear algebra • differential equation • basic knowledge programming in Python.
8	**Integration in curriculum**	semester: 3
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung

		Presentation (30 min.) + Written Report (ca. 10 pages) *
11	**Grading procedure**	Seminarleistung (100%) Presentation (50 %) + Written Report (50 %)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 65867	**Seminar AIBE**	**5 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt!	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	Prof. Dr. Björn Eskofier
5	**Contents**	Topics in Topology such as 1) The Nagata–Smirnov metrization theorem 2) Compactifications (including Stone–Čech compactification) 3) Topological groups (connection with group theory and measure theory) 4) Local fields (connection with field theory) 5) Stone–Weierstrass theorem (connection with functional analysis) 6) Topological dimension theory 7) The imbedding theorem 8) The fundamental group of Sn
6	**Learning objectives and skills**	After following this seminar, the student • knows different topics in topology; • has acquired deep insight on one specific topic in topology; • can illustrate the various concepts and results treated in this seminar with relevant examples; • is able to explore some problems, examples, applications or extensions related to topology, independently using the literature; • has practiced presentations on mathematics.
7	**Prerequisites**	Knowledge of set theoretic topology.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung
11	**Grading procedure**	Seminarleistung (100%)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	
16	**Bibliography**	Topology, James Munkres, Pearson Education Limited 2014

1	**Module name** 47586	**Seminar Fantastic Datasets and where to find them** Seminar: Fantastic datasets and where to find them	**5 ECTS**
2	Courses / lectures	Hauptseminar: Fantastic datasets and where to find them (2 SWS) Students are required to take part in the *in-person* meetings. Significant time is dedicated to self-paced working on the OER.	5 ECTS
3	Lehrende	Luisa Neubig Prof. Dr. Andreas Kist René Groh	

4	**Module coordinator**	Prof. Dr. Andreas Kist
5	**Contents**	Datasets are crucial to train modern artificial intelligence algorithms. In this module, students will be first faced with the theoretical background of datasets, how datasets are created and disseminated, as well as comply to the FAIR principles. We will cover dataset repositories and data types. In the first three weeks, students will create their own set of data and metadata and will experience the design and creation process of a dataset. In the second block of the module, students are assigned to a given dataset from a pre-selection of datasets important in the field of machine learning and artificial intelligence. The students' task is to create an *open educational resource* (**OER**), similar to a YouTube video, about their assigned dataset explaining the back story of the dataset, as well as its usage in a contemporary context. The generation of the **OER** will be self-paced with the option to work on the **OER** during the normal seminar hours. In the third block, students will be assigned to two other dataset **OERs** of their peer group and will give constructive feedback. The constructive feedback and the **OERs** will be discussed in the full group. Finally, the students will incorporate the feedback to their **OERs** and publish them openly on a dedicated seminar YouTube channel.
6	**Learning objectives and skills**	**Subject competence** Students acquire broad knowledge of (biomedical) datasets and how they are created (Knowledge). Through the course, students will be able to reproduce examples of different dataset modalities and describe advantages and disadvantages of datasets (Understanding). Through the course, students will be able to classify and grade the quality of a dataset, and explain the limitations of a given dataset (Apply and Evaluate/Judge). Students will be further able to characterize data sets independently (Analyze). Students gain a comprehensive insight into which criteria are important in the construction of new data sets by creating their own one (Create). **Learning or methodological competence and self-competence**

		Students learn to present a data set in a structured and coherent way through the creation of an open educational resource (OER) video. The also learn how to record, edit, compile and disseminate content. Students are given the opportunity to learn how to communicate effectively using their own words and give constructive feedback to others.
7	**Prerequisites**	We **strongly recommend** previous knowledge and ideally hands-on experience in Artificial Intelligence and/or Deep Learning to understand the implications discussed in the seminar.
8	**Integration in curriculum**	semester: 3
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung Successful generation of an OER (>= 10 min Video) based on a developed storyboard. *
11	**Grading procedure**	Seminarleistung (100%) OER (100%). The grade will be determined by evaluating the video content (storyboard) and the production quality. The exact metrics will be communicated at the beginning of the seminar.
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german or english
16	**Bibliography**	• Hylén, J. (2020). Open educational resources: Opportunities and challenges. • Ehlers, U. D. (2011). Extending the territory: From open educational resources to open educational practices. Journal of open, flexible and distance learning, 15(2), 1-10. • Nichols, T. E. et al. Best practices in data analysis and sharing in neuroimaging using MRI. Nat. Neurosci. 20, 299–303 (2017). • Horien, C. et al. A hitchhiker’s guide to working with large, open-source neuroimaging datasets. Nat Hum Behav 5, 185–193 (2021). • Wilkinson, M. D. et al. The FAIR Guiding Principles for scientific data management and stewardship. Sci. Data 3, 160018 (2016).

1	**Module name** 65866	**Seminar Machine Learning / Artificial Intelligence**	**5 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt!	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	Prof. Dr. Björn Eskofier
5	**Contents**	Topics in Topology such as 1) The Nagata–Smirnov metrization theorem 2) Compactifications (including Stone–Čech compactification) 3) Topological groups (connection with group theory and measure theory) 4) Local fields (connection with field theory) 5) Stone–Weierstrass theorem (connection with functional analysis) 6) Topological dimension theory 7) The imbedding theorem 8) The fundamental group of Sn
6	**Learning objectives and skills**	After following this seminar, the student • knows different topics in topology; • has acquired deep insight on one specific topic in topology; • can illustrate the various concepts and results treated in this seminar with relevant examples; • is able to explore some problems, examples, applications or extensions related to topology, independently using the literature; • has practiced presentations on mathematics.
7	**Prerequisites**	Knowledge of set theoretic topology.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung
11	**Grading procedure**	Seminarleistung (100%)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	
16	**Bibliography**	Topology, James Munkres, Pearson Education Limited 2014

1	**Module name** 47619	**Seminar Machine Learning in MRI** Seminar: Machine learning in MRI	**5 ECTS**
2	Courses / lectures	Hauptseminar: Machine Learning in MRI (4 SWS) Attendance is compulsory for the mid-term presentations.	5 ECTS
3	Lehrende	Vanya Saksena Erik Gösche	

4	**Module coordinator**	Prof. Dr. Florian Knoll
5	**Contents**	We will cover recent machine learning developments in the areas of Magnetic Resonance (MR) data acquisition, image generation, image analysis and image interpretation. We will go over papers from leading international journals and conferences. Students can either suggest their own topics/papers or select from a range of papers presented by the lecturers. Each student will then study the assigned papers, discuss them with the lectures and at the end of the semester give a presentation about the key findings.
6	**Learning objectives and skills**	After completing this course, students will be able to: • critically read and understand a scientific paper in the fields of medical imaging and machine learning. • present a complex topic in their own words to their peers.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 3
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212 Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung Presentation (20 Minutes + 10 Minutes discussion) Written report (5-7 pages) *
11	**Grading procedure**	Seminarleistung (100%) Presentation and discussion 50%, Report 50%
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 150 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	

1	**Module name** 65896	**Seminar RMA**	**5 ECTS**
2	Courses / lectures	Seminar: Seminar: Research in Movement Analysis (2 SWS)	5 ECTS
3	Lehrende	Prof. Dr. Anne Koelewijn Markus Gambietz	

4	**Module coordinator**	Prof. Dr. Anne Koelewijn
5	**Contents**	The goal of this module is for students to learn and apply how to perform research in movement analysis. Teams of 3-4 students will select a related research question or come up with their own idea and record optical motion capture data in a proof-of-concept study. Students will acquire in-depth understanding by implementing core movement analysis algorithms, namely forward kinematics, scaling, inverse kinematics, and inverse dynamics, in python from scratch together with their teammates. In three assignments, each student will need to demonstrate the functionality and understanding of the implementation, which is then used for processing the recorded movement data. Next, teams will process their data and solve the research tasks. Each student will write a 3-page report and present their findings. This module will start with an introductory session, where the first assignment and projects will be presented. Then, students select research questions and form groups. The next sessions will contain introductions to the measurement, assignments and demonstration of the assignments. Then, students receive help in several Q&A sessions to ensure successful data analysis and report writing. Presentations will occur in the final sessions.
6	**Learning objectives and skills**	Understanding: Students… • can explain how to conduct movement analysis experiments • can discuss state of the art movement analysis processing techniques • can explain core movement analysis algorithms in depth • can explain experimental design and limitations in biomechanics • can explain variable types and time series in movement analysis Application: Students… • can record and analyse optimal motion capture data • are able to write an academic report about a research project Evaluate: Students… • are able to interpret movement data • can critically assess research outcomes Social skills: Students… • can cooperate and carry out group work responsibly are able to give a target-group specific presentation of complex topics
7	**Prerequisites**	1) compulsory prerequisites: None

		2) recommended prerequisites: Gait analysis and simulation (GAS)
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212 • MSc Medizintechnik • MSc AI • MSc Data Science The seminar can be taken from the 1st master's semester onwards. 5th or 6th semester bachelor students can join on an exceptional basis.
10	**Method of examination**	Seminarleistung Students must pass all three assignments, where they need to demonstrate functionality and understanding of their implementations. Each student will give a presentation including a Q&A. The presentation will be 12 minutes (8+4). Each student will write a report (3 pages, double-column format). *
11	**Grading procedure**	Seminarleistung (100%) The grading will be based on the % score that is achieved in the presentation and the written report. The % score of the presentation and the written report both count 50%. E.g., a student who scores 90% on the written report and 81% on the presentation will receive a final score of 86%, which equals the grade of 1.7. A student who scores 20% and 70% will receive a final score of 45%, which equals the grade of 5.0.
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Winter, D. A. (2009). Biomechanics and motor control of humanmovement. John Wiley & Sons. • Nitschke, M. et al. (2020). Efficient trajectory optimization for curved running using a 3D musculoskeletal model with implicit dynamics. Nature scientific reports • Dorschky, E. et al. (2020). CNN-Based Estimation of Sagittal Plane Walking and Running Biomechanics From Measured and Simulated Inertial Sensor Data. Frontiers in. Bioengineering and Biotechnology. • Fleischmann, S. et al. (2024). Exploring Dataset Bias and Scaling Techniques in Multi-Source Gait Biomechanics: An Explainable Machine Learning Approach. ACM Transactions on Intelligent Systems and Technology. • Weiß, A. et al. (2025). Simulating surfing with optimal control:Sensor fusion for biomechanical analysis. Multibody System Dynamics.

		• Dorschky, E. et al. (2019). Estimation of gait kinematics and kinetics from inertial sensor data using optimal control of musculoskeletal models. Journal of Biomechanics. • Gambietz, M. et al. (2024). Contributing Components of Metabolic Energy Models to Metabolic Cost Estimations in Gait. IEEE Transactions on Biomedical Engineering

1	**Module name** 96835	**Seminar und Praktikum Biosignalverarbeitung** Seminar and laboratory course: Biosignal processing	**5 ECTS**
2	Courses / lectures	Seminar: Seminar und Praktikum zur Biosignalverarbeitung (4 SWS)	5 ECTS
3	Lehrende	Dr. Jana Dahlmanns	

4	**Module coordinator**	Dr. Jana Dahlmanns apl. Prof. Dr. Clemens Forster
5	**Contents**	Es werden verschiedene klinisch orientierte Methoden vorgestellt, mit denen verschiedene Vitalparameter am Menschen erfasst werden. Dazu werden zunächst die theoretischen Grundlagen im Seminar mittels Referaten vorgestellt. Anschließend werden im Praktikum entsprechende Versuche und Messungen durchgeführt. Zu jedem Praktikum muss eine Ausarbeitung (Praktikumsbericht) erstellt werden, in der Ergebnisse und Beobachtungen mit gängigen Methoden der Signalverarbeitung weiter analysiert und diskutiert werden. In this module, various clinically oriented methods are presented with which different vital parameters are recorded in humans. To this end, the theoretical principles are first presented in the seminar by means of lectures. Subsequently, corresponding experiments and measurements are carried out in the practical course. A report must be written for each practical course in which the results and observations are further analyzed and discussed using standard signal processing methods.
6	**Learning objectives and skills**	Inhalt des Seminars: Vorstellung klinisch relevanter Biosignale, Verfahren zu deren Ableitung und Weiterverarbeitung. In 7 Praktikumsnachmittagen werden Versuche und Messungen an den Teilnehmern durchgeführt und die abgeleiteten Signale sollen anschließend mit verschiedenen Verfahren nachbearbeitet werden. Folgende Versuche sind vorgesehen: • Ableitung des EKG. Auswertung dazu: Einfluss von Abtastfrequenz und Filtereinstellung, Detektion und Eliminierung von Störungen, QRS-Detektion und Analyse von Spätpotentialen. • Nerv- und Muskelsignale: Ableitung von EMG und ENG zur Bestimmung der Nervenleitgeschwindigkeit. Prinzip der elektrischen Stimulation von Nerv und Muskel. • Spirometrie: Atemvolumina und deren Messung mittels Spirometrie. Messung des Atemwegswiderstandes und dessen Abhängigkeit von der Atemstellung. Automatische Bestimmung der gesuchten Größen. • Kreislauf: Messung des Blutdrucks nach Riva-Rocci, mittels automatischen Geräten und kontinuierlich. Analyse der Blutdruckregelung bei Belastung (Orthostase, körperliche Anstrengung). Analyse der Herzfrequenz in Abhängigkeit von der Atmung. Herzratenvariabilität.

		• EEG: Ableitung eines EEG. Klassifikation hinsichtlich der Frequenzanteile. Ableitung und Auswertung ereigniskorrelierter Potentiale im EEG. • Otoakustische Emissionen (OAE): Auslösen und Registrieren von OAE bei verschiedenen Lautstärken. Analyse von OAE. • Demonstration verschiedener Geräte und Verfahren zur Untersuchung am Patienten: Sensorische und akustische Schwellenmessungen, Gleichgewichtsregulation, Untersuchung der Farbempfindung, Gesichtsfeldmessung (Perimetrie). Content of the seminar: Presentation of clinically relevant biosignals, methods for their derivation and further processing. In 7 practical sessions, experiments and measurements will be carried out on the participants and the derived signals will then be post-processed using various methods. The following experiments will be carried out: • Recording of the ECG. Evaluation of this: Influence of sampling frequency and filter setting, detection and elimination of interference, QRS detection and analysis of late potentials. • Nerve and muscle signals: recording of EMG and ENG to determine the nerve conduction velocity. Principle of electrical stimulation of nerve and muscle. • Spirometry: respiratory volumes and their measurement using spirometry. Measurement of airway resistance and its dependence on breathing position. Automatic determination of the required parameters. • Circulation: Measurement of blood pressure according to Riva-Rocci, using automatic devices and continuously. Analysis of blood pressure regulation during exercise (orthostasis, physical exertion). Analysis of heart rate as a function of breathing. Heart rate variability. • EEG: recording of an EEG. Classification with regard to frequency components. Recording and evaluation of event-related potentials in the EEG. • Otoacoustic emissions (OAE): triggering and recording of OAE at different volumes. Analysis of OAEs. • Demonstration of various devices and procedures for examination on patients: sensory and acoustic threshold measurements, balance regulation, examination of color perception, visual field measurement (perimetry).
7	**Prerequisites**	Grundlagen der Anatomie und Physiologie für Medizintechniker, Naturwissenschaftler und Ingenieure Fundamentals of Anatomy and Physiology for Engineers
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Medical Data Science Master of Science Data Science 20212
10	**Method of examination**	Variabel Seminarvortrag und Praktikumsprotokolle *

11	**Grading procedure**	Variabel (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 75 h Independent study: 75 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german german or english
16	**Bibliography**	

1	**Module name** 96970	**Seminar Visual Computing** Seminar: Visual computing	**5 ECTS**
2	Courses / lectures	Hauptseminar: Seminar Visual Computing (2 SWS)	5 ECTS
3	Lehrende	Prof. Dr. Tim Weyrich Prof. Dr.-Ing. Tobias Günther	

4	**Module coordinator**	Prof. Dr.-Ing. Tobias Günther Prof. Dr. Tim Weyrich
5	**Contents**	This seminar covers advanced topics in visual computing, including both seminal research papers, as well as the latest research results. The seminar provides an opportunity to obtain a comprehensive overview of research questions in visual computing, as well as allows students to dive deeper into a chosen topic. Each student presents one scientific publication and explains its content to fellow students taking the course. Thereby, students practice their argumentation and presentation skills. For each paper, a supervisor is provided, who answers questions and gives pointers on the presentation slide design. The seminar is concluded with a short written report. The main topics include: • human performance capture (faces, eyes, speech), • animation (motion controllers, speech synthesis, shape modelling) • fabrication (caustic design, robot design), • appearance modelling (subsurface scattering), • Monte Carlo rendering (importance sampling, participating media), • differentiable rendering (neural rendering, inverse rendering), • denoising (non-local means and deep learning), • physics simulation (fluid simulation) The seminar contains the paper presentations by the students and introductory lectures on scientific dissemination. **Grading** Each student presents a paper, which is a selected from a set of papers in the first session. The presentation duration is 30 minutes with an additional 10 minutes for questions. Presentations begin approximately 3-4 weeks after the start of the semester. The presentation contributes to 70% of the final grade. A written report with a duration of 5-10 pages constitutes the remaining 30%, for which a LaTeX template is provided. The presentation time slots are grouped by topic and cannot be chosen. An important aspect of the grading is the subsequent discussion. To spur discussions, students are encouraged to write a brief abstract about each paper, which can be uploaded on StudOn before the presentation. The voluntary abstracts are graded and if more than 80% of the available points are reached the final grade is improved by 0.3 or 0.4 grade points, respectively.
6	**Learning objectives and skills**	Students learn to: • present current research topics in visual computing • perform a thorough literature review

		• cite scientific literature correctly • comprehend scientific texts • improve their presentation and argumentation skills • practice scientific writing
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Studienrichtung Data bases and knowledge representation Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung
11	**Grading procedure**	Seminarleistung (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german english
16	**Bibliography**	

1	**Module name** 635405	**Seminar Wissensrepräsentation und -verarbeitung** Knowledge representation and -processing	**5 ECTS**
2	Courses / lectures	Hauptseminar: Seminar Wissensrepräsentation und -verarbeitung (2 SWS)	-
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Michael Kohlhase apl. Prof. Dr. Florian Rabe
5	**Contents**	Dieses Seminar behandelt ausgewählte Themen aus dem Gebiet der Wissensrepräsentation und -Verarbeitung, mit einem Fokus auf mathematisches Wissen. Die Vortragsthemen sind sehr unterschiedlich im Schwierigkeitsgrad, sie reichen von Einführungsthemen für ambitionierte Bachelor-Studenten bis zur Forschungsfront für Doktoranden. Sie spiegeln recht gut die Forschungsinteressen der KWARC Gruppe wieder. Daher ist dieses Seminar sehr gut geeignet um in die Arbeitsgruppe einzusteigen (z.B. für eine Promotion).
6	**Learning objectives and skills**	Aktuelle Fachliteratur verstehen, Forschungsthemen für ein Fachpublikum verständlich aufbereiten und vortragen, Kommunikation mit Experten. Fachkompetenz Wissen Die Studierenden geben grundlegende Definitionen und Resultate aus einem vertieften Bereich der Wissensrepräsentation und -Verarbeitung wieder. Verstehen Die Studierenden erläutern grundlegende algorithmische und deduktive Verfahren. Sie tragen durch Literaturstudium erworbenes Wissen vor und erläutern es einem kleinem Fachpublikum aus Mitstudierenden. Anwenden Die Studierenden erläutern Anwendungen theoretischer Methoden in konkreten informatischen Kontexten. Erschaffen Die Studierenden bereiten Resultate des Gebiets und ihre Herleitung eigenständig zur Präsentation auf. Lern- bzw. Methodenkompetenz Die Studierenden erarbeiten sich selbständig den Inhalt wissenschaftlicher Veröffentlichungen und geben diesen in einem strukturierten Vortrag verständlich wieder. Sozialkompetenz Die Studierenden arbeiten in einer größeren Gruppe an komplexen Problemen und erläutern eigene Einsichten den Mitstudierenden in verständlicher Form.
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Studienrichtung Data bases and knowledge representation Master of Science Data Science 20212

10	**Method of examination**	Seminarleistung
11	**Grading procedure**	Seminarleistung (100%)
12	**Module frequency**	Every semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german or english
16	**Bibliography**	Wird in der Veranstaltung im persönlichen Betreuungsgespräch zwischen Lehrenden und Studierenden gemeinsam für den Seminarvortrag ausgewählt.

1	**Module name** 97090	**Simulation und Modellierung I** Simulation and modelling I	**5 ECTS**
2	Courses / lectures	Übung: Exercises to Simulation and Modeling I (2 SWS) Übung: Q&A SaM I (2 SWS) Vorlesung: Simulation and Modeling I (2 SWS)	2,5 ECTS 2,5 ECTS 2,5 ECTS
3	Lehrende	Anna Baron Jonathan Fellerer Prof. Dr. Reinhard German	

4	**Module coordinator**	Prof. Dr. Reinhard German
5	**Contents**	Das Modul vermittelt die Grundlagen der diskreten Ereignissimulation und beinhaltet • diskrete Simulation • analytische Modellierung (z.B. Warteschlangen) • Eingabemodellierung (z.B. Fitting-Verfahren) • Zufallszahlenerzeugung • statistische Ausgabeanalyse • Modellierungsparadigmen (u.a. Ereignis-/Prozessorientierung, Warteschlangen, Automaten, Petri-Netze, UML, graphische Bausteine) • kontinuierliche und hybride Simulation • Simulationssoftware • Fallstudien Content: Overview of the various kinds of simulation • discrete simulation (computational concepts, simulation of queuing systems, simulation in Java, professional simulation tools) • required probability concepts and statistics, modeling paradigms (e.g., event/process oriented, queuing systems, Petri nets, UML statecharts) • input modeling (selecting input probability distributions) • random number generation (linear congruential generators and variants, generating random variates) • output analysis (warm-up period detection, independent replications, result presentation) • continuous and hybrid simulation (differential equations, numerical solution, hybrid statecharts) • simulation software, case studies, parallel and distributed simulation.
6	**Learning objectives and skills**	Die Studierenden • erwerben Kenntnisse über Verfahren und Realisierungsmöglichkeiten der diskreten Simulation mit Ausblick auf andere Simulationsarten • erwerben Kenntnisse über statistische Aspekte der Simulation, die für die Anwendung wichtig sind • wenden statistische Methoden zur Analyse und Bewertung von Eingabe- sowie Ausgabedaten an

		- erwerben praktische Erfahrung mit kommerziellen Simulationswerkzeugen - erwerben Erfahrungen bei der Simulation in verschiedenen Anwendungsbereichen (u.a. Rechnernetze, Fertigungssysteme, Materialflusssysteme) - entwickeln eigenständig anhand von Beispielaufgaben Simulationsmodelle unter Verwendung verschiedener Modellierungsparadigmen - können in Gruppen kooperativ und verantwortlich arbeiten Learning targets and competences: Students - gain knowledge about methods and realization possibilities of discrete simulation with an outlook on other types of simulation - gain knowledge of statistical aspects of simulation that are important for practice - apply statistical methods for analysis and evaluation of input and output data - gain hands-on experience with commercial simulation tools - gain experience in simulation in various fields of application (including computer networks, manufacturing systems, material flow systems) - independently develop simulation models on the basis of sample tasks using different modeling paradigms - can work in groups cooperatively and responsibly
7	**Prerequisites**	elementare Programmierkenntnisse, vorzugsweise in Java, Mathematikkenntnisse in Analysis, wie z.B. im 1. Semester der angewandten Mathematik vermittelt Recommended background knowledge: basic programming skills, preferably in Java, mathematics skills in analysis, such as taught in the first semester in applied mathematics.
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Simulation and Numerics Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten) Prüfungsleistung/examination: Klausur, benotet, 5 ETCS/written exam, graded, 5 ETCS Dauer (in Minuten)/duration (in minutes): 90 Anteil an der Berechnung der Modulnote/Share in the calculation of the module grade: 100.0 % Die im Rahmen der Übung gestellten (zwei-)wöchentlichen Übungsaufgaben müssen bestanden werden, um das Gesamtmodul anrechnen lassen zu können. Die Übung gilt als bestanden, wenn mindestens 50% der Punkte korrekt bearbeitet wurden. Die Bearbeitung erfolgt in Gruppen von 3 oder 4 Studenten. Die Abgabe erfolgt in Präsenz zu dedizierten Übungsterminen. Wurden mindestens 70% der Punkte erreicht, wird die Endnote der bestandenen schriftlichen Prüfung entsprechend einer Notenstufe (0.3 oder 0.4) verbessert.

		Wurden mindestens 90% der Punkte erreicht, wird die Endnote der bestandenen schriftlichen Prüfung entsprechend zwei Notenstufe (0.6 oder 0.7) verbessert. -- The (bi-)weekly exercise tasks must be passed in order to receive credit for the entire module. The exercise is considered to be passed if at least 50% of the points have been correctly processed. The work is done in groups of 3 or 4 students. The submission is done in presence on dedicated exercise dates. If at least 70% of the points are achieved, the grade of the passed written exam will be improved by one grade level (0.3 or 0.4). If at least 90% of the points are achieved, the grade of the passed written exam will be improved by two grade levels (0.6 or 0.7). *
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Law, "Simulation Modeling and Analysis, 5th ed., McGraw Hill, 2014

1	**Module name** 43370	**Simulation und Wissenschaftliches Rechnen 1** Simulation and scientific computing 1	**7,5 ECTS**
2	Courses / lectures	Übung: Tafelübung zu Simulation und Wissenschaftliches Rechnen 1 (2 SWS)	2,5 ECTS
		Übung: Rechnerübung zu Simulation und wissenschaftliches Rechnen 1 (2 SWS)	-
		Vorlesung: Vorlesung zu Simulation und Wissenschaftliches Rechnen 1 (2 SWS)	2,5 ECTS
		Tutorium: Tutorium zu Simulation und Wissenschaftliches Rechnen 1 (2 SWS)	2,5 ECTS
3	Lehrende	Niklas Heidenreich Prof. Dr. Christoph Pflaum	

4	**Module coordinator**	Prof. Dr. Christoph Pflaum Prof. Dr. Ulrich Rüde
5	**Contents**	• Performance Optimierung für numerische Algorithmen • OpenMP Parallelisierung • Finite Differenzen Diskretisierung im Ort • Praktische Abschätzung des Diskretisierungsfehlers und der Konvergenzgeschwindigkeit numerischer Verfahren • Software Entwicklung im Bereich des wissenschaftlichen Rechnens • MPI Parallelisierung • Finite Differenzen Diskretisierung für zeitabhängige Probleme
6	**Learning objectives and skills**	Die Studierenden • lernen Techniken zur Optimierung von Algorithmen im Bereich des wissenschaftlichen Rechnens • lernen selbständig Algorithmen auf Parallelrechnern zu implementieren und zu optimieren • lernen theoretisch die Stabilität von numerischen Algorithmen zu untersuchen
7	**Prerequisites**	Voraussetzung ist ein Modul im Bereich Numerik
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Simulation and Numerics Master of Science Data Science 20212
10	**Method of examination**	Übungsleistung Klausur (90 Minuten)
11	**Grading procedure**	Übungsleistung (bestanden/nicht bestanden) Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 135 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	german german or english
16	**Bibliography**	• Lehrbuch: G. Hager und G. Wellein, Introduction to High Performance Computing for Scientists and Engineers, CRC Press, 2010. • Lehrbuch: Goedecker und Adolfy Hoisie. Performance Optimization of Numerically Intensive Codes, SIAM, 2001. • Lehrbuch: Gropp, Lusk, Skjellum, Using MPI. The MIT Press, 1999. • Lehrbuch: Alexandrescu, Modern C++ Design, Generic Programming and Design Patterns. Addison-Wesley, 2001. • Lehrbuch: Burden, Faires, Numerical Analysis, Brooks, 2001. • Lehrbuch: Chandra at. al., Programming in OpenMP, Academic Press, 2001.

1	**Module name** 43870	**Simulation und Wissenschaftliches Rechnen 2**	**7,5 ECTS**
2	Courses / lectures	Tutorium: Tutorium zu Simulation und Wissenschaftliches Rechnen 2 (SoSe 2025) Vorlesung: Vorlesung zu Simulation und wissenschaftliches Rechnen 2 (SoSe 2025) Übung: Rechnerübung zu Simulation und wissenschaftliches Rechnen 2 (SoSe 2025) Übung: Übung zu Simulation und Wissenschaftliches Rechnen 2 (SoSe 2025)	- - - -
3	Lehrende	Prof. Dr. Christoph Pflaum Benjamin Mann	

4	**Module coordinator**	Prof. Dr. Christoph Pflaum
5	**Contents**	• Einführung in Mehrgitterverfahren • Theorie und Anwendung der Methode der finiten Elemente • Implementierung von Finite Elemente Verfahren • allegmeine 3-dimensionale Diskretisierungsgitter • Fluiddynamik, Finite Differenzen und Lattice Boltzmann Verfahren • Finite Elemente in der Strukturmechanik • Numerische Lösung der Maxwell'schen Gleichungen
6	**Learning objectives and skills**	Die Studierenden • lernen verschiedene numerische Verfahren zum Lösen partieller Differentialgleichungen kennen • lernen grundlegende Kenntnisse zur Implementierung der entsprechenden Algorithmen • werden in die Entwicklung von Simulationstechniken im Bereich des wissenschaftlichen Rechnens, die • Analyse und Entwicklung von Diskretisierungen für partielle Differentialgleichungen • und die Entwicklung von Software im Bereich des wissenschaftlichen Rechnens eingeführt.
7	**Prerequisites**	Solides Hintergrundwissen in Ingenieurmathematik und einer höheren Programmiersprache (vorzugsweise C/C++)
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Simulation and Numerics Master of Science Data Science 20212
10	**Method of examination**	Klausur mit Übungsleistung (60 Minuten)
11	**Grading procedure**	Klausur mit Übungsleistung (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 135 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	german english
16	**Bibliography**	• Briggs, Henson, McCormick, A Multigrid Tutorial. SIAM, ISBN 0-89871-462-1. • Strang, Fix, An Analysis of the Finite Element Method. Wellesley-Cambridge Press, ISBN 0-9614088-8-X. • Axelsson, Barker, Finite Element Solution of Boundary Value Problems. Siam, ISBN 0-89871-499-0. • Braess, Finite Elemente. Springer, ISBN 3-540-61905-4. • Braess, Finite elements. Cambridge University Press, ISBN 0521011957. • Großmann, Roos, Numerik partieller Differentialgleichungen. Teubner, ISBN 3-519-02089-0. • Großmann, Roos, Numerische Behandlung partieller Differentialgleichungen. Teubner, ISBN 3-519-22089-X. • Grossmann, Roos, Stynes, Numerical treatment of partial differential equations. Springer, ISBN 978-3-540-71582-5.

1	**Module name** 65945	**Sovereignty and Public Sphere** Sovereignty and public sphere	**5 ECTS**
2	Courses / lectures	Online-Kurs: Sovereignty and Public Sphere (3 SWS)	-
3	Lehrende	Prof. Dr. Johannes Helbig	

4	**Module coordinator**	Prof. Dr. Johannes Helbig
5	**Contents**	Digitization has brought about business models with a concentration of capital and market power that is unprecedented in the history of economy. These models have a profound impact on our social interaction and our behavior and thus increasingly challenge our sovereignty as individuals and as societies. The seminar will use current research findings to examine the related phenomena, uncover their technological causes and interdependencies, and develop perspectives for societal action.
6	**Learning objectives and skills**	Content specific: Participants • understand the impact of digitization on individual and public opinion formation and on society • develop a notion of the interdependencies between capital/ economy, engineering/technology, and politics/society • feel encouraged by various approaches to constructive value compliant design for systems, eco systems, and societies General: Participants • train the discourse of an interdisciplinary topic from different scientific perspectives • build up on their skills to comprehend a scientific argumentation, to present it convincingly to their peers, and to elaborate it stringently in a written paper
7	**Prerequisites**	Bachelor degree recommended
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	International Information Systems Master of Science Data Science 20212 Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung Vortrag 45min, schriftliche Ausarbeitung 5-10 Seiten *
11	**Grading procedure**	Seminarleistung (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	?? semester (no information for Module duration available)
15	**Teaching and examination language**	german or english
16	**Bibliography**	• Aral, Sinan (2020). The Hype Machine. New York: Currency.

		• Reich, Bob; Sahami, Mehran & Weinstein, Jeremy M. (2021). System Error: Where big Tech went wrong and how we can reboot. London: Hodder & Stoughton • Zuboff, Shoshana (2019). The Age of Surveillance Capitalism: The fight for a human future at the new frontier of power. New York: PublicAffairs • Forestal, Jennifer (2022). Designing for Democracy: how to build community in digital environments. New York: Oxford University Press

1	**Module name** 44455	**Speech and Language Processing**	**5 ECTS**
2	Courses / lectures	Vorlesung: Speech and Language Understanding (2 SWS) (SoSe 2025) Übung: Speech and Language Understanding Exercises (0 SWS) (SoSe 2025)	5 ECTS -
3	Lehrende	Alexander Barnhill Abner Hernandez Prof. Dr.-Ing. Andreas Maier	

4	**Module coordinator**	Prof. Dr.-Ing. Andreas Maier
5	**Contents**	Nach Behandlung der grundlegenden Mechanismen menschlicher Spracherzeugung und Sprachwahrnehmung gibt die Vorlesung eine detaillierte Einführung in (vornehmlich) statistisch orientierte Methoden der maschinellen Erkennung gesprochener Sprache. Schwerpunktthemen sind Merkmalgewinnung, Vektorquantisierung, akustische Sprachmodellierung mit Hilfe von Markovmodellen, linguistische Sprachmodellierung mit Hilfe stochastischer Grammatiken, prosodische Information sowie Suchalgorithmen zur Beschleunigung des Dekodiervorgangs. After focussing on of the basic mechanisms of human speech generation and speech perception the lecture gives a detailed introduction to (mainly) statistically oriented methods of automatic recognition of spoken language. Main topics are feature extraction, vector quantization, acoustic speech modeling with the help of Markov models, linguistic speech modeling with the help of stochastic grammars, prosodic information as well as search algorithms to speed up the decoding process.
6	**Learning objectives and skills**	Die Studierenden • verstehen die Grundlagen der menschlichen Sprachproduktion und die akustischen Eigenschaften unterschiedlicher Phonemklassen • erklären den allgemeinen Aufbau eines Mustererkennungssystems • verstehen Abtastung, das Abtasttheorem und Quantisierung in Bezug auf Sprachsignale • verstehen die Fourier-Transformation und mathematische Modelle der Sprachproduktion • verstehen harte und weiche Vektorquantisierungsmethoden • verstehen unüberwachtes Lernen (EM-Algorithmus) • verstehen Hidden Markov-Modelle (HMMs) • erklären stochastische Sprachmodelle The students • understand the principles of human speech production and acoustic properties of the different phoneme classes • explain the general pipeline of a pattern recognition system

		• understand sampling, the sampling theorem, and quantization w.r.t. speech signals • understand Fourier transformation and mathematical models of speech production • understand hard and soft vector quantization methods • understand unsupervised learning (EM-algorithm) • understand Hidden Markov Models (HMMs) • explain stochastic language models
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Klausur (60 Minuten)
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Niemann H.: Klassifikation von Mustern; Springer, Berlin 1983 • Niemann H.: Pattern Analysis and Understanding; Springer, Berlin 1990 • Schukat-Talamazzini E.G.: Automatische Spracherkennung; Vieweg, Wiesbaden 1995 • º Rabiner L.R., Juang B.H.: Fundamentals of Speech Recognition; Prentice Hall, New Jersey 1993

1	**Module name** 96430	**Statistical Signal Processing** Statistical signal processing	**5 ECTS**
2	Courses / lectures	Übung: Übung zur Statistischen Signalverarbeitung (1 SWS) Vorlesung: Statistische Signalverarbeitung (3 SWS)	- 5 ECTS
3	Lehrende	Prof. Dr.-Ing. Sebastian Schlecht Baoqi Bai	

4	**Module coordinator**	Prof. Dr.-Ing. Sebastian Schlecht
5	**Contents**	The course concentrates on fundamental methods of statistical signal processing and their applications. The main topics are: • Discrete-time stochastic processes in the time and frequency domain: Random variables (RVs), probability distributions and densities, expectations of random variables, transformation of RVs, vectors of normally distributed RVs, time-discrete random processes: probability distribution and densities, expectation, stationarity, cyclostationarity, ergodicity, correlation functions and correlation matrices, spectral representations, principal component analysis (PCA), Karhunen-Loève transform (KLT). • Estimation theory: estimation criteria, prediction, classical and Bayesian parameter estimation (including MMSE, Maximum Likelihood, and Maximum A Posteriori estimation), Cramer-Rao bound • Linear signal models: Parametric models (cepstral decomposition, Paley-Wiener theorem, spectral flatness), non-parametric models (all-pole, all-zero and pole-zero models, lattice structures, Yule-Walker equations, PARCOR coefficients, cepstral representation) • Signal estimation: Supervised estimation, problem classes, orthogonality principle, MMSE estimation, linear MMSE estimation for normally distributed random processes, optimum FIR filtering, optimum linear filtering for stationary processes, prediction and smoothing, Kalman filters, optimum multichannel filtering (Wiener filter, LCMV, MVDR, GSC) • Adaptive filtering: Gradient methods, LMS, NLMS, APA and RLS algorithms and their convergence behavior
6	**Learning objectives and skills**	The students: • analyze the statistical properties of random variables, random vectors, and stochastic processes by probability density functions and expectations as well as correlation functions and matrices and their frequency-domain representations • know the Gaussian distribution and its role to describe the properties of random variables, vectors and processes • understand the differences between classical and Bayesian estimation, derive and analyze MMSE and ML estimators for specific estimation problems, especially for signal estimation

		• analyze and evaluate optimum linear MMSE estimators (single- and multichannel Wiener filter and Kalman filter) for direct and inverse supervised estimation problems • evaluate adaptive filters for the identification of optimum linear estimators.
7	**Prerequisites**	Courses on signals and systems as well as digital signal processing strongly recommended
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	Klausur (90 Minuten) Written exam of 90min duration.
11	**Grading procedure**	Klausur (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• A. Papoulis, S. Pillai: Probability, Random Variables and Stochastic Processes; McGraw-Hill, 2002 • D. Manolakis, V. Ingle, S. Kogon: Statistical and Adaptive Signal Processing; Artech House, 2005

1	**Module name** 65869	**Steuerung partieller Differentialgleichungen** Control of partial differential equations	**10 ECTS**
2	Courses / lectures	Zu diesem Modul sind in diesem Semester keine Lehrveranstaltungen oder Lehrveranstaltungsgruppen hinterlegt!	
3	Lehrende	No lecturers available since there are no courses / lectures for this module for this semester!	

4	**Module coordinator**	apl. Prof. Dr. Martin Gugat
5	**Contents**	• Existenz und Eindeutigkeit von Lösungen von Anfangsrandwertproblemen • Konzepte der exakten Steuerbarkeit • Konzepte der Optimalsteuerung für hyperbolische Systeme • Sensitivitätsanalyse • Exponentielle Stabilität • Lyapunovfunktionen • Randstabilisierung • Verzögerungen Die Präsentation des Stoffes erfolgt in Vorlesungsform. Die weitere Aneignung der wesentlichen Begriffe und Techniken erfolgt durch Selbststudium begleitender Literatur, unterstützt durch Zusammenkünfte innerhalb der Übungen.
6	**Learning objectives and skills**	Die Studierenden • nennen und erklären exemplarische Grundbegriffe zu Problemen der optimalen Steuerung und der Stabilisierung für Anfangsrandwertprobleme mit der Wellengleichung • stellen Probleme der optimalen Steuerung auf und analysieren sie • entwickeln stabilisierende Rückkopplungssteuerungen und beweisen die exponentielle Stabilität Diese Fähigkeiten sind insbesondere für technische und naturwissenschaftliche Anwendungen von Bedeutung.
7	**Prerequisites**	Kenntnisse der mathematischen Analyse (Analysis 1+2 und Lineare Algebra 1+2). Integration.
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Studienrichtung Data bases and knowledge representation Master of Science Data Science 20212 Studienrichtung Mathematische Theorie / Grundlagen der Data Science Master of Science Data Science 20212
10	**Method of examination**	mündlich
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	no Module frequency information available!
13	**Workload in clock hours**	Contact hours: 75 h Independent study: 225 h

14	**Module duration**	1 semester
15	**Teaching and examination language**	
16	**Bibliography**	• F. Tröltzsch, Steuerung partieller Differentialgleichungen, Vieweg-Verlag 2003 • J.-M. Coron, Control and Nonlinearity, AMS 2007 • M. Gugat, Optimal boundary control and boundary stabilization of hyperbolic systems, Birkhäuser 2015 • G. Bastin, J.-M. Coron, Stability and Boundary Stabilization of 1-D Hyperbolic Systems, Birkhäuser 2016

1	**Module name** 65970	**Stochastische Analysis** Stochastic analysis	**5 ECTS**
2	Courses / lectures	Vorlesung: Stochastische Analysis (2 SWS) Übung: Übung zur Stochastischen Analysis (2 SWS)	5 ECTS -
3	Lehrende	Prof. Dr. Torben Krüger	

4	**Module coordinator**	Prof. Dr. Torben Krüger
5	**Contents**	• Itokalkulus • Diffusionsprozesse • Stochastische Differentialgleichungen • Die Präsentation des Stoffes erfolgt in Vorlesungsform.
6	**Learning objectives and skills**	Die Studierenden erwerben die Fähigkeit komplexere Strukturen der Stochastik selbständig zu erfassen und auf exemplarische Problemstellungen anzuwenden. Diese bilden eine Basis für eine Spezialisierung in Stochastik undentsprechenden wirtschaftsmathematischen Themen.
7	**Prerequisites**	empfohlen: Kenntnisse der Wahrscheinlichkeitstheorie sind zum Verständnis hilfreich
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Mathematisch statistische Datenanalyse Master of Science Data Science 20212
10	**Method of examination**	mündlich Dauer der mündlichen Prüfung: 15 Min. *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 45 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	Die vorbereitende Literatur wird für jede Lehrveranstaltung jedes Semester neu festgelegt.

1	**Module name** 669768	**SWAT-Intensivübung** SWAT intensive tutorial	**5 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the summer semester.	
3	Lehrende	-	

4	**Module coordinator**	Prof. Dr.-Ing. Richard Lenz
5	**Contents**	• Entwurf und Implementierung einer typischen Web-Applikation • Kreatives Arbeiten im Team • Agile Softwareentwicklung • Verwendung von aktuellen Technologien • Moderne Programmiertechniken
6	**Learning objectives and skills**	Die Studierenden • konzipieren und implementieren eine mehrschichtige Web-Anwendung. • bewerten den Arbeitsaufwand von Aufgaben. • wenden agile Entwicklungsmethoden im Rahmen von Softwareentwicklung an. • arbeiten kooperativ und verantwortlich in Gruppen und können das eigene Kooperationsverhalten sowie die Zusammenarbeit in der Gruppe kritisch reflektieren und optimieren. • arbeiten sich eigenständig in Technologien ein, stellen diese Technologien in Präsentationen vor und wenden sie im Projekt an.
7	**Prerequisites**	• Algorithmen und Datenstrukturen: Objektorientierung • Konzeptionelle Modellierung: Datenmodellierung und UML • Softwareentwicklung in Großprojekten: Entwurfsmustern und IT-Vorgehensmodellen • Systemprogrammierung: Betriebssystem-Architektur • Rechnerkommunikation: Transferprotokollen • Implementierung von Datenbanksystemen: Schichtenarchitektur, Transaktionen • eBusiness Technologies: Scrum und RUP, Advanced XML, OOA&D crash course (Adv. UML), O/R-Mapping, Component Models, Web Basics, Web Services, Presentation Tier (MVC, AJAX, HTML5)
8	**Integration in curriculum**	semester: 4
9	**Module compatibility**	Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Portfolio
11	**Grading procedure**	Portfolio (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 115 h Independent study: 35 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	german
16	**Bibliography**	• Elemental Design Patterns, Smith, 2012 • Patterns of Enterprise Application Architecture, Fowler, 2003 • Scrum mit User Stories, Wirdemann, 2011 • Agile Testing, Crispin and Gregory, 2009 • More Agile Testing, Crispin and Gregory, 2015

1	**Module name** 65884	**Theory of Neural Dynamics and Applications to Machine Learning based on Reservoir Computing** Theory of neural dynamics and applications to machine learning based on reservoir computing	**5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Marius Yamakou
5	**Contents**	• Biological background of neurons • Type I and II spiking neuron models • Separation of time scales • Phase plane and bifurcation analysis • Stochastics and sources of variability • Simulations of spiking neural models • Stochastic and coherence resonances • Synapses and neural connectivity • Hebbian learning algorithms • Simulations of recurrent neural networks • Introduction to reservoir computing • Properties of a good reservoir • Echo-state network (ESN) • Liquid-state machine (LSM) • Implementation of LSM with spiking neural • The accompanying exercises will provide a deeper understanding of spiking neurons and reservoir computing
6	**Learning objectives and skills**	The Students • explain how biological neurons encode information • explain the differences between biological & artificial neurons • perform multiple time scales & bifurcation analysis • explain the sources of noise in spiking neurons • explain the Hebbian learning algorithm • simulate spiking neural networks with Python • explain the differences btw deep learning & reservoir computing • explain the necessary properties of a good reservoir • autonomously design and implement ENS and LSM • compare the efficiency of ESN and LSM in a prediction problem • discuss the social impact of applications of reservoir computing
7	**Prerequisites**	Empfohlen: Analysis-Module des Bachelorstudiums
8	**Integration in curriculum**	semester: 2
9	**Module compatibility**	Studienrichtung Machine Learning / Artificial Intelligence Master of Science Data Science 20212

10	**Method of examination**	Seminarleistung
11	**Grading procedure**	Seminarleistung (100%)
12	**Module frequency**	Irregular
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	
16	**Bibliography**	• Gerstner, Wulfram, et al. Neuronal dynamics: From single neurons to networks and models of cognition.Cambridge University Press, 2014. • Lukoševičius, Mantas, et al. Reservoir computing trends. KI-Künstliche Intelligenz 26 (2012): 365-371.

1	**Module name** 47612	**Tracking Olympiad**	**5 ECTS**
2	Courses / lectures	Hauptseminar: Tracking Olympiad (4 SWS) (SoSe 2025) Attendance is required throughout the seminar.	5 ECTS
3	Lehrende	Prof. Dr. Andreas Kist Luisa Neubig René Groh	

4	**Module coordinator**	Prof. Dr. Andreas Kist
5	**Contents**	Computer vision is one of the major tasks and applications of artificial intelligence (AI). Gaining hands-on experience is therefore of great importance for future AI developers. In the Tracking Olympiad, students utilize latest object detection and tracking algorithms to track a freely, randomly moving object ("HexBug) in a given arena. The students will be provided with a set of videos that contain the ground-truth positional information and implement an own tracking technique. At the beginning of the seminar, all students are divided into teams which compete with each other to find the best strategy for tracking the HexBug. The teams tracking prediction needs to be an algorithm that incorporates each students tracking algorithm. The teams score will be evaluated by applying the teams tracking algorithm to previously unseen/withheld videos. Further, the team acquires and annotates own data to improve their tracking algorithms. Each team selects videos that are tested by the other teams algorithm and are subsequently ranked similar to a soccer league table. The aim of this seminar is to enable each student developing an own AI-powered tracking algorithm that is an integral part of a team solution. The Tracking Olympiad consists of two sessions in a given week, one with a journal club explaining AI tracking concepts by students and one for open Q&A depending on the individual students progress with voluntary developmental time.
6	**Learning objectives and skills**	Students • will be able to create own code • are able to create acquire and annotate own data • can document their code • will strengthen their team skills • can develop tracking algorithms • will learn about latest AI methods • can present complex topics • can extract relevant information from journal papers
7	**Prerequisites**	None
8	**Integration in curriculum**	no Integration in curriculum available!
9	**Module compatibility**	Artificial intelligence in biomedical engineering (AIBE) Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung

		The seminar requires a presentation of a contemporary computer vision paper with implementing/using the published code on the seminar's dataset for each student. The student is required to create a tracking algorithm. The algorithmic details will be presented by the student in a written report (10-15 pages, JMLR style). *
11	**Grading procedure**	Seminarleistung (100%) The grade is the arithmetic mean of the talk (50%) and the written report (50%).
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Burger and Burge, Principles of Digital Image Processing (all volumes) • Howes and Minichino, Learning OpenCV 4 Computer Vision with Python 3 • Sebastian Raschka, Python Machine Learning: Machine Learning and Deep Learning with Python, scikit-learn, and TensorFlow 2 • Aurélien Géron, Hands-on Machine Learning with Scikit-Learn, Keras, and TensorFlow • Pereira et al., Quantifying behaviour to understand the brain, Nat Neurosci 2020

1	**Module name** 498723	**Transformationen in der Signalverarbeitung** Transforms in signal processing	**2,5 ECTS**
2	Courses / lectures	Vorlesung: Transformationen in der Signalverarbeitung (2 SWS) (SoSe 2025)	2,5 ECTS
3	Lehrende	PD Dr.-Ing. Jürgen Seiler	

4	**Module coordinator**	PD Dr.-Ing. Jürgen Seiler
5	**Contents**	Das Modul "Transformationen in der Signalverarbeitung" behandelt mehrere verschiedene Transformationen, die im Rahmen der Signalverarbeitung Verwendung finden. Dabei werden zuerst die grundlegenden Konzepte von Transformationen diskutiert und die Vorteile die Transformationen mit sich bringen erläutert. Im Anschluss daran werden die grundlegenden Eigenschaften von Integraltransformationen betrachtet und die Laplace- und die Fourier-Transformation im Detail untersucht. Um auch zeitlich veränderliche Signale gut transformieren zu können werden danach die Kurzzeit-Fourier-Transformation und die Gabor-Transformation eingeführt. Im Anschluss daran erfolgt eine Betrachtung der Auswirkung der Abtastung auf transformierte Signale, bevor die z-Transformation als Transformation für diskrete Signale behandelt wird. Abschließend erfolgt die Betrachtung weiterer Transformationen für diskrete Signale wie der Diskreten Fourier-Transformation oder linearer Block-Transformationen. The module "Transforms in Signal Processing" covers several different transforms which are used in the field of signal processing. For this, first the basic concepts of transforms are discussed and the advantages which are offered by the different transforms are presented. Subsequent to this, fundamental properties of integral transforms are considered and the Laplace- and the Fourier-Transform are examined in detail. To be able to transform time-varying signals, the Short-Time Fourier-Transform and the Gabor-Transform are introduced, afterwards. Subsequent to this, the impact of sampling on transformed signals is analyzed before the z-Transform as a transform for discrete signals is covered. Finally, further transforms for discrete signals like the Discrete Fourier-Transform or Linear-Block Transforms are discussed.
6	**Learning objectives and skills**	Die Studierenden können nach Besuch der Vorlesung • Anwendungsmöglichkeiten von Transformationen bestimmen • Integraltransformationen gegenüberstellen und untersuchen • die Existenz von Transformationen hinterfragen • die Eindeutigkeit von Transformationen überprüfen • Sätze und Eigenschaften von Transformationen entwickeln • zu Transformationen zugehörige inverse Transformationen einschätzen • die Zusammenhänge zwischen verschiedenen Transformationen einschätzen • auf Zusammenhänge zwischen Ausgangssignalen und transformierten Signalen folgern • Symmetriebeziehungen von Transformationen ausarbeiten

		• Zusammenhänge zwischen kontinuierlichen und diskreten Signalen ausarbeiten Educational Objectives and Competences: After attending the lecture, students will be able to • determine applications of transforms • contrast and examine integral transforms • question the existence of transforms • evaluate the uniqueness of transforms • develop theorems and properties of transforms • evaluate to transforms corresponding inverse transforms • evaluate the relationships between different transforms • asses the relationship between original signal and transformed signals • devise the symmetry properties of transforms • devise the relationship between continuous and discrete signals
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	mündlich Mündliche Prüfung von 30 min Dauer. *
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 45 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	K. Krüger, Transformationen - Grundlagen und Anwendungen in der Nachrichtentechnik, Vieweg Verlag, Braunschweig B. Girod, R. Rabenstein, A. Stenger, Einführung in die Systemtheorie, B. G. Teubner Verlag, Stuttgart

1	**Module name** 65084	**Transport Phenomena** Transport phenomena	**5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	Prof. Dr. Günther Grün
5	**Contents**	**Ordinary Differential Equations** 1) Generalities on first order differential equations and preliminary material. Equivalence of differential equation of order n to vector equation of the first order. Linear equations of the first order. Method of separation of variables. Exact differential equations. The uniqueness problem: an example. Some integral inequalities: Gronwall's Lemma and Bihari's Lemma. Generalities on Banach spaces. Banach fixed point Theorem. 2) Existence and Uniqueness theorems for ODEs within the Picard-Lindelöf framework. Local existence and uniqueness Theorem for the Cauchy problem: proof of the result via the method of successive approximations and via Banach fixed point theorem. Ascoli-Arzelà theorem. Peano existence theorem: proof via the polygonal method and via Schauder point fixed theorem. Other uniqueness Theorems. Some global problems for ordinary differential equations: global uniqueness, global existence and the behavior of saturated solutions. Dependence of solutions on initial values. Differential inequalities and the comparison method. A criterion of global existence. **Transport Equations** 1) Method of characteristics. Well-posedness of transport equation and continuity equation within the Cauchy-Lipschitz framework. 2) Transport equations on graph. Well-posedness of linear transport equations with piecewise constant coefficients on networks. Network topology, function space on networks. Semigroup Theory.
6	**Learning objectives and skills**	Students are able to: • use language and techniques of ordinary differential equations (with smooth and irregular vector fields), especially regarding local and global existence, uniqueness theorems, regularity and stability of the solutions; • use language and techniques related to transport equations on the full space, the torus and graphs; • work out the examples and applications that accompany the theory.
7	**Prerequisites**	Recommended: knowledge of linear algebra and calculus; basic knowledge of functional analysis.
8	**Integration in curriculum**	semester: 1

9	**Module compatibility**	Studienrichtung Simulation and Numerics Master of Science Data Science 20212
10	**Method of examination**	mündlich (20 Minuten)
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 35 h Independent study: 115 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Ahmad, S. & Ambrosetti, A. A Textbook on Ordinary Differential Equations. Springer, 2015. • Corduneau, C. Principles of Differential and Integral Equations. Allyn and Bacon Inc., 1971. • Evans, L.C.. Partial Differential Equations. AMS, 2010. • Piccoli, B. & Garavello, M. Traffic Flow on Networks. AIMS on Applies Math. Vol I. 2006 • Handouts and lecture notes distributed via StudOn.

1	**Module name** 65940	**Trustworthy Artificial Intelligence** Trustworthy artificial intelligence	**5 ECTS**
2	Courses / lectures	Online-Kurs: Trustworthy Artificial Intelligence (3 SWS)	-
3	Lehrende	Prof. Dr. Johannes Helbig	

4	**Module coordinator**	Prof. Dr. Johannes Helbig
5	**Contents**	AI-based systems are increasingly complementing and replacing human cognition and appearing as agents in the world. They control processes, generate and filter knowledge, make judgments and decisions. The seminar deals with the question of how our security, our interests and our ethical values can be safeguarded in the process, especially against the background of limited explainability of deeply networked and self-learning systems.
6	**Learning objectives and skills**	Content specific: Participants • appreciate the disruptive potential of artificial agents on our lives and societies • develop a notion of the engineering, ethical, and philosophical challenges and their interdependencies • reflect various constructive approaches to trustworthiness along the whole system design/development value chain General: Participants • train the discourse of an interdisciplinary topic from different scientific perspectives • build up on their skills to comprehend a scientific argumentation, to present it convincingly to their peers, and to elaborate it stringently in a written paper
7	**Prerequisites**	Bachelor degree recommended
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	International Information Systems Master of Science Data Science 20212 Studienrichtung Data bases and knowledge representation Master of Science Data Science 20212 Technische Schlüsselqualifikationen Master of Science Data Science 20212
10	**Method of examination**	Seminarleistung Vortrag 45min, schriftliche Ausarbeitung 5-10 Seiten *
11	**Grading procedure**	Seminarleistung (100%)
12	**Module frequency**	Only in winter semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	?? semester (no information for Module duration available)
15	**Teaching and examination language**	german or english

16	**Bibliography**	• Russell, Stuart (2019). Human Compatible: AI and the Problem of Control. London: Allen Lane • Christian, Brian (2020). The Alignment Problem: Machine Learning and Human Values. New York: W.W. Norton & Company • Nida-Rümelin, Julian and Weidenfeld, Nathalie (2018). Digitaler Humanismus: Eine Ethik für das Zeitalter der Künstlichen Intelligenz. München: Piper Verlag

1	**Module name** 96314	**Virtual Vision** Virtual vision	**2,5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lehrende		

4	**Module coordinator**	PD Dr. Christian Herglotz

5	**Contents**	• Human Vision
		• Field of view and fovea
		• Dynamic Range
		• Stereoscopy
		•
		  ◦ Brightness
		  ◦ 3D and depth
		  ◦ Colors
		  ◦ Spatial and temporal resolution
		• Energy efficiency in video communications

6	**Learning objectives and skills**	The students • give an overview on basic properties of the human visual system • know and explain all hardware and software components necessary to perform video capturing, processing, and display. • describe differences and properties of video formats such as fisheye, 360°, or high dynamic range • distinguish video formats and discuss advantages and disadvantages • show real-time demonstrations of these video formats with common portable devices • assess the quality and the compression performance of video formats • come up with new strategies to improve processing algorithms like stitching or compression.
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Multimedia Engineering Master of Science Data Science 20212
10	**Method of examination**	mündlich Oral exam of 30 min duration
11	**Grading procedure**	mündlich (100%)
12	**Module frequency**	Only in winter semester The exam is still offered but not the lecture any more.
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 45 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	english
16	**Bibliography**	References for further reading will be given in the lecture.

1	**Module name** 65091	**Wahrscheinlichkeitstheorie** Probability theory	**10 ECTS**
2	Courses / lectures	Vorlesung: Wahrscheinlichkeitstheorie (4 SWS) (SoSe 2025) Übung: Zentralübung zur Wahrscheinlichkeitstheorie (1 SWS) (SoSe 2025) Tutorium: Tutorien zur Wahrscheinlichkeitstheorie (1 SWS) (SoSe 2025)	10 ECTS 3 ECTS 0 ECTS
3	Lehrende	Prof. Dr. Torben Krüger	

4	**Module coordinator**	Prof. Dr. Torben Krüger
5	**Contents**	• Mengensysteme, messbare Abbildungen, Maße, Integrationstheorie • Maße mit Dichten • Podukträume, unabhängige Zufallsvariablen und gekoppelte Experimente • Bedingte Erwartungen und Martingale • Mehrdimensionale Normalverteilungen • Stochastische Ungleichungen und Grenzwertsätze • 0-1 Gesetze • Grenzwertsätze • Große Abweichungen • Grundlagen stochastischer Prozesse Die Präsentation des Stoffes erfolgt in Vorlesungsform. Die weitere Aneignung der wesentlichen Begriffe und Techniken erfolgt durch Präsenzübungen und Hausaufgaben.
6	**Learning objectives and skills**	Die Studierenden • erkennen und erklären die formale maßtheoretische Grundlage der Wahrscheinlichkeitstheorie und übertragen diese. • erfassen und formulieren zufällige Phänomene mit mathematisch komplexeren Strukturen. • nennen und erklären die wichtigsten stochastischen Prozesse, die in den Anwendungen eine Rolle spielen. • sammeln und bewerten relevante Informationen und erkennen Zusammenhänge zu anderen mathematischen Themenfeldern. • klassifizieren und lösen selbstständig Probleme analytisch.
7	**Prerequisites**	empfohlen: Stochastische Modellbildung, sowie Grundlagen in Analysis und Linearer Algebra
8	**Integration in curriculum**	semester: 1
9	**Module compatibility**	Studienrichtung Mathematisch statistische Datenanalyse Master of Science Data Science 20212
10	**Method of examination**	Übungsleistung Klausur (90 Minuten)
11	**Grading procedure**	Übungsleistung (bestanden/nicht bestanden)

		Klausur (100%)
12	**Module frequency**	Only in summer semester
13	**Workload in clock hours**	Contact hours: 105 h Independent study: 195 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	• Bauer: Einfu?hrung in die Wahrscheinlichkeitstheorie • Breiman: Probability • Durrett: Probability • Klenke: Wahrscheinlichkeitstheorie