UNIVERSITÄT ZU LÜBECK

Module Guide for the Study Path

Master CLS 2023

Version from 14. April 2025

mathematics

MML with specialization in Image Processing

MML with specialization in Genetic Statistics

Elective

CS3100-KP08, CS3100SJ14 - Signal Processing (SignalV14)

Duration:	**Turnus of offer:**	**Credit points:**
1 Semester	each winter semester	8

Course of study, specific field and term:

- Master CLS 2023 (compulsory), mathematics, 1st semester
- Bachelor Biophysics 2024 (compulsory), computer science, 5th semester
- Bachelor Robotics and Autonomous Systems 2020 (compulsory), Robotics and Autonomous Systems, 5th semester
- Bachelor Computer Science 2019 (optional subject), major subject informatics, Arbitrary semester
- Bachelor Computer Science 2019 (compulsory), Canonical Specialization Bioinformatics and Systems Biology, 5th semester
- Bachelor MES 2020 (compulsory), computer science, 5th semester
- Bachelor Media Informatics 2020 (optional subject), computer science, 5th or 6th semester
- Bachelor Medical Informatics 2019 (optional subject), computer science, 4th to 6th semester
- Bachelor Computer Science 2014 (compulsory), specialization field robotics and automation, 5th semester
- Bachelor Computer Science 2014 (compulsory), specialization field bioinformatics, 5th semester
- Bachelor Computer Science 2016 (compulsory), Canonical Specialization Bioinformatics, 5th semester
- Bachelor Computer Science 2016 (optional subject), major subject informatics, Arbitrary semester
- Bachelor Computer Science 2016 (compulsory), Canonical Specialization Web and Data Science, 5th semester
- Master CLS 2016 (compulsory), mathematics, 1st semester
- Bachelor Robotics and Autonomous Systems 2016 (compulsory), Robotics and Autonomous Systems, 5th semester
- Bachelor IT-Security 2016 (optional subject), computer science, Arbitrary semester
- Bachelor Biophysics 2016 (compulsory), computer science, 5th semester
- Bachelor Medical Informatics 2014 (compulsory), computer science, 5th semester
- Bachelor MES 2014 (compulsory), computer science, 5th semester
- Bachelor Media Informatics 2014 (optional subject), computer science, 5th or 6th semester
- Bachelor Computer Science 2014 (optional subject), central topics of computer science, 5th semester

Classes and lectures:

- Signal Processing (lecture, 2 SWS)
- Signal Processing (exercise, 1 SWS)
- Image Processing (lecture, 2 SWS)
- Image Processing (exercise, 1 SWS)

Workload:

- 110 Hours private studies
- 90 Hours in-classroom work
- 40 Hours exam preparation

Contents of teaching:

- Linear time-invariant systems
- Impulse response
- Convolution
- Fourier transform
- Transfer function
- Correlation and energy density of deterministic signals
- Sampling
- Discrete-time signals and systems
- Discrete-time Fourier transform
- z-Transform
- FIR and IIR filters
- Block diagrams
- FIR filter design
- Discrete Fourier transform (DFT)
- Fast Fourier transform (FFT)
- Characterization and processing of random signals
- Introduction, interest of visual information
- 2D Sampling
- Image enhancement
- Edge detection
- Multiresolution concepts: Gaussian and Laplacian Pyramid, wavelets
- Principles of image compression
- Segmentation
- Morphological image processing

- Students work self-actingly and independently with regard to the roles of GSP of the University of Lübeck.

Qualification-goals/Competencies:

- Students are able to explain the fundamentals of linear system theory.
- They are able to define and competently explain the essential elements of signal processing mathematically.
- They will have a command of mathematical methods for the description and analysis of continuous-time and discrete-time signals and systems.
- They are able to design digital filters and know various structures for their implementation.
- They are able to explain the basic techniques for describing and processing of random signals.
- They will have basic knowledge of two-dimensional system theory.
- They are able to describe the main techniques for image analysis and image enhancement.
- They are able to apply the learned principles in practice.

Grading through:

- written exam

Responsible for this module:

- Prof. Dr.-Ing. Alfred Mertins

Teacher:

- Institute for Signal Processing

- Prof. Dr.-Ing. Alfred Mertins

Literature:

- A. Mertins: Signaltheorie: Grundlagen der Signalbeschreibung, Filterbänke, Wavelets, Zeit-Frequenz-Analyse, Parameter- und Signalschätzung - Springer-Vieweg, 3. Auflage, 2013
- A. K. Jain: Fundamentals of Digital Image Processing - Prentice Hall, 1989
- Rafael C. Gonzalez, Richard E. Woods: Digital Image Processing - Prentice Hall 2003

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester (at least 50% of max. points).

Module exam:
- CS3100-L1: Signal Processing, written exam, 90 min, 100% of module grade

MA3445-KP05 - Graph Theory (GraphTKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Bachelor Computer Science 2019 (optional subject), Extended optional subjects, Arbitrary semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Bachelor Computer Science 2016 (optional subject), advanced curriculum, Arbitrary semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Graph theory (lecture, 2 SWS)
- Graph theory (exercise, 1 SWS)

Workload:

- 85 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Hamiltonian graphs and degree sequences
- Menger's theorem - new proofs
- Matchings and decompositions of graphs
- The theorems of Turan and Ramsey
- Vertex and edge colourings
- The four colour theorem

Qualification-goals/Competencies:

- Ability to solve discrete problems using graph theoretical methods
- Knowledge of proof techniques and ideas of discrete mathematics
- Knowledge of fundamental and selected recent research results
- Ability to learn independently by studying relevant literature

Grading through:

- Oral examination

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)

Responsible for this module:

- PD Dr. rer. nat. Christian Bey

Teacher:

- Institute for Mathematics

- PD Dr. rer. nat. Christian Bey

Literature:

- F. Harary: Graph Theory - Reading, MA:.Addison-Wesley 1969
- R. Diestel: Graphentheorie - Berlin: Springer 2010 (4th edition)
- D. Jungnickel: Graphen, Netzwerke und Algorithmen - Mannheim: BI-Wissenschaftsverlag1994
- J. Bang-Jensen, G. Gutin: Digraphs: Theory, Algorithms and Applications - London: Springer 2001
- B. Bollobas: Modern Graph Theory - Berlin: Springer 1998

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA3445-L1: Graph Theory, oral exam, 30 min, 100 % of module grade

MA4100-KP05 - Survival Analysis (UebAnaKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional suject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Survival Analysis (lecture, 2 SWS)
- Survival Analysis (exercise, 1 SWS)

Workload:

- 90 Hours private studies
- 30 Hours work on project
- 15 Hours in-classroom work
- 15 Hours exam preparation

Contents of teaching:

- Introduction to survival analysis
- Kaplan-Meier method
- Log rank test
- The Cox regression model and its characteristics
- Evaluating the proportional hazards assumption
- Stratified Cox model
- Parametric survival analysis
- Event time analyses for recurrent events
- Event time analysis for competing risks
- Design aspects for RCTs

Qualification-goals/Competencies:

- The students are able to explain the different censoring mechanisms leading to survival analysis.
- They are able to define the most important terms of survival analysis.
- They are able to calculate point and interval estimators for the Kaplan-Meier approach.
- They are able to calculate the log-rank test for two or more groups.
- They are able to explain the assumption of proportionality of the Cox model.
- They are able to estimate Cox models.
- They are able to check the assumption of proportionality.
- They are able to calculate exponential and Weibull models.
- They can explain the specifics of recurrent events and competing risks.
- They can estimate models for recurrent events and competing risks.
- They can design an RCT with a time-to-event endpoint.

Grading through:

- Oral examination

Requires:

- Biostatistics 2 (MA2600-KP07)
- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)
- Stochastics 2 (MA4020-KP07)
- Stochastics 1 (MA2510-KP04, MA2510)

Responsible for this module:

- Dr. Maren Vens

Teacher:

- Institute of Medical Biometry and Statistics

- Dr. Maren Vens

Literature:

- Kleinbaum DG, Klein M: Survival Analysis: A Self-Learning Text - 3rd Edition - 2012

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4100-L1: Survival Analysis, oral exam, 30 min, 100 % of module grade

MA4320-KP05 - Optimisation methods for machine learning (OptvML)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Bachelor CLS 2016 (optional subject), mathematics, 6th semester
- Master CLS 2016 (optional subject), mathematics, 2nd or 4th semester
- Bachelor CLS 2023 (optional subject), mathematics, 6th semester
- Master CLS 2023 (optional subject), mathematics, 2nd or 4th semester

Classes and lectures:

- MA4320-V: Optimisation methods for machine learning (lecture, 2 SWS)
- MA4320-Ü: Optimisation methods for machine learning (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Objective functions in machine learning (e.g. hinge loss, log loss, expected risk, empirical risk)
- Optimisation methods for machine learning (e.g. stochastic gradient method,Adam, stochastic quasi-Newton method)
- Applications (e.g. classification, regression, speech and image recognition)

Qualification-goals/Competencies:

- Students can model machine learning problems as optimisation problems.
- They understand the advantages and disadvantages and areas of application of individual optimisation methods.
- They can apply typical proof techniques.
- They can select optimisation methods and implement them in practice for new models.
- Interdisciplinary aspects:
- Students can put theoretical concepts into practice.
- They have implementation experience.
- They are able to abstract practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Optimization (MA4030-KP08, MA4030)
- Optimization (Advanced Mathematics) (MA4031-KP08)

Responsible for this module:

- Prof. Dr. rer. nat. Jan Modersitzki

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Modersitzki
- Prof. Dr. rer. nat. Jan Lellmann
- Dr. rer. nat. Florian Mannel

Literature:

- Goodfellow, Bengio, Courville: Deep Learning - MIT Press
- Bottou, Curtis, Nocedal: Optimization Methods for Large-Scale Machine Learning - SIAM
- Bubeck: Convex Optimization: Algorithms and Complexity - Now Publishers Inc
- Lan: First-order and Stochastic Optimization Methods for Machine Learning - Springer

Language:

- German and English skills required

Notes:

Admission requirements for taking the module:
- None (the competences of the modules mentioned under Requires are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Ungraded preliminary examinations are exercises and their presentation. These must have been completed and positively assessed before the first examination.

Module Exam(s):
- MA4320-L1: Optimisation methods for machine learning, written exam, 90min, or oral exam, 30min, according to the lecturer, 100% of the module grade

MA4330-KP05 - Biosignal analysis (BioSAKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	5

Course of study, specific field and term:

- Master CLS 2023 (compulsory), mathematics, 2nd semester
- Master CLS 2016 (compulsory), mathematics, 2nd semester

Classes and lectures:

- Biosignal analysis (lecture, 2 SWS)
- Biosignal analysis (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Hilbert spaces
- Fourier series and Fourier transformation
- generalized functions
- discrete wavelet tranformation
- least square techniques
- application to biological and medical data

Qualification-goals/Competencies:

- Students have in-depth knowledge of the mathematical background of signal analysis
- They master different methodsof one-dimensional signal analysis
- They have practical skills in the application of these methods
- They have skills in working with Mathematica or MatLab

Grading through:

- Exercises
- written exam

Requires:

- Analysis 2 (MA2500-KP04, MA2500)

Responsible for this module:

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Teacher:

- Institute for Mathematics

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller
- Prof. Dr. rer. nat. Jürgen Prestin

Literature:

- S. Mallat: A wavelet tour of signal processing - Academic Press, 1998
- A. N. Kolmogorov, S.V. Fomin: Reelle Funktionen und Funktionalanalysis - Deutscher Verlag der Wissenschaften 1975

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments during the semester

Module exam(s):
- MA4330-L1: Biosignal analysis, written exam (60 min), 100 % of the module grade

MA4341-KP05 - Time series analysis (ZeitAnKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Time series analysis (lecture, 2 SWS)
- Time series analysis (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Simple discriptive and explorative methods: smoothing, differentiating, autocorrelation, cross correlation
- Linear time series models: MA-processes, AR-processes, ARIMA-processes
- Time series and models with long-range dependencies
- Time series in the frequency domain:autocorrelation function, spectral density and its estimation
- nonlinear methods by examples
- analysis and modelling of data from life sciences (software: R, Mathematica, SPSS)

Qualification-goals/Competencies:

- Students have basic knowledge of concepts and ideas of time series analysis
- They master simple linear methods of time series analysis
- They have competencies in analysis and modelling of real-world time series

Grading through:

- Oral examination

Requires:

- Stochastics 2 (MA4020-KP07)

Responsible for this module:

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Teacher:

- Institute for Mathematics
- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Literature:

- R. Schlittgen, B.Streitberg: Zeitreihenanalyse - Oldenburg-Verlag, München, Wien 1994
- P.J. Brockwell, R.A. Davis: Time Series: Theory and Methods - Springer, New York 1991

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4341-L1: Time series analysis, oral exam, 30 min, 100 % of module grade

MA4345-KP05 - Functional Analysis (AKFunkKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Functional Analysis (lecture, 2 SWS)
- Functional Analysis (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- metric spaces
- elements of topology, in particular, compactness
- Banach and Hilbert spaces
- L^p-spaces
- duality
- bounded linear functionals and operators

Qualification-goals/Competencies:

- Understanding the transfer of simple analytic ideas to general structures
- Learning and applying techniques of functional analysis

Grading through:

- written exam

Requires:

- Analysis 2 (MA2500-KP04, MA2500)

Responsible for this module:

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Teacher:

- Institute for Mathematics

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Literature:

- A. N. Kolmogorov, S. V. Fomin: Reelle Funktionen und Funktionalanalysis - Deutscher Verlag der Wissenschaften, Berlin 1975

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4345-L1: Functional Analysis, oral exam, 30 min, 100 % of module grade

MA4400-KP05 - Chaos and Complexity (ChaKomKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master Biophysics 2019 (optional subject), Elective, 1st or 2nd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Chaos and Complexity (lecture, 2 SWS)
- Chaos and Complexity (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Time-discrete dynamical systems and stochastic processes
- Nonlinearity and chaos
- Ergodicity
- Symbolic dynamics
- Information-theoretic complexity measures
- Ordinal time series analysis
- Biological and medical applications, in particular EEG analysis

Qualification-goals/Competencies:

- Students get insights into basic aspects of nonlinear dynamics
- They have skills in analyzing and modeling complex data and time series
- They have competencies in simulating and illustrating nonlinear dynamic phenomena

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Stochastics 1 (MA2510-KP04, MA2510)
- Analysis 1 (MA2000-KP08, MA2000)

Responsible for this module:

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Teacher:

- Institute for Mathematics

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Literature:

- M. Brin, G. Stuck: Introduction to Dynamical Systems - Cambridge University Press 2002
- J. M. Amigó: Permutation Complexity in Dynamical Systems - Springer 2010
- R. L. Devaney: An Introduction to Chaotic Dynamical Systems - Westview Press 2003

Language:

- depends on the chosen courses

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4400-L1: Chaos and Complexity, oral exam, 30 min, 100 % of module grade

Lecture notes in English

MA4410-KP05 - Approximation Theory (ApproxKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Approximation theory (lecture, 2 SWS)
- Approximation theory (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Fundamentals of functional analysis
- Best approximation
- Linear methods, trigonometric kernels
- Theorems of Jackson and Bernstein
- Moduli of continuity
- Singular integrals
- Theorem of Banach-Steinhaus
- Interpolation methods
- Stability inequalities

Qualification-goals/Competencies:

- practicing mathematical techniques (developing mathematical intuition and its formal justification, training the ability to abstract, reasoning)
- application of basic concepts from functional analysis and the theory of function spaces
- Learning the basic principles of approximation theory
- Understanding the relationship between order of convergence and smoothness
- Knowledge of the basic approximation methods
- application of computer algebra for visualization and better understanding of the methods used

Grading through:

- exercises, project, oral or written exam

Responsible for this module:

- Prof. Dr. rer. nat. Jürgen Prestin

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Jürgen Prestin

Literature:

- P. L. Butzer, R. J. Nessel: Fourier Analysis and Approximation - Birkhäuser Verlag 1971
- R. A. Devore, G. G. Lorentz: Constructive Approximation - Springer 1993

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4410-L1: Approximation Theory, oral exam, 30 min, 100 % of module grade

MA4450-KP05 - Modeling Biological Systems (MoBSKP05)		
Duration:	**Turnus of offer:**	**Credit points:**
1 Semester	each winter semester	5

Course of study, specific field and term:

- Master CLS 2023 (compulsory), mathematics, 1st semester

Classes and lectures:

- Modeling Biological Systems (lecture, 2 SWS)
- Modeling Biological Systems (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Elementary time-discrete deterministic models
- Structured time-discrete population dynamics
- Galton-Watson processes
- Modeling of data and data analysis

Qualification-goals/Competencies:

- Students have knowledge of elementary time-discrete models for modeling biological processes
- They develop skills in connecting ideas from different fields of mathematics
- They have competencies in data analysis and modelling
- They develop competencies in interdisciplinary work

Grading through:

- exercises and project assignments
- written exam

Responsible for this module:

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Teacher:

- Institute for Mathematics

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Literature:

- F. Braer, C. Castillo-Chavez: Mathematical Models in Population Biology - New York: Springer 2000
- H. Caswell: Matrix Population Models - Sunderland: Sinauer Associates 2001
- S. N. Elaydi: An Introduction to Difference Equations - New York: Springer 1999
- B. Huppert: Angewandte Lineare Algebra - Berlin: de Gruyter 1990
- U. Krengel: Einführung in die Wahrscheinlichkeitstheorie und Statistik - Wiesbaden: Vieweg 2002
- E. Seneta: Non-negative Matrices and Markov Chains - New York: Springer 1981

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Module exam(s):
- MA4450-L1: Modeling Biological Systems, written exam, 90 min, 100 % of module grade

MA4453-KP05 - Evolutionary Dynamics: Population Genetic and Ecological Models (EDPGEMKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Evolutionary Dynamics: Population Genetic and Ecological Models (lecture, 2 SWS)
- Evolutionary Dynamics: Population Genetic and Ecological Models (exercise, 1 SWS)

Workload:

- 65 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Basics of mathematical population genetics
- Discrete stochastic models
- Genetic drift
- Natural selection
- Coupling of genetic and ecological models
- Dynamics of infectious diseases
- Handling publicly available data on the spread of infectious diseases

Qualification-goals/Competencies:

- The students can explain the basic biological and mathematical concepts of population genetics.
- The students can construct simple stochastic models and analyse them formally.
- The students can perform approximations of simple models.
- The Students will be able to contextualize mathematical models and data.

Grading through:

- Oral examination

Responsible for this module:

- Prof. Dr. Arne Traulsen

Teacher:

- Max Planck Institute for Evolutionary Biology
- Institute for Mathematics

- Prof. Dr. Arne Traulsen
- MitarbeiterInnen des Instituts
- Dr. Christian Hilbe
- Dr. Hildegard Uecker
- Dr. Chaitanya Gokhale

Literature:

- S.P. Otto and T.Day: A Biologist s Guide to Mathematical Modeling in Ecology and Evolution. - Princeton University Press, 2007

Language:

- offered only in English

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4453-L1: Evolutionary Dynamics: Population Genetic and Ecological Models, oral exam, 30 min, 100 % of module grade

MA4454-KP05 - Evolutionary Dynamics: Game Theory (EvDyGTKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Evolutionary Game Theory - from Basics to Recent Developments (lecture, 2 SWS)
- Evolutionary Game Theory - from Basics to Recent Developments (exercise, 1 SWS)

Workload:

- 65 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Basics of classical game theory
- Deterministic and stochastic evolutionary game theory
- The evolution of cooperation and punishment
- Repeated games
- Applications in genetics, ecology and social dynamics

Qualification-goals/Competencies:

- The students can explain and apply the basic concepts of game theory.
- They can construct evolutionary models based on game theoretic interactions.
- They can analyse evolutionary games formally.

Grading through:

- Oral examination

Responsible for this module:

- Prof. Dr. Arne Traulsen

Teacher:

- Max Planck Institute for Evolutionary Biology
- Institute for Mathematics

- Prof. Dr. Arne Traulsen
- N.N.

Literature:

- M.A. Nowak: Evolutionary Dynamics - Exploring the equations of life - Harvard University Press, 2006
- Broom & Rychtar: Game-Theoretical Models in Biology - Chapman & Hall, 2013

Language:

- offered only in English

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4454-L1: Evolutionary Dynamics: Game Theory, oral exam, 30 min, 100 % of module grade

MA4501-KP05 - Mathematics of Image Processing (MaBVKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	every second winter semester	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 3rd semester
- Master CLS 2023 (compulsory), mathematics, 1st semester

Classes and lectures:

- Mathematics in Image Processing (lecture, 2 SWS)
- Mathematics in Image Processing (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Functional-analytic models
- Well-posedness and regularization
- Introduction to calculus of variations, Euler-Lagrange equation
- Image restauration
- Segmentation and lifting methods
- Evolution equations in image processing (discretization, stability)

Qualification-goals/Competencies:

- Students have a solid mathematical understanding of typical image processing methods.
- They can compare and assess typical mathematical image processing methods.
- They can derive typical mathematical methods for image processing.
- They understand fundamental discretization techniques and their numerical analysis.
- They understand typical numerical methods for image processing.
- They are able to implement fundamental numerical methods for image processing.
- Interdisciplinary qualifications:
- Students have advanced skills in modeling.
- They can translate theoretical concepts into practical solutions.
- They are experienced in implementation.
- They can think abstractly about practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Analysis 2 (MA2500-KP09)

Responsible for this module:

- Prof. Dr. rer. nat. Jan Modersitzki

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Modersitzki
- Prof. Dr. rer. nat. Jan Lellmann

Literature:

- Gonzales/Woods: Digital Image Processing - Prentice Hall
- Russ: The Image Processing Handbook - CRC Press
- Handels: Medizinische Bildverarbeitung - Vieweg+Teubner

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None (Familiarity with the topics of the required modules is assumed, but the modules are not a formal prerequisite for attending the course).

Prerequisites for the exam:
- Homework assignments and their presentation are ungraded examination prerequisites which have to be completed and positively evaluated before the first examination.

Examination:
- MA4501-L1: Mathematics in Image Processing, written examination (90 min) or oral examination (30 min) as decided by examiner, 100% of final mark

MA4510-KP05 - Wavelet Theory (WaveThKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Wavelet Theory (lecture, 2 SWS)
- Wavelet Theory (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Haar system
- Discrete Haar transformation
- Orthonormal wavelet bases
- Multiresolution Analysis
- Algorithms for reconstruction and decomposition
- Periodic wavelets
- Multivariate generalizations

Qualification-goals/Competencies:

- practicing mathematical techniques (developing mathematical intuition and its formal justification, training the ability to abstract, reasoning)
- application of basic concepts from functional analysis and the theory of function spaces
- Knowledge of the basic principles of wavelet analysis
- Understanding the applications in signal analysis
- The students learn how to work with wavelet algorithms and wavelet software.
- application of computer algebra for visualization and better understanding of the methods used

Grading through:

- exercises, project, oral or written exam

Responsible for this module:

- Prof. Dr. rer. nat. Jürgen Prestin

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Jürgen Prestin

Literature:

- I. Daubechies: Ten lectures on wavelets - SIAM Publ., Philadelphia, 1992
- A.K. Louis, P. Maass, A. Rieder: Wavelets - Teubner Studienbücher Mathematik, 1994

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4510-L1: Wavelet Theory, oral exam, 30 min, 100 % of module grade

MA4610-KP05 - Stochastic processes (StoProKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	normally each year in the winter semester	5

Course of study, specific field and term:

- Master CLS 2023 (compulsory), mathematics, 1st or 3rd semester
- Master CLS 2016 (compulsory), mathematics, 1st or 3rd semester

Classes and lectures:

- Stochastic processes (lecture, 2 SWS)
- Stochastic processes (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Conditional expectation
- Stochastic processes
- Filtrations
- Martingales
- Brownian motion

Qualification-goals/Competencies:

- To develop some insight into stochastic processes based on selected classes of processes
- Training of a stochastic way of thinking
- Application of basic ideas and concepts of stochastic analysis

Grading through:

- written exam

Requires:

- Stochastics 2 (MA4020-KP07)
- Stochastics 1 (MA2510-KP04, MA2510)

Responsible for this module:

- Prof. Dr. rer. nat. Andreas Rößler

Teacher:

- Institute for Mathematics
- Prof. Dr. rer. nat. Andreas Rößler

Literature:

- L. C. G. Rogers, D. Williams: Diffusions, Markov Processes, and Martingales, Vol. 1, Foundations - 2nd edition, Cambridge University Press, 2000
- L. C. G. Rogers, D. Williams: Diffusions, Markov Processes, and Martingales, Vol. 2, Ito Calculus - 2nd edition, Cambridge University Press, 2014
- Ioannis Karatzas, Steven E. Shreve: Brownian Motion and Stochastic Calculus - Springer Verlag, 2nd edition, 1991

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Module exam(s):
- MA4610-L1: Stochastic processes, written exam, 90 min, 100 % of module grade

MA4611-KP05 - Markov Processes (MarkPrKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Markov Processes (lecture, 2 SWS)
- Markov Processes (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Markov chains and random walks
- time-continuous Markov processes
- Brownian Motion
- Poisson process
- birth-and-death processes
- life science applications

Qualification-goals/Competencies:

- Mastering some important classes of stochastic processes and understanding possible applications

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Teacher:

- Institute for Mathematics

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4611-L1: Markov Processes, oral exam, 30 min, 100 % of module grade

MA4614-KP05 - Numerical methods for partial differential equations (NMPDGKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Numerical methods for partial differential equations (lecture, 2 SWS)
- Numerical methods for partial differential equations (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Introduction to the theory of partial differential equations
- Numerics for partial differential equations
- Discretization of initial and boundary value problems
- Numerical approximation schemes
- Error analysis
- Stability and consistency

Qualification-goals/Competencies:

- To impart basic principles of numerics for partial differential equations
- To learn methods of proofs as well as the application of results from numerics for partial differential equations
- Accomplished handling of essential concepts and results as well as of selected advanced topics

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Numerics 2 (MA4040-KP06)
- Numerics 1 (MA3110-KP06)
- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)
- Analysis 2 (MA2500-KP09)
- Analysis 1 (MA2000-KP08, MA2000)

Responsible for this module:

- Prof. Dr. rer. nat. Andreas Rößler

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Andreas Rößler
- MitarbeiterInnen des Instituts

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4614-L1: Numerical methods for partial differential equations, written exam (90 min) or oral exam (30 min), 100 % of module grade

Literature will be announced in the lecture.

MA4615-KP05 - Numerical methods for stochastic processes (NuStPrKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Numerical methods for stochastic processes (lecture, 2 SWS)
- Numerical methods for stochastic processes (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Basic principles of stochastic processes in continuous time
- Stochastic differential equations
- Discrete time approximations for solutions of stochastic differential equations
- Numerical schemes for strong and weak approximations

Qualification-goals/Competencies:

- To impart basic principles of stochastic processes and of some numerical schemes
- To learn methods of proof as well as the application of algorithms
- Accomplished handling of essential concepts and results as well as of selected advanced topics

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Stochastic processes (MA4610-KP05)
- Stochastics 2 (MA4020-KP07)
- Stochastics 1 (MA2510-KP04, MA2510)

Responsible for this module:

- Prof. Dr. rer. nat. Andreas Rößler

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Andreas Rößler

Literature:

- P. E. Kloeden, E. Platen: Numerical Solution of Stochastic Differential Equations - Springer-Verlag, Berlin, 1999
- P. E. Kloeden, E. Platen, H. Schurz: Numerical Solution of SDE Through Computer Experiments - Springer-Verlag, Berlin, 2003
- G. N. Milstein, M. V. Tretyakov: Stochastic Numerics for Mathematical Physics - Springer-Verlag, Berlin, 2004

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4615-L1: Numerical methods for stochastic processes, written exam (90 min) or oral exam (30 min), 100 % of module grade

MA4616-KP05 - Advanced Numerics (HoeNumKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Advanced Numerics (lecture, 2 SWS)
- Advanced Numerics (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Numerics for ordinary differential equations
- One-step methods, local and global error analysis
- Orders of consistence and convergence
- Stiff differential equations, implicit schemes, stability

Qualification-goals/Competencies:

- To impart basic principles of numerics for differential equations
- To learn methods of proofs as well as the application of results from numerics for differential equations
- Accomplished handling of essential concepts and results as well as of selected advanced topics

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Numerics 2 (MA4040-KP06)
- Numerics 1 (MA3110-KP06)

Responsible for this module:

- Prof. Dr. rer. nat. Andreas Rößler

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Andreas Rößler

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4616-L1: Advanced Numerics, written exam (90 min) or oral exam (30 min), 100 % of module grade

Literature will be announced in the lecture.

MA4617-KP05 - Stochastic differential equations (StDiGlKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Stochastic differential equations (lecture, 2 SWS)
- Stochastic differential equations (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Stochastic processes, Brownian motion
- Stochastic integration
- Ito formula
- Stochastic differential equations

Qualification-goals/Competencies:

- To impart basic principles of stochastic processes and stochastic differential equations
- To learn methods of proof as well as the application of results from stochastic analysis
- Accomplished handling of essential concepts and results as well as of selected advanced topics

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Stochastic processes (MA4610-KP05)
- Stochastics 2 (MA4020-KP07)
- Stochastics 1 (MA2510-KP04, MA2510)

Responsible for this module:

- Prof. Dr. rer. nat. Andreas Rößler

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Andreas Rößler

Literature:

- Bernt Oksendal: Stochastic Differential Equations: An Introduction with Applications - Springer Verlag, 6th edition, 2013
- Ioannis Karatzas, Steven E. Shreve: Brownian Motion and Stochastic Calculus - Springer Verlag, 2nd edition, 1991
- Philip Protter: Stochastic Integration and Differential Equations - Springer Verlag, 2005
- K. L. Chung, R. J. Williams: Introduction to Stochastic Integration - Birkhäuser, 2nd edition, 1990

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4617-L1: Stochastic differential equations, written exam (90 min) or oral exam (30 min), 100 % of module grade

MA4618-KP05 - Introduction to stochastic partial differential equations (EinSPDKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Introduction to stochastic partial differential equations (lecture, 2 SWS)
- Introduction to stochastic partial differential equations (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Gaussian measures on Hilbert spaces
- Infinite-dimensional Brownian motion
- Martingales on Banach spaces
- Stochastic integration in Hilbert spaces
- Existence of solutions for SPDEs

Qualification-goals/Competencies:

- To impart basic principles of the theory for stochastic partial differential equations
- To learn methods of proofs as well as the application of results from the theory for stochastic partial differential equations
- Accomplished handling of essential concepts and results as well as of selected advanced topics

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Stochastic processes (MA4610-KP05)
- Stochastics 2 (MA4020-KP07)
- Stochastics 1 (MA2510-KP04, MA2510)

Responsible for this module:

- Prof. Dr. rer. nat. Andreas Rößler

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Andreas Rößler
- MitarbeiterInnen des Instituts

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4618-L1: Introduction to stochastic partial differential equations, written exam (90 min) or oral exam (30 min), 100 % of module grade

Literature will be announced in the lecture.

MA4630-KP05 - Fourier Analysis (FouAnaKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional suject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Fourier Analysis (lecture, 2 SWS)
- Fourier Analysis (exercise, 1 SWS)

Workload:

- 65 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Theory of the Fourier transform
- Fourier transform in the Hilbert space
- Summability methods
- Applying Fourier transforms in solving differential equations
- Laplace and Mellin transforms
- Numerical aspects and relation to discrete Fourier transforms

Qualification-goals/Competencies:

- Practicing mathematical techniques (developing mathematical intuition and its formal justification, training the ability to abstract, reasoning)
- Application of basic concepts from functional analysis and the theory of function spaces
- Knowledge of integral transforms
- A comprehensive understanding for the Fourier transform
- Application of computer algebra for visualization and better understanding of the methods used

Grading through:

- exercises, project, oral or written exam

Responsible for this module:

- Prof. Dr. rer. nat. Jürgen Prestin

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Jürgen Prestin

Literature:

- Chandrasekharan, K.: Classical Fourier Transforms - Springer 1989
- Pinsky, M. A.: Introduction to Fourier Analysis and Wavelets - Brooks/Cole 2002

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4630-L1: Fourier Analysis, oral exam, 30 min, 100 % of module grade

MA4650-KP05 - Matrix algebra (MatAlgKP05)

Duration:	Turnus of offer:	Credit points:	Max. group size:
1 Semester	every second year	5	20

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Matrix algebra (lecture, 2 SWS)
- Matrix algebra (exercise, 1 SWS)

Workload:

- 60 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Properties of matrices
- Special matrices
- Quadratic forms
- Decompositions
- Generalized inverses
- Differentiation
- Probability calculation
- Derivation and calculation of estimators
- Design matrices
- Linear hypotheses
- Examples: multiple linear regression, weighted least-squares estimation, shrinkage estimation

Qualification-goals/Competencies:

- Students know numerous rules of matrix algebra.
- They understand proofs, especially concerning generalized linear models and multivariate procedures.
- They command matrix calculus.
- They apply linear algebra to linear models.
- They can deal with practical problems from statistics in an abstract manner.

Grading through:

- written exam

Requires:

- Biostatistics 2 (MA2600-KP07)
- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)
- Analysis 2 (MA2500-KP09)

Responsible for this module:

- PD Dr. rer. pol. Reinhard Vonthein

Teacher:

- Institute of Medical Biometry and Statistics

- PD Dr. rer. pol. Reinhard Vonthein
- MitarbeiterInnen des Instituts

Literature:

- Schmidt, K., Trenkler, G.: Einführung in die Moderne Matrix-Algebra: Mit Anwendungen in der Statistik - Springer: Heidelberg 2006, ISBN 9783540330073
- Toutenburg, H.: Lineare Modelle - Physica: Heidelberg 1992 und 2006, ISBN 978-3790815191
- Fahrmeir, L., Kneib, T., Lang, S.: Regression: Modelle, Methoden und Anwendungen - Springer: Heidelberg 2007, ISBN 9783642343339

- Healy, Michael: Matrices for Statistics - ISBN 9780198507024

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4650-L1: Matrix algebra, written exam, 90 min, 100 % of module grade

MA4665-KP05 - Statistical Learning (StaLerKP05)

Duration:	Turnus of offer:	Credit points:	Max. group size:
1 Semester	every second year	5	20

Course of study, specific field and term:

- Master Medical Informatics 2019 (optional subject), Medical Data Science / Artificial Intelligence, 1st or 2nd semester
- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Statistical Learning (lecture, 2 SWS)
- Statistical Learning (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Application scenarios and research questions for prediction models (focus: risk prediction)
- Study design and data preprocessing
- Overview of different machine learning methods (concepts, advantages and disadvantages)
- Development of prediction models
- Evaluation of prediction performance
- Comparison of prediction models
- Variable selection
- Extension to time-to-event outcomes with censoring

Qualification-goals/Competencies:

- Students can define research questions for applications of pediction models
- They can explain the individual steps in the development and evaluation of prediction models
- They can describe frequently occurring errors and problems as well als possible solutions
- They can describe central ideas of different machine learning methods and select suitable methods for applications
- They can develop and evaluate models in the programming language R

Grading through:

- project work
- Viva Voce or test

Requires:

- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)

Responsible for this module:

- Prof. Dr. rer. nat. Silke Szymczak

Teacher:

- Institute of Medical Biometry and Statistics

- Prof. Dr. rer. nat. Silke Szymczak
- MitarbeiterInnen des Instituts

Literature:

- Thomas Gerds und Michael Kattan: Medical Risk Prediction Models With Ties to Machine Learning - CRC Press: Bota Raton, FL (2022)

Language:

- German or English

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- None

Module exam(s):
- MA4665-L1: Statistical Learning, oral exam (20 min) or written exam (60 min), 50 % of module grade
- MA4665-L2: Research project incl. presentation and code documentation, 50 % of module grade

MA4666-KP05 - Interpretable Statistical Learning (IStLern)

Duration:	Turnus of offer:	Credit points:	Max. group size:
1 Semester	every second year	5	20

Course of study, specific field and term:

- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2023 (optional subject), mathematics, Arbitrary semester
- Master CLS 2016 (optional subject), mathematics, Arbitrary semester
- Master Medical Informatics 2019 (optional subject), Medical Data Science / Artificial Intelligence, 1st or 2nd semester

Classes and lectures:

- Interpretable Statistical Learning (lecture, 2 SWS)
- Interpretable Statistical Learning (exercise, 1 SWS)

Workload:

- 60 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours programming
- 15 Hours exam preparation

Contents of teaching:

- Definition: Interpretable statistical learning
- Interpretable models
- Global model-agnostic methods
- Partial Dependence Plots (PDP)
- Accumulated Local Effects (ALE)
- Variable importance measures
- Local model-agnostic methods
- Individual Conditional Expectation (ICE)
- Local Surrogates (LIME)
- Counterfactional Explanations
- Shapley Werte, SHAP

Qualification-goals/Competencies:

- Students can explain the central ideas of interpretable statistical learning.
- They know the difference between model-based and model-agnostic methods.
- The can explain the differences between different methods for model interpretation.
- They can choose suitable methods for a given applicational setting.
- They can implement and apply these methods in R.

Grading through:

- Viva Voce or test

Requires:

- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)

Teacher:

- Institute of Medical Biometry and Statistics

- Dr. rer. hum. biol. Björn-Hergen Laabs

Literature:

- Molnar, C.: Interpretable Machine Learning: A Guide for Making Black Box Models Explainable - Springer, New York 2022 (2nd ed.)
- Hastie, T., Tibshirani, R., Friedmann, J.: The Elements of Statistical Learning: Data Mining, Inference and Prediction - Springer, New York 2009 (2nd ed.)
- Wu, X., Kumar, V.: The Top Ten Algorithms in Data Mining - CRC Press, Boca Raton 2009

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module
- None (the competences of the modules mentioned under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- None

Module Exam(s):
- MA4666-L1: Interpretable Statistical Learning, oral exam (20 min) or written exam (60 min), 100% of the module grade

MA4670-KP05 - Combinatorics (KombiKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- combinatorics (lecture, 2 SWS)
- combinatorics (exercise, 1 SWS)

Workload:

- 85 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Permutations, combinations, variations
- Partitions
- Generating functions
- Recurrence equations
- Sums and differences
- Inclusion - exclusion

Qualification-goals/Competencies:

- Learning the basics of combinatorics
- Knowledge of different proof techniques and combinatorial approaches
- Teaching fundamental results and deepening some selected aspects of combinatorics
- Ability to learn independently by studying relevant literature

Grading through:

- Oral examination

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)
- Analysis 1 (MA2000-KP08, MA2000)

Responsible for this module:

- PD Dr. rer. nat. Christian Bey

Teacher:

- Institute for Mathematics

- PD Dr. rer. nat. Christian Bey

Literature:

- Peter Tittmann: Einführung in die Kombinatorik - Spektrum Akademischer Verlag 2000
- Richard A. Brualdi: Introductory Combinatorics - Pearson Prentice Hall 2004

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4670-L1: Combinatorics, oral exam, 30 min, 100 % of module grade

MA4675-KP05 - Algebra (AlgebrKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Algebra (lecture, 2 SWS)
- Algebra (exercise, 1 SWS)

Workload:

- 85 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Groups (semigroups, subgroups, homomorphisms, invariant subgroups, isomorphism theorems, products of groups)
- Rings (units, ring homomorphisms, polynomial rings, quotient fields, ideals)
- Field extensions (field characteristic, prime fields, field degree, algebraic and transcendent elements, algebraical field extensions, splitting field of a polynomial)
- Geometric constructions (compass-and-straightedge construction, field of constructible points, constructing regular polygons)

Qualification-goals/Competencies:

- Learning the basics of algebra
- Knowledge of different proof techniques and algebraic approaches
- Teaching fundamental results and deepening some selected aspects of algebra
- Ability to learn independently by studying relevant literature

Grading through:

- Oral examination

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)

Responsible for this module:

- PD Dr. rer. nat. Christian Bey

Teacher:

- Institute for Mathematics

- PD Dr. rer. nat. Christian Bey

Literature:

- G. Fischer: Lehrbuch der Algebra - Vieweg, 2011 (2. Auflage)
- M. Artin: Algebra - Birkhäuser, 1998
- B. L. van der Waerden: Algebra I - Springer, 1993 (9. Auflage)

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4675-L1: Algebra, oral exam, 30 min, 100 % of module grade

MA4735-KP05 - Geometry (GeoKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Geometry (lecture, 2 SWS)
- Geometry (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Euclidean Geometry
- Non-Euclidean Geometries
- Introduction to Differential Geometry

Qualification-goals/Competencies:

- Mastery of basic geometric results
- Gaining an overview over different geometries and their specifics

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Analysis 2 (MA2500-KP09)
- Analysis 1 (MA2000-KP08, MA2000)
- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)

Responsible for this module:

- PD Dr. rer. nat. Christian Bey

Teacher:

- Institute for Mathematics

- PD Dr. rer. nat. Christian Bey

Literature:

- Bär: Elementare Differentialgeometrie
- Berger: Geometry I, II
- Coxeter: Introduction to Geometry
- Knörrer: Geometrie
- Kumaresan, Santhanam: An Expedition to Geometry
- Nikulin, Shafarevich: Geometries and Groups
- McCleary: Geometry from a Differentiable Viewpoint
- Rees: Notes on Geometry
- Sossinsky: Geometries
- Stahl: A Gateway to Modern Geometry, The Poincare Half-Plane

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4735-L1: Geometry, oral exam, 30 min, 100 % of module grade

MA4750-KP05 - Topology (TopoKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Topology (lecture, 2 SWS)
- Topology (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Topological spaces and continuous maps
- Fundamental group and covering spaces
- Introduction to Homology
- Applications

Qualification-goals/Competencies:

- Mastery of basic results and proof techniques of topology
- Understanding of applications of topological methods

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Analysis 2 (MA2500-KP09)
- Analysis 1 (MA2000-KP08, MA2000)
- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)

Responsible for this module:

- PD Dr. rer. nat. Christian Bey

Teacher:

- Institute for Mathematics

- PD Dr. rer. nat. Christian Bey

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4750-L1: Topology, oral exam, 30 min, 100 % of module grade

MA4760-KP05 - Integral Theorems in Analysis (IntAnaKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Integral Theorems in Analysis (lecture, 2 SWS)
- Integral Theorems in Analysis (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Integration on submanifolds
- Gauss' Integral Theorem and applications
- One-forms, line integrals, Green's Integral Theorem
- Higher-order differential forms, Integration
- Stokes' Integral Theorem and applications
- Cauchy's Integral Theorem and applications

Qualification-goals/Competencies:

- Mastery of basic results and proof techniques of vector analysis
- Understanding of applications of vector analysis

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Analysis 2 (MA2500-KP09)
- Analysis 1 (MA2000-KP08, MA2000)
- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)

Responsible for this module:

- PD Dr. rer. nat. Christian Bey

Teacher:

- Institute for Mathematics

- PD Dr. rer. nat. Christian Bey

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4760-L1: Integral Theorems in Analysis, oral exam, 30 min, 100 % of module grade

MA4801-KP05 - Elliptic Functions and Function Theory (EFFThKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Elliptic Functions and Function Theory (lecture, 2 SWS)
- Elliptic Functions and Function Theory (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Complex analysis
- Periodic functions and lattices
- Simple and double periods
- Liouville Theorem, residue theorem
- Weierstrass P-, Zeta- and Sigma-function
- The field of elliptic functions
- Elliptic integrals
- Moduls of elliptic functions

Qualification-goals/Competencies:

- Getting familiar with and developing skills in concepts and techiques in complex analysis
- Extension of the background for different applications, e.a. signal processing, to develop problem solving strategies
- Getting familiar with Mathematica in the considered topic
- Developing competencies for self-sufficient problem solving
- Gaining experience in project work in the field

Grading through:

- exercises, project, oral or written exam

Responsible for this module:

- Prof. Dr. Reinhard Schuster

Teacher:

- Institute for Mathematics

- Prof. Dr. Reinhard Schuster

Literature:

- Andrews, G. E., Askey, R. and Roy, R.: Special Functions - Cambridge University Press 1999
- Armitage, J. V. and Eberlein, W. F.: Elliptic Functions - Cambridge University Press 2006
- Hurwitz, A.: Vorlesungen über Allgemeine Funktionentheorie und Elliptische Funktionen - Springer 2000
- Koecher, M und Krieg, A.: Elliptische Funktionen und Modulformen - Springer 2007
- Stramp, W., Ganzha, V. und Vorozhtsov, E.: Höhere Mathematik mit Mathematica - Vieweg 1997
- Werner, A.: Elliptische Kurven in der Kryptographie - Springer 2002
- Whittaker, E. T. and Watson, G. N.: A course of modern analysis - Cambridge University Press 1902 (Reprinted 1999)

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4801-L1: Elliptic Functions and Function Theory, written exam (90 min) or oral exam (30 min), 100 % of module grade

MA4802-KP05 - Theory of Relativity (RelaThKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Theory of Relativity (lecture, 2 SWS)
- Theory of Relativity (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Part A, Special Relativity:
- Classical space time references system and Newton laws
- Electrodynamics, Lorentz and Minkowsky geometry
- Hyperbolic geometry und trigonometry
- Time-like, space-like and light cone
- Relativistic kinematics
- Simultaneity and velocity addition
- Length contraction and time dilatation
- Twin paradox
- Mass and energy relativistic
- Part B, General Theory of Relativity:
- Four-dimensional space time as a manifold
- Christoffel symbols, curvature tensor, covariant derivative
- Coupling of matter and fields with geometry by the Einstein equation
- Equivalence principle for mass

Qualification-goals/Competencies:

- Getting familiar with concepts and gaining competencies on special and general relativity
- Extension of the mathematic and physical background for different applications to develop problem solving strategies
- Getting familiar with Mathematica in the considered field
- Developing competencies for self-sufficient problem solving of tasks on the theory of relativity
- Gaining experience in project work in the field

Grading through:

- exercises, project, oral or written exam

Responsible for this module:

- Prof. Dr. Reinhard Schuster

Teacher:

- Institute for Mathematics

- Prof. Dr. Reinhard Schuster

Literature:

- Baumann, G.: Mathematica for Theoretical Physics. Part 1: Classical Mechanics and Nonlinear Dynamics. Part 2: Electrodynamics, Quantum Mechanics, General Relativity, and Fractals - Springer 2005
- Goenner, H.: Spezielle Relativitätstheorie und die klassische Feldtheorie - Spectrum 2003
- Gray A., Abbena, E. and Salomon, S.: Modern Differential Geometry of Surfaces with Mathematica. Studies in Advanced Mathematics - Chapman and Hall 2006
- Haken, H. und Wolf, H. Ch.: Atom- und Quantenphysik. Einführung in die experimentellen und theoretischen Grundlagen - Springer

2003
- Hawking, S. W. and Ellis, G. F. R.: The large scale structure of space-time - Cambridge Monographs on Mathematical Physics 1973, 2006
- Helgason, S.: Differential Geometry, Lie Groups and Symmetric Spaces. Graduate Studies in Mathematics - American Mathematical Society 1978, 2001
- Kobayashi, S. and Nomizu, K.: Foundations of Differential Geometry I, II - Interscience Publishers 1963
- Schröder, U. E.: Gravitation. Einführung in die Allgemeine Relativitätstheorie - Harri Deutsch 2007
- Weber, H. J. und Arfen, G. B.: Essential Mathematical Methods for Physics - Elsevier 2004
- Weil, H.: Raum - Zeit - Materie. Vorlesungen über allgemeine Relativitätstheorie - Springer 1923
- Wald, R. M.: General Relativity - The University of Chicago Press 1984

Language:
- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4801-L1: Theory of Relativity, written exam (90 min) or oral exam (30 min), 100 % of module grade

MA4803-KP05 - Number Theory (ZahlThKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Number Theory (lecture, 2 SWS)
- Number Theory (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Divisibility of integers, Farey sequencees, Fibonacci Numbers
- Approximation of real numbers by rational numbers
- Modulo operations: Complete and reduced residue system, Theorems of Euler and Fermat
- Representation of natural numbers sums of 2, 3 or 4 squares
- Quadratic residues
- Quadratic reciprocity
- Prime number criteria and pseudo prime numbers
- Pythagorean triples
- Rational points on curves of degree 2
- Number theoretic functions
- Prime number theorem, prime numbers in arithmetic progression
- Riemann zeta function and its functional equation
- Known problems and conjectures, i.e. Goldbach conjecture
- Stochastic prime numbers

Qualification-goals/Competencies:

- Theoretical knowledge of the mentioned topics
- Historical and most recent issues
- Solve questions in this filed
- Recognize interdisciplinary aspects

Grading through:

- exercises, project, oral or written exam

Responsible for this module:

- Prof. Dr. Reinhard Schuster

Teacher:

- Institute for Mathematics

- Prof. Dr. Reinhard Schuster

Literature:

- Chandrasekharan: Einführung in die analytische Zahlentheorie - Springer Lecture Notes 2008
- Bundschuh: Einführung in die Zahlentheorie - Springer 1992
- Menzer: Zahlentheorie: Fünf ausgewählte Themenstellungen der Zahlentheorie - Oldenbourg Wissenschaftsverlag 2010
- Remmert u. Ullrich: Elementare Zahlentheorie - Birkhäuser 1995
- Rempe: Primzahltests für Einsteiger: Zahlentheorie - Algorithmik - Kryptographie - Vieweg+Teubner 2009
- Scharlau, Opolka: Von Fermat bis Minkowski: Eine Vorlesung über Zahlentheorie und ihre Entwicklung - Springer 2009

- Scheid: Zahlentheorie - Spektrum 2003
- Schmidt: Einführung in die algebraische Zahlentheorie - Springer 2009
- Weil: Zahlentheorie - Spektrum 1992
- Winogradow: Elemente der Zahlentheorie - Prestel-Verlag 1956

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4803-L1: Number Theory, written exam (90 min) or oral exam (30 min), 100 % of module grade

MA4804-KP05 - Special Functions (SpFunkKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Minor in Teaching Mathematics, Master of Education 2023 (optional subject), mathematics, 2nd or 3rd semester
- Minor in Teaching Mathematics, Master of Education 2017 (optional subject), mathematics, 2nd or 3rd semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Special Functions (lecture, 2 SWS)
- Special Functions (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Algebraic operations with complex numbers
- Exponential function, angle functions, hyperbolic angle functions, derived functions
- Gamma and beta functions
- Hypergeometric function
- Bessel function, Legendre function, Laguerre function, Tscheybyscheff function, Hermite function, Jacobi hypergeometric function
- Elliptic functions, theta functions
- Number theoretic functions
- Riemann zeta function
- Used mathematical theories and concepts:
- Complex function theory
- Infinite products
- Differential equations (ordinary, partial)
- Functional equations
- Integral representation
- Taylor series expansions for eigenvalues and eigenfunctions (using space and time, defined on geometric objects)
- Producing functions (a Taylor series in two variables is considered as a series in one variable and the coefficients are special functions in the other variable)
- Addition theorems
- Fourier transformations
- Transformation groups, matrix groups

Qualification-goals/Competencies:

- Theoretical knowlege of the mentioned topics
- Historical and latest questions
- Solve questions in this field
- Recognize interdisciplinary aspects

Grading through:

- exercises, project, oral or written exam

Responsible for this module:

- Prof. Dr. Reinhard Schuster

Teacher:

- Institute for Mathematics

- Prof. Dr. Reinhard Schuster

Literature:

- Andrews G.E., Askey R., Roy R.: Special Functions.Encyclopedia of Mathematics and its Application 71 - Cambridge University Press 2006
- Courant, R., Hilbert, D.: Methoden der mathematischen Physik - Springer 1993
- Erdélyi, A. , Magnus, W., Oberhettinger, F., Tricomi, F.: Higher Transcendental Functions - McGraw-Hill, New York, 1953
- Fichtenholz, G.M.: Differential- und Integralrechnung, Band 1-3 - H. Deutsch 1997
- Hurwitz, A., Courant, R.: Vorlesungen über Allgemeine Funktionentheorie und Elliptische Funktionen - Springer 2000
- Stegun, I. A., Abramowitz, M.: Handbook of Mathematical Functions - Dover Press
- Strampp, W., Ganzha, V., Vorozhtsov, E.: Höhere Mathematik mit Mathematica, Bd.4, Funktionentheorie, Fouriertransformationen und Laplacetransformationen: Funktionentheorie, Fourier- und Laplacetransformation - Vieweg 1997
- Wawrzynczyk, A.: Group Representations and Special Functions - Reidel Publishing Company 1983
- Whittaker, E. T., Watson, G. N.: A Cource of Modern Analysis - Cambridge University Press 1902 ... 1999

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4804-L1: Special Functions, written exam (90 min) or oral exam (30 min), 100 % of module grade

MA4940-KP05 - Test and estimation theory (TSchThKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	5

Course of study, specific field and term:

- Master CLS 2023 (compulsory), mathematics, 2nd semester
- Master CLS 2016 (compulsory), mathematics, 2nd semester

Classes and lectures:

- Test and estimation theory (lecture, 2 SWS)
- Test and estimation theory (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Parametric theory and nonparametric hints about point and interval estimation, and statistical tests
- Properties of estimators: consistency, unbiasedness, sufficiency, efficiency
- Construction of estimators: score function, maximum likelihood, bias correction, theorems of Rao-Crámer, Rao-Blackwell, and Lehmann-Schefé, multi-parametric exponential family
- Properties of confidence intervals: exact, coverage probability, pivot statistics
- Construction of Wald, score, and ML confidence intervalls; delta method
- Properties of statistical tests: power function, unbiasedness, best tests, Lemma of Neyman and Pearson, consistency and asymptotic relative efficiency
- Construction of likelihood ratio, Wald, score, MLR, and conditional tests

Qualification-goals/Competencies:

- Students know the definitions of central theoretical concepts in the theory of estimation and testing.
- They have understood properties and construction principles.
- They apply construction principles to problems with one or more parameters.
- They prove properties of estimators and tests.
- They assess tests and estimators by their properties.
- They construe statistical tests and confidence intervals for problems with distributions they did not know before.

Grading through:

- written exam

Requires:

- Stochastics 2 (MA4020-KP07)
- Stochastics 1 (MA2510-KP04, MA2510)
- Biostatistics 2 (MA2600-KP07)
- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)

Responsible for this module:

- PD Dr. rer. pol. Reinhard Vonthein

Teacher:

- Institute of Medical Biometry and Statistics

- PD Dr. rer. pol. Reinhard Vonthein

Literature:

- Lehmann, E.L., Romano, Joseph P.: Testing Statistical Hypotheses - ISBN-13 9780387988641
- Lehmann, E.L., Casella, George: Theory of Point Estimation - ISBN-13 9780387985022
- Held, L.: Methoden der statistischen Inferenz - Spektrum 2008 - ISBN 978-3-8274-1939-2
- Rüger, B.: Test- und Schätztheorie: Band I: Grundlagen - Oldenbourg 1999 - ISBN 3 486-23650-4
- Rüger, B.: Test- und Schätztheorie: Band II: Statistische Tests - Oldenbourg 2002 - ISBN 3 486-25130-9

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Module exam(s):
- MA4940-L1: Test and estimation theory, written exam, 90 min, 100 % of module grade

MA4944-KP05 - Multivariate Statistics (MulStaKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	every second year	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Multivariate Statistics (lecture, 2 SWS)
- Multivariate Statistics (exercise, 1 SWS)

Workload:

- 55 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 20 Hours exam preparation

Contents of teaching:

- Multivariate probability distributions
- Multiple and multivariate regression
- Discriminant analysis and logistic regression
- Cluster analysis with various distance and similarity measures
- Principal component and factor analysis
- Correspondence analysis and multidimensional scaling
- Structural equation models

Qualification-goals/Competencies:

- Students command a broad repertoire of multivariate statistical methods.
- They are able to explain the ideas behind several representative methods.
- They apply these methods by hand and with R packages.
- They analyse problems and choose suitable methods.
- They are able to decide for a better option, e.g. standardization, variance structures, distance measures, factor numbers or rotations.
- They develop multivariate models.

Grading through:

- written exam

Requires:

- Biostatistics 2 (MA2600-KP07)
- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)
- Stochastics 2 (MA4020-KP07)
- Stochastics 1 (MA2510-KP04, MA2510)

Responsible for this module:

- PD Dr. rer. pol. Reinhard Vonthein

Teacher:

- Institute of Medical Biometry and Statistics

- PD Dr. rer. pol. Reinhard Vonthein
- MitarbeiterInnen des Instituts

Literature:

- Fahrmeir, Ludwig; Hamerle, Alfred; Tutz, Gerhard: Multivariate statistische Verfahren - ISBN-13 9783110138061
- Johnson, R. J.; Wichern, D. W.: Applied Multivariate Statistical Analysis - 5. Ed. Prentice Hall, 2002 - ISBN-13: 000-0131877151

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4944-L1: Multivariate Statistics, written exam, 90 min, 100 % of module grade

MA4947-KP05 - Modern Nonparametric statistics (NpStatKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	every second year	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Nonparametric statistics (lecture, 2 SWS)
- Nonparametric statistics (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours work on project
- 15 Hours exam preparation

Contents of teaching:

- Application scenarios for modern nonparametric methods
- Permutation tests
- Rank-based tests and effect measures
- Evaluation of methods through simulation studies

Qualification-goals/Competencies:

- Knowledge of the most important nonparametric statistical methods
- Understanding of the respective advantages and disadvantages of parametric and nonparametric methods
- Competence in the selection of appropriate methods in application situations
- Experience in planning, conducting and interpreting simulation studies for method s evaluation

Grading through:

- project work
- Viva Voce or test

Requires:

- Biostatistics 2 (MA2600-KP07)
- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)

Responsible for this module:

- Prof. Dr. rer. nat. Silke Szymczak

Teacher:

- Institute of Medical Biometry and Statistics

- Prof. Dr. rer. nat. Silke Szymczak
- MitarbeiterInnen des Instituts

Literature:

- Edgar Brunner, Arne C. Bathke, Frank Konietschke: Rank and Pseudo-Rank Procedures for Independent Observations in Factorial Designs - ISBN 978-3-030-02912-8

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- None

Module exam(s):
- MA4947-L1: Nonparametric statistics, oral exam (20 min) or written exam (60 min), 60 % of module grade
- MA4947-L2: Small group research project including lecture and code documentation, 40 % of module grade

MA4955-KP05 - Applied Multiple Regression (AMuRegKP05)

Duration:	Turnus of offer:	Credit points:	Max. group size:
1 Semester	every second year	5	20

Course of study, specific field and term:

- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Applied Multiple Regression (lecture, 2 SWS)
- Applied Multiple Regression (exercise, 1 SWS)

Workload:

- 85 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Need and use of multivariable analyses in epidemiological and clinical research
- Types of outcome variables and available multivariable models
- Incorporation of independent variables in the model
- Dealing with the issues of limited sample size and missing data
- Coding and entering the variables in the model
- Assessing the regression coefficient and strength of the model
- Checking the underlying assumptions and improving the fit of the model
- Communicating the results to the publishing house
- R programming for applied regression

Qualification-goals/Competencies:

- The students are able to understand different study designs and multivariable models.
- They are able to understand impact of a variable on an outcome in a multivariable model.
- They are able to understand assumptions underlying the model.
- They are able to design their own multivariable analysis plan.
- They are able to interpret and critically evaluate the published studies.
- They are able to communicate their own study results using the standard available guidelines.
- They are able to program multiple regression analyses in R.

Grading through:

- project work

Requires:

- Generalized Linear Models (MA4962-KP05)
- Biostatistics 2 (MA2600-KP07)

Responsible for this module:

- PD Dr. rer. pol. Reinhard Vonthein

Teacher:

- Institute of Medical Biometry and Statistics

- Louis Macias, Ph.D.

Literature:

- John Fox. 2016: Applied Regression Analysis - 3rd ed. Los Angeles SAGE. ISBN -13: 978-1-4522-0566-3
- Mitchell H. Katz 2011: Multivariable Analysis: A Practical Guide for Clinicians and Public Health Researchers - 3rd ed. Cambridge University Press. ISBN -13: 978-0-521-14107-9
- Andrew Gelman, Jennifer Hill, Aki Vehtari, 2020: Regression and Other Stories - Cambridge University Press. ISBN 13:978-1-1391-6187-9
- Werner Vach. 2012: Regression Models as a Tool in Medical Research - Chapman and Hall/CRC. ISBN: 978-1-466-51748-6

Language:

- offered only in English

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4955-L1: Project work with documentation and presentation

MA4962-KP05 - Generalized Linear Models (VLModKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th and 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester

Classes and lectures:

- Generalized Linear Models (lecture, 2 SWS)
- Generalized Linear Models (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 30 Hours programming
- 15 Hours exam preparation

Contents of teaching:

- General overview of generalized linear models (GLM): - link and response function, - GLM algorithms: Newton-Raphson, Fisher Scoring, iterated weighted least squares, - convergence, - quality of the adaption, - residuals
- Continuous response models: Gaussian, log-normal, Gamma, log-Gamma for survival analysis, inverse Gaussian
- Dichotomous response models: logit, probit, cloglog
- Count data: Poisson, negative binomial with over- and underdispersion
- Ordinal response models: proportional odds model
- Disordered categorial response models: Multinomial logit and probit model
- Censored continuous response models: Tobit model

Qualification-goals/Competencies:

- The students are able to explain the theoretical bases of generalized linear models (GLM).
- They are able to explain areas of application for GLM.
- They are able to select a suitable GLM.
- They are able to estimate GLMs in R.
- They are able to explain the R source code in a presentation.
- They are able to judge the results of GLMs in R critically.
- They are able to evaluate algorithmic challenges of GLMs.
- They are able to explain conceptual problems of GLMs for categorialresponse variables.
- They are able to implement GLM in R.
- They are able to apply regression diagnostics to GLMs and to judge the results.
- They are able to describe the most important estimation algorithms for GLMs.
- They are able to list the statistical properties of GLMs.

Grading through:

- Viva Voce or test

Requires:

- Biostatistics 2 (MA2600-KP07)

Responsible for this module:

- Prof. Dr. rer. biol. hum. Inke König

Teacher:

- Institute of Medical Biometry and Statistics

- Prof. Dr. rer. biol. hum. Inke König

Literature:

- Agresti, Alan: Foundations of Linear and Generalized Linear Models - Wiley, 2015

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments as specified at the beginning of the semester

Module exam(s):
- MA4962-L1: Generalized Linear Models, written exam (90 min) or oral exam (30 min), 100 % of module grade

MA4970-KP05 - Design of Experiments and Analysis of Variance (VerVarKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 1st, 2nd, or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester

Classes and lectures:

- Design of Experiments and Variance Analysis (lecture, 2 SWS)
- Design of Experiments and Variance Analysis (exercise, 1 SWS)

Workload:

- 85 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Regression modeling and analysis of variance
- Generalized inverse
- Singular linear models
- Factorial designs
- The Latin square and the Graeco-Latin square designs
- Experiments with block factors
- Fixed and random effects
- The split-plot design

Qualification-goals/Competencies:

- Students know the differences between planned experiments and observational studies.
- Students can enumerate the advantages of the statistical multi-factorial design.
- Students can interpret correctly the analysis of variance results of experimental designs.
- Students can select and implement an appropriate experimental design and conduct corresponding variance analysis.
- Students can formulate the analysis of variance as a regression model in matrix notation.
- Students understand the statistical properties of linear regression model with a singular design matrix and a singular hypothesis matrix.
- Students can estimate linear regression model with a singular design matrix and a singular hypothesis matrix.
- Students can create and interpret graphs for summarizing results and model diagnostics.
- Acquisition of knowledge in English technical language.

Grading through:

- Viva Voce or test

Requires:

- Biostatistics 2 (MA2600-KP07)
- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)

Responsible for this module:

- PD Dr. rer. pol. Reinhard Vonthein

Teacher:

- Institute of Medical Biometry and Statistics

- Dr. Maren Vens
- Louis Macias, Ph.D.

Literature:

- Kursbuch: Montgomery, Douglas C. 2012: Design and Analysis of Experiments. 10th ed. - John Wiley & Sons, New York. ISBN 978-1-119-49244-3
- Supplementary literature: Mason, Robert L., Gunst, Richard F., Hess, James L. 2003: Statistical Design and Analysis of Experiments. 2nd ed. - John Wiley & Sons, New York. ISBN 0-471-37216-1

Language:

- German or English

Notes:

Admission requirements for taking the module:
- MA1600-KP04: Biostatistics 1 and
- MA2600-KP07: Biostatistics 2 successfully completed

Admission requirements for participation in module examination(s):
- Successful completion of exercises as specified at the beginning of the semester

Module exam(s):
- MA4970-L1: Experimental design and analysis of variance, written exam (90 min) or oral exam (30 min), 100% of module grade

(share of Institute of Medical Biometry and Statistics in V is 100%)
(share of Institute of Medical Biometry and Statistics in Ü is 100%)

MA5008-KP05 - Mathematical course (PrakMaKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	on request	5 (Typ B)

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 2nd or 3rd semester
- Bachelor CLS 2023 (optional subject), mathematics, 5th or 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th or 6th semester
- Master CLS 2016 (optional subject), mathematics, 2nd or 3rd semester

Classes and lectures:

- Mathematical course (practical course, 5 SWS)

Workload:

- 120 Hours in-classroom work
- 30 Hours written report

Contents of teaching:

- Planning and execution of a scientific project by mathematical methods
- Presenting the methods and results in a detailed written report

Qualification-goals/Competencies:

- Ability to analyze a given problem and to develop mathematical approaches for it
- Ability to make oneself familiar with adequate mathematical structures without any help
- Ability to integrate partial results into the overall solution
- Proficiency in documenting and presenting results

Grading through:

- Written report

Responsible for this module:

- Prof. Dr. rer. nat. Jürgen Prestin

Teacher:

- Institutes of the Department of Computer Science/ Engineering

- Alle prüfungsberechtigten Dozentinnen/Dozenten des Studienganges

Language:

- German or English

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Written report

Module exam(s):
- MA5008-L1: Mathematical course, ungraded course, 0 % of module grade, must be passed

MA5030-KP05 - Image Registration (BildreKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	every second winter semester	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 1st or 3rd semester
- Master CLS 2023 (compulsory), mathematics, 1st or 3rd semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th semester
- Master CLS 2016 (optional subject), mathematics, 1st or 3rd semester

Classes and lectures:

- Image Registration (lecture, 2 SWS)
- Image Registration (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Introduction and basic principles
- Interpolation
- Deformation models
- Landmark-based registration
- Parametric registration
- Non-parametric registration and regularization strategies

Qualification-goals/Competencies:

- Students know the fundamental concepts of image registration.
- They are able to translate concrete problems into adequate models.
- They have experience with parametric registration and can determine optimal parameters.
- They understand nonparametric image registration.
- Interdisciplinary qualifications:
- Students have advanced skills in modeling.
- They can translate theoretical concepts into practical solutions.
- They are experienced in implementation.
- They can think abstractly about practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Analysis 2 (MA2500-KP09)

Responsible for this module:

- Prof. Dr. rer. nat. Jan Modersitzki

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Modersitzki
- Prof. Dr. rer. nat. Jan Lellmann

Literature:

- Goshtasby: 2D and 3D Image Registration - Wiley
- Modersitzki: Numerical Methods for Image Registration - Oxford University Press
- Modersitzki: FAIR: Flexible Algorithms for Image Registration - SIAM
- Rohr: Landmark-Based Image Analysis - Kluwer

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None (Familiarity with the topics of the required modules is assumed, but the modules are not a formal prerequisite for attending the course).

Prerequisites for the exam:
- Examination prerequisites can be determined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively assessed before the first examination.

Examination:
- MA5030-L1: Image Registration, written examination (90 min) or oral examination (30 min) as decided by examiner, 100 % of final mark

MA5033-KP05 - Quantum Image Computing (QuantumIC)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 2nd or 4th semester
- Bachelor CLS 2023 (optional subject), mathematics, 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 6th semester
- Master CLS 2016 (optional subject), mathematics, 2nd or 4th semester

Classes and lectures:

- Quantum Image Computing (lecture, 2 SWS)
- Quantum Image Computing (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Foundations (unitary transformations, qubits, measurements, quantum circuits)
- Quantum image models and quantum image operations
- Recent quantum image processing algorithms
- Adiabatic quantum computing
- Quantum optimization for computer vision

Qualification-goals/Competencies:

- Students know the mathematical foundations of quantum computing and their application.
- Students are familiar with advanced quantum computing models, in particular in image processing and computer vision.
- Students are able to translate practical problems into working algorithms.
- Students can implement algorithms on quantum computers in a modern programming language.
- Interdisciplinary qualifications:
- Students have advanced modeling skills.
- Students can translate theoretical concepts into practical solutions.
- Students have implementation experience.
- Students can think abstractly about practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)

Responsible for this module:

- Prof. Dr. rer. nat. Jan Lellmann

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Lellmann
- Prof. Dr. rer. nat. Jan Modersitzki

Literature:

- Nielsen, Chuang: Quantum Computation and Quantum Information - Cambridge University Press
- Yan, Venegas-Andraca: Quantum Image Processing - Springer

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None (Familiarity with the topics of the required modules is assumed, but the modules are not a formal prerequisite for attending the course).

Prerequisites for the exam:
- Homework assignments and their presentation are ungraded examination prerequisites which have to be completed and positively evaluated before the first examination.

Examination:
- MA5033-L1: Quantum Image Computing, written examination (90 min) or oral examination (30 min) as decided by examiner, 100% of final mark

MA5034-KP05 - Calculus of Variations and Partial Differential Equations (VarPDGKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	every second summer semester	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 2nd or 4th semester
- Bachelor CLS 2023 (optional subject), mathematics, 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 6th semester
- Master CLS 2016 (optional subject), mathematics, 2nd or 4th semester

Classes and lectures:

- Calculus of Variations and Partial Differential Equations (lecture, 2 SWS)
- Calculus of Variations and Partial Differential Equations (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Motivation and application examples
- Functional-analytic foundations
- Direct methods in the calculus of variations
- The dual space, weak convergence, Sobolev spaces
- Optimality conditions
- Classification of partial differential equations and typical PDEs
- Fundamental solutions, maximum principle
- Finite elements for elliptical partial differential equations

Qualification-goals/Competencies:

- Students understand variational modeling.
- They are able to formulate basic physical problems in a variational setting.
- They understand the connections between variational methods and partial differential equations.
- They can derive optimality conditions for energy functionals.
- They understand the mathematical theory behind selected variational problems.
- They can implement selected fundamental variational problems.
- They can formulate selected practical problems in the variational setting.
- Interdisciplinary qualifications:
- Students have advanced skills in modeling.
- They can translate theoretical concepts into practical solutions.
- They are experienced in implementation.
- They can think abstractly about practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr. rer. nat. Jan Modersitzki

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Modersitzki
- Prof. Dr. rer. nat. Jan Lellmann

Literature:

- Vogel: Computational Methods for Inverse Methods - SIAM
- Aubert, Kornprobst: Mathematical Problems in Image Processing: Partial Differential Equations and the Calculus of Variations - Springer
- Scherzer, Grasmair, Grossauer, Haltmeier, Lenzen: Variational Methods in Imaging - Springer

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None (Familiarity with the topics of the required modules is assumed, but the modules are not a formal prerequisite for attending the course).

Prerequisites for the exam:
- Homework assignments and their presentation are ungraded examination prerequisites which have to be completed and positively evaluated before the first examination.

Examination:
- MA5034-L1: Calculus of Variations and Partial Differential Equations, written examination (90 min) or oral examination (30 min) as decided by examiner, 100 % of final mark

MA5035-KP05 - Non-smooth Optimization and Analysis (NiOpAnKP05)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 2nd or 4th semester
- Bachelor CLS 2023 (optional subject), mathematics, 6th semester
- Master CLS 2016 (optional subject), mathematics, 2nd or 4th semester
- Bachelor CLS 2016 (optional subject), mathematics, 6th semester

Classes and lectures:

- Non-smooth Optimization and Analysis (lecture, 2 SWS)
- Non-smooth Optimization and Analysis (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 30 Hours work on project
- 10 Hours exam preparation

Contents of teaching:

- Introduction to non-smooth analysis: convexity, subdifferentials, existence, Legendre- Fenchel conjugate, duality
- First- and higher-order numerical optimization methods: PDHG and interior-point methods
- Approximation of discrete and non-convex problems
- Generalized derivatives and Clarke subdifferential, semismooth Newton methods
- Applications in image processing and computer vision

Qualification-goals/Competencies:

- The students understand the strengths of non-smooth models.
- They can devise and analyse models for simple problems.
- They understand the advantages, disadvantages, and application areas of each optimization method.
- They know how to select and specialize a suitable optimization method for a given model.
- Interdisciplinary qualifications:
- Students have advanced skills in modeling.
- They can translate theoretical concepts into practical solutions.
- They are experienced in implementation.
- They can think abstractly about practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Optimization (Advanced Mathematics) (MA4031-KP08)
- Optimization (MA4030-KP08, MA4030)

Responsible for this module:

- Prof. Dr. rer. nat. Jan Lellmann

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Lellmann
- Prof. Dr. rer. nat. Jan Modersitzki

Literature:

- Rockafellar, Wets: Variational Analysis - Springer
- Boyd, Vandenberghe: Convex Optimization - Cambridge University Press
- Ben-Tal, Nemirovski: Lectures on Modern Convex Optimization - SIAM
- Paragios, Chen, Faugeras: Handbook of Mathematical Models in Computer Vision - Springer

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None (Familiarity with the topics of the required modules is assumed, but the modules are not a formal prerequisite for attending the course).

Prerequisites for the exam:
- Homework assignments and their presentation are ungraded examination prerequisites which have to be completed and positively evaluated before the first examination.

Examination:
- MA5035-L1: Non-smooth Optimization and Analysis, written examination (90min) or oral examination (30 min) as decided by examiner, 100 % of final mark

MA5037-KP05 - Optimization of Complex Systems (OpkoSy05)

Duration:	Turnus of offer:	Credit points:
1 Semester	irregularly	5

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics, 2nd or 4th semester
- Bachelor CLS 2023 (optional subject), mathematics, 6th semester
- Master CLS 2016 (optional subject), mathematics, 2nd or 4th semester
- Bachelor CLS 2016 (optional subject), mathematics, 6th semester

Classes and lectures:

- Optimization of Complex Systems (lecture, 2 SWS)
- Optimization of Complex Systems (exercise, 1 SWS)

Workload:

- 85 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Model problems (e.g. optimal control of heating processes, optimal design)
- Optimum conditions
- Optimization process

Qualification-goals/Competencies:

- Students know how the control of selected complex systems can be modeled as an optimization problem.can be modeled as an optimization problem.
- They know the optimality conditions of these optimization problems.
- They can select optimization methods and implement them in practice for new models.
- Interdisciplinary aspects:
- Students can put theoretical concepts into practice.
- They have experience in implementation.
- They can abstract practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Optimization (Advanced Mathematics) (MA4031-KP08)
- Optimization (MA4030-KP08, MA4030)

Responsible for this module:

- Prof. Dr. rer. nat. Jan Modersitzki

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Lellmann
- Prof. Dr. rer. nat. Jan Modersitzki
- Dr. rer. nat. Florian Mannel

Literature:

- Tröltzsch:: Optimale Steuerung partieller Differentialgleichungen - Vieweg+Teubner Verlag
- Hinze, Ulbrich, Ulbrich, Pinnau: Optimization with PDE Constraints - Springer Dordrecht
- Ulbrich: Semismooth Newton Methods for Variational Inequalities and Constrained Optimization Problems in Function Spaces - SIAM

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None (Familiarity with the topics of the required modules is assumed, but the modules are not a formal prerequisite for attending the course).

Prerequisites for the exam:
- Homework assignments and their presentation are ungraded examination prerequisites which have to be completed and positively evaluated before the first examination.

Examination:
- MA5035-L1: Optimization of Complex Systems, written examination (90min) or oral examination (30 min) as decided by examiner, 100% of final mark

MA5008-KP04 - Mathematical course (PrakMaKP04)

Duration:	Turnus of offer:	Credit points:
1 Semester	on request	4 (Typ B)

Course of study, specific field and term:

- Master CLS 2023 (optional subject), mathematics / computer science, 2nd or 3rd semester
- Master CLS 2016 (optional subject), mathematics / computer science, 2nd or 3rd semester

Classes and lectures:

- Mathematical course (practical course, 4 SWS)

Workload:

- 100 Hours in-classroom work
- 20 Hours written report

Contents of teaching:

- Planning and execution of a scientific project by mathematical methods
- Presenting the methods and results in a detailed written report

Qualification-goals/Competencies:

- Ability to analyze a given problem and to develop mathematical approaches for it
- Ability to make oneself familiar with adequate mathematical structures without any help
- Ability to integrate partial results into the overall solution
- Proficiency in documenting and presenting results

Grading through:

- Written report

Responsible for this module:

- Prof. Dr. rer. nat. Jürgen Prestin

Teacher:

- Institutes of the Department of Computer Science/ Engineering

- Alle prüfungsberechtigten Dozentinnen/Dozenten des Studienganges

Language:

- English, except in case of only German-speaking participants

CS3000-KP04, CS3000 - Algorithm Design (AlgoDesign)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Master CLS 2023 (optional subject), computer science, 3rd semester
- Bachelor Computer Science 2019 (compulsory), foundations of computer science, 5th semester
- Bachelor Robotics and Autonomous Systems 2020 (optional subject), computer science, 5th or 6th semester
- Bachelor Medical Informatics 2019 (optional subject), computer science, 4th to 6th semester
- Bachelor Computer Science 2016 (compulsory), foundations of computer science, 5th semester
- Master CLS 2016 (optional subject), computer science, 3rd semester
- Bachelor Robotics and Autonomous Systems 2016 (optional subject), computer science, 5th or 6th semester
- Bachelor IT-Security 2016 (compulsory), computer science, 5th semester
- Bachelor Medical Informatics 2014 (optional subject), computer science, 5th or 6th semester
- Bachelor Computer Science 2014 (compulsory), foundations of computer science, 5th semester
- Bachelor CLS 2010 (optional subject), computer science, 5th or 6th semester
- Bachelor Computer Science 2012 (compulsory), foundations of computer science, 5th semester

Classes and lectures:

- Algorithm Design (lecture, 2 SWS)
- Algorithm Design (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 10 Hours exam preparation

Contents of teaching:

- Dynamic programming and heuristic search methods
- Complex data structures and union find data structures
- Efficiency analysis and correctness proofs
- Probabilistic algorithms
- Online algorithms
- Graph, matching and scheduling problems
- String processing
- Approximation algorithms

Qualification-goals/Competencies:

- The students can safely apply the principles of algorithm design.
- They can analyze algorithms with respect to correctness and efficiency.
- They are able to apply these principles to concrete problems.
- They can contribute their proficiency in solving similar algorithmic problems.

Grading through:

- written exam

Requires:

- Stochastics 1 (MA2510-KP04, MA2510)
- Theoretical Computer Science (CS2000-KP08, CS2000)
- Algorithms and Data Structures (CS1001-KP08, CS1001)

Responsible for this module:

- Prof. Dr. Rüdiger Reischuk

Teacher:

- Institute for Theoretical Computer Science

- Prof. Dr. Rüdiger Reischuk
- Prof. Dr. rer. nat. Till Tantau

Literature:

- J. Kleinberg, E. Tardos: Algorithm Design - Addison Wesley, 2005

- T. Cormen, C. Leiserson, R. Rivest, C. Stein: Introduction to Algorithms - MIT Press, 2009
- S. Skiena: The Algorithmic Design Manual - Springer, 2012

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Prerequisites for the exam:
- Successful completion of homework and project assignments as specified at the beginning of the semester.

Module exam(s):
- CS3000-L1: Algorithm Design, written exam, 90 min, 100 % of module grade

CS3420-KP04, CS3420 - Cryptology (Krypto14)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Master CLS 2023 (optional subject), computer science, 3rd semester
- Bachelor Computer Science 2019 (optional subject), major subject informatics, Arbitrary semester
- Bachelor Media Informatics 2020 (optional subject), computer science, 4th or 6th semester
- Bachelor Robotics and Autonomous Systems 2020 (optional subject), computer science, 5th or 6th semester
- Bachelor Medical Informatics 2019 (optional subject), computer science, 4th to 6th semester
- Bachelor Computer Science 2016 (optional subject), major subject informatics, Arbitrary semester
- Master CLS 2016 (optional subject), computer science, 3rd semester
- Bachelor Robotics and Autonomous Systems 2016 (optional subject), computer science, 5th or 6th semester
- Bachelor IT-Security 2016 (compulsory), IT-Security, 3rd semester
- Bachelor Medical Informatics 2014 (optional subject), computer science, 5th or 6th semester
- Bachelor Computer Science 2014 (optional subject), central topics of computer science, 5th or 6th semester

Classes and lectures:

- Cryptology (lecture, 2 SWS)
- Cryptology (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 10 Hours exam preparation

Contents of teaching:

- history of cryptography, classical systems
- mathematical and algorithmic basics
- design principles for cryptographic applications
- symmetric crypto systems
- public key crypto systems, digital signatures
- efficient implementation of crypto systems
- methods in cryptoanalysis
- cryptographic protocols

Qualification-goals/Competencies:

- The students are able to model and analyze IT security.
- They know basic cryptographic primitives and protocols.
- They can recognize cryptographic weakness.
- They can apply standard techniques in cryptology.
- They can explain and assess the historical and social significance of encrypting information.

Grading through:

- written exam

Responsible for this module:

- Prof. Dr. Maciej Liskiewicz

Teacher:

- Institute for Theoretical Computer Science

- Prof. Dr. Maciej Liskiewicz

Literature:

- J von zur Gathen: CryptoSchool - Springer 2015
- A. Beutelspacher, H. Neumann, T. Schwarzpaul: Kryptopgrafie in Theorie und Praxis - Vieweg 2005
- D. Wätjen: Kryptographie - Springer 2018
- J. Katz, Y. Lindell: Introduction to Modern Cryptography - Chapman & Hall, 2008
- C. Bauer: Secret History - The Story of Cryptology - CRC Press 2013
- B. Schneier: Applied Cryptography - J. Wiley 1996

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Successful completion of exercise sheets as specified at the beginning of the semester

Module exam(s):
- CS3420-L1: Cryptology, written exam, 90 minutes, 100% of module grade

CS4250-KP04, CS4250 - Computer Vision (CompVision)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	4

Course of study, specific field and term:

- Master CLS 2023 (optional subject), computer science, 2nd or 3rd semester
- Master MES 2020 (optional subject), computer science / electrical engineering, Arbitrary semester
- Master Computer Science 2019 (optional subject), Elective, Arbitrary semester
- Master Media Informatics 2020 (optional subject), computer science, Arbitrary semester
- Master Biophysics 2019 (optional subject), Elective, 2nd semester
- Master Biomedical Engineering (optional subject), advanced curriculum, 2nd semester
- Master CLS 2016 (optional subject), computer science, 2nd or 3rd semester
- Master MES 2014 (optional subject), computer science / electrical engineering, 1st or 2nd semester
- Master Media Informatics 2014 (optional subject), computer science, Arbitrary semester
- Master Computer Science 2012 (optional subject), advanced curriculum imaging systems, 2nd or 3rd semester
- Master CLS 2010 (compulsory), computational life science / imaging, 2nd semester
- Master MES 2011 (advanced curriculum), imaging systems, signal and image processing, 2nd semester
- Master Computer Science 2012 (optional subject), advanced curriculum signal and image processing, 2nd or 3rd semester
- Master Computer Science 2012 (compulsory), specialization field robotics and automation, 2nd semester
- Master Computer Science 2012 (compulsory), specialization field bioinformatics, 2nd semester
- Master Computer Science 2012 (optional subject), advanced curriculum intelligent embedded systems, 2nd semester

Classes and lectures:

- Computer Vision (lecture, 2 SWS)
- Computer Vision (exercise, 1 SWS)

Workload:

- 55 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Introduction to human and computer vision
- Sensors, cameras, optics and projections
- Image features: edges, intrinsic dimension, Hough transform, Fourier descriptors, snakes
- Range imaging and 3-D cameras
- Motion and optical flow
- Object recognition
- Example applications

Qualification-goals/Competencies:

- Students can understand the basics of computer vision.
- They can explain and perform camera choice and calibration.
- They can explain and apply the basic methods for feature extraction, motion estimation, and object recognition.
- They can indicate appropriate methods for different kinds of computer-vision applications.

Grading through:

- Oral examination

Responsible for this module:

- Prof. Dr.-Ing. Erhardt Barth

Teacher:

- Institute for Neuro- and Bioinformatics

- Prof. Dr.-Ing. Erhardt Barth

Literature:

- Richard Szeliski: Computer Vision: Algorithms and Applications - Springer, Boston, 2011
- David Forsyth and Jean Ponce: Computer Vision: A Modern Approach - Prentice Hall, 2003

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Regular participation in the exercises as specified at the beginning of the semester
- Successful completion of exercise slips as specified at the beginning of the semester

Module exam(s):
- CS4250-L1: Computer Vision, oral exam, 100% of module grade

Is identical to module XM2330 of the University of Applied Sciences Lübeck

CS4405-KP04, CS4405 - Neuroinformatics (NeuroInf)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	4

Course of study, specific field and term:

- Master CLS 2023 (compulsory), computer science, 2nd semester
- Master Auditory Technology 2022 (optional subject), Auditory Technology, 2nd semester
- Master Auditory Technology 2017 (optional subject), Auditory Technology, 2nd semester
- Master MES 2020 (optional subject), computer science / electrical engineering, Arbitrary semester
- Master CLS 2016 (compulsory), computer science, 2nd semester
- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st or 2nd semester
- Master MES 2014 (optional subject), computer science / electrical engineering, Arbitrary semester
- Master MES 2011 (optional subject), mathematics, 2nd semester
- Bachelor MES 2011 (optional subject), optional subject medical engineering science, 6th semester
- Master Computer Science 2012 (optional subject), advanced curriculum organic computing, 2nd or 3rd semester
- Master MES 2011 (advanced curriculum), imaging systems, signal and image processing, 2nd semester
- Master Computer Science 2012 (optional subject), advanced curriculum intelligent embedded systems, 2nd or 3rd semester
- Master Computer Science 2012 (compulsory), specialization field robotics and automation, 2nd semester
- Master Computer Science 2012 (compulsory), specialization field bioinformatics, 2nd semester
- Master CLS 2010 (compulsory), computer science, 2nd semester

Classes and lectures:

- Neuroinformatics (lecture, 2 SWS)
- Neuroinformatics (exercise, 1 SWS)

Workload:

- 55 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- The human brain and abstract neuron models
- Learning with a single neuron:* Perceptrons* Max-Margin Classification* LDA and logistic Regression
- Network architectures:* Hopfield-Networks* Multilayer-Perceptrons* Deep Learning
- Unsupervised Learning:* k-means, Neural Gas and SOMs* PCA & ICA* Sparse Coding

Qualification-goals/Competencies:

- The students are able to understand the principle function of a single neuron and the brain as a whole.
- They know abstract neuronal models and they are able to name practical applications for the different variants.
- They are able to derive a learning rule from a given error function.
- They are able to apply (and implement) the proposed learning rules and approaches to solve unknown practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr. rer. nat. Thomas Martinetz

Teacher:

- Institute for Neuro- and Bioinformatics

- Prof. Dr. rer. nat. Thomas Martinetz
- Prof. Dr. rer. nat. Amir Madany Mamlouk

Literature:

- S. Haykin: Neural Networks - London: Prentice Hall, 1999
- J. Hertz, A. Krogh, R. Palmer: Introduction to the Theory of Neural Computation - Addison Wesley, 1991
- T. Kohonen: Self-Organizing Maps - Berlin: Springer, 1995
- H. Ritter, T. Martinetz, K. Schulten: Neuronale Netze: Eine Einführung in die Neuroinformatik selbstorganisierender Netzwerke - Bonn: Addison Wesley, 1991

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Successful completion of exercises as specified at the beginning of the semester

Module Exam(s):
- CS4405-L1: Neuroinformatics, written exam, 90 min, 100% of module grade

According to the old version of the MES Bachelor Examination Regulations (until WS 2011/2012), an elective subject is scheduled for the 4th semester instead of the 6th semester.

CS4440-KP04, CS4440 - Molecular Bioinformatics (MolBioInfo)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Master CLS 2023 (optional subject), computer science, 3rd semester
- Master Molecular Life Science 2023 (optional subject), mathematics / computer science, 1st semester
- Master CLS 2016 (optional subject), computer science, 3rd semester
- Master MES 2011 (advanced curriculum), biophysics and biomedical optics, 2nd semester
- Master CLS 2010 (optional subject), computer science, 1st or 3rd semester
- Master Computer Science 2012 (compulsory), specialization field bioinformatics, 1st semester

Classes and lectures:

- Molecular Bioinformatics (lecture, 2 SWS)
- Molecular Bioinformatics (exercise, 1 SWS)

Workload:

- 55 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Methods for fast genome comparison
- Analysis of data describing gene expression profiles and sequence variation
- Advanced usage of biological databases (for sequences, motifs, structures, gene regulation and interactions)

Qualification-goals/Competencies:

- The students can apply indexing based software to Next Generation sequence data.
- They can use and design databases for molecularbiological research.
- They are able to detect statistically significant changes in Microarray data.

Grading through:

- written exam

Requires:

- Introduction to Bioinformatics (CS1400-KP04, CS1400)

Responsible for this module:

- Prof. Dr. rer. nat. Thomas Martinetz

Teacher:

- Institute for Neuro- and Bioinformatics

- Prof. Dr. Bernhard Haubold
- Prof. Dr. rer. nat. Thomas Martinetz
- MitarbeiterInnen des Instituts
- Prof. Lars Bertram

Literature:

- M. S. Waterman: Introduction to Computational Biology - London: Chapman and Hall 1995
- B. Haubold, T. Wiehe: Introduction to Computational Biology - Birkhäuser 2007
- R. Durbin, S. Eddy, A. Krogh, G. Mitchison: Biological sequence analysis. Probabilistic models - Cambridge, MA: Cambridge University Press
- J. Setubal, J. Meidanis: Introduction to computational molecular - Pacific Grove: PWS Publishing Company
- D. M. Mount: Bioinformatics - Sequence and Genome - New York: Cold Spring Harbor Press

Language:

- English, except in case of only German-speaking participants

Notes:

Prerequisites for the module:
- None

Prerequisites for admission to the written examination:
- Successful completion of exercises as specified at the beginning of the semester

Module exam(s):
- CS4440-L1: Molecular Bioinformatics, written exam, 90 min, 100 % of module grade

CS5450-KP04, CS5450 - Machine Learning (MaschLern)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Master CLS 2023 (optional subject), computer science, 3rd semester
- Master Auditory Technology 2022 (optional subject), computer science, 1st semester
- Master MES 2020 (optional subject), computer science / electrical engineering, Arbitrary semester
- Master Media Informatics 2020 (optional subject), computer science, Arbitrary semester
- Master Medical Informatics 2019 (optional subject), Medical Data Science / Artificial Intelligence, 1st or 2nd semester
- Master Auditory Technology 2017 (optional subject), computer science, 1st semester
- Master CLS 2016 (optional subject), computer science, 3rd semester
- Master MES 2014 (optional subject), computer science / electrical engineering, Arbitrary semester
- Master MES 2011 (optional subject), mathematics, 1st or 2nd semester
- Master MES 2011 (advanced curriculum), imaging systems, signal and image processing, 1st or 2nd semester
- Master Medical Informatics 2014 (optional subject), computer science, 1st or 2nd semester
- Master CLS 2010 (optional suject), computer science, Arbitrary semester
- Master Computer Science 2012 (optional subject), specialization field robotics and automation, 3rd semester
- Master Computer Science 2012 (optional subject), specialization field bioinformatics, 3rd semester

Classes and lectures:

- Machine Learning (lecture, 2 SWS)
- Machine Learning (exercise, 1 SWS)

Workload:

- 55 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Representation learning, including manifold learning
- Statistical learning theory
- VC dimension and support vector machines
- Boosting
- Deep learning
- Limits of induction and importance of data ponderation

Qualification-goals/Competencies:

- Students can understand and explain various machine-learning problems.
- They can explain and apply different machine learning methods and algorithms.
- They can chose and then evaluate an appropriate method for a particular learning problem.
- They can understand and explain the limits of automatic data analysis.

Grading through:

- Oral examination

Responsible for this module:

- Prof. Dr.-Ing. Erhardt Barth

Teacher:

- Institute for Neuro- and Bioinformatics

- Prof. Dr.-Ing. Erhardt Barth
- Prof. Dr. rer. nat. Thomas Martinetz

Literature:

- Chris Bishop: Pattern Recognition and Machine Learning - Springer ISBN 0-387-31073-8
- Vladimir Vapnik: Statistical Learning Theory - Wiley-Interscience, ISBN 0471030031

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- None

Module exam(s):
- CS5450-L1: Machine Learning, oral examination, 100% of module grade

ME2451-KP04, ME2451 - Control Systems (RegTech)

Duration:	Turnus of offer:	Credit points:
1 Semester	every summer semester	4

Course of study, specific field and term:

- Master CLS 2023 (optional subject), computer science, 2nd or 4th semester
- Master MES 2020 (optional subject), computer science / electrical engineering, Arbitrary semester
- Master CLS 2016 (optional subject), computer science, 2nd or 4th semester
- Master MES 2014 (optional subject), computer science / electrical engineering, 2nd or 4th semester
- Master MES 2011 (optional subject), advanced curriculum, 2nd or 4th semester

Classes and lectures:

- Control Systems (lecture, 2 SWS)
- Control Systems (exercise, 1 SWS)

Workload:

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 10 Hours exam preparation

Contents of teaching:

- Modeling of dynamic systems
- Dynamic behavior of systems
- Feedback concepts
- Controller design in time domain
- System representation in frequency domain
- Stability
- Controller design in frequency domain

Qualification-goals/Competencies:

- Students can model physical systems mathematically as well as describe and analyze their dynamic behavior.
- Students know the fundamental tools and can formulate requirements with respect to systems in the time and frequency domain. Students are able to design control loops using time and frequency domain-based tools.
- Students are able to analyze stability of feedback systems and can evaluate the resulting dynamic properties with respect to control performance and robustness.

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr. Philipp Rostalski

Teacher:

- Institute for Electrical Engineering in Medicine

- Prof. Dr. Philipp Rostalski

Literature:

- G.F. Franklin, J.D. Powell, A. Emami-Naeini: Feedback Control of Dynamic Systems - Pearson Verlag - 2014
- J. Lunze: Regelungstechnik 1 - Springer Verlag 2012
- J. Lunze: Regelungstechnik 2 - Springer Verlag 2012

Language:

- German and English skills required

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- None

Module exam(s):
- ME2451-L1: Control Systems, oral exam, 100% of module grade

LS4020 C - Module part LS4020C: Single Molecule Methods (Einzelstru)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	3

Course of study, specific field and term:

- Master CLS 2023 (Module part of a compulsory module), computational life science / life sciences, 3rd semester
- Master MLS 2018 (Module part of a compulsory module), structure biology, 1st semester
- Master Infection Biology 2018 (Module part of a compulsory module), Interdisciplinary modules, 1st semester
- Master Biophysics 2019 (Module part of a compulsory module), biophysics, 1st semester
- Master CLS 2016 (Module part of a compulsory module), MML with specialization in Life Science, 3rd semester
- Master MLS 2016 (Module part of a compulsory module), structure biology, 1st semester
- Master Infection Biology 2012 (Module part of a compulsory module), Interdisciplinary modules, 1st semester
- Master CLS 2010 (module part), computational life science / life sciences, 3rd semester
- Master MLS 2009 (Module part of a compulsory module), structure biology, 1st semester

Classes and lectures:

- Single Molecule Methods (lecture, 2 SWS)

Workload:

- 60 Hours private studies
- 30 Hours in-classroom work

Contents of teaching:

- Physical basics of fluorescence
- Photo physics
- Microscopy techniques
- Protein labeling
- Fluorescence resonance energy transfer
- Single molecule enzymology
- Single molecule protein folding
- Physical basics of optical tweezers
- Protein folding with optical tweezers

Qualification-goals/Competencies:

- Understanding of the physical basics of single molecule methods
- Understanding of the benefits of single molecule methods
- Understanding of the limits of single molecule methods

Grading through:

- see Notes

Responsible for this module:

- Siehe Hauptmodul

Teacher:

- Institute of Physics

- Prof. Dr. rer. nat. Christian Hübner

Literature:

- Lakowicz, Joseph R: Principles of Fluorescence Spectroscopy - ISBN 978-0-387-46312-4
- Markus Sauer, Johan Hofkens, Jörg Enderlein: Handbook of Fluorescence Spectroscopy and Imaging: From Ensemble to Single Molecules - ISBN: 978-3-527-31669-4

Language:

- offered only in English

Notes:

Is module part of:
- LS4021-KP06 (former LS4020-IB) -> Prof. Hübner
- LS4020-KP06 (former LS4020-MLS) and LS4020-KP12 -> Prof. Peters
- LS4027-KP06 start 2023

This module part is identical to LS4020 C-MIW without seminar.

MA5009-KP03 - Master's Seminar mathematics (MSMathe03)

Duration:	Turnus of offer:	Credit points:
1 Semester	each semester	3 (Typ B)

Course of study, specific field and term:

- Master CLS 2023 (compulsory), Interdisciplinary modules, 3rd semester

Classes and lectures:

- Advanced Master's Seminar mathematics (seminar, 2 SWS)

Workload:

- 30 Hours private studies
- 30 Hours in-classroom work
- 15 Hours written report
- 15 Hours oral presentation (including preparation)

Contents of teaching:

- The students study a scientific topic of their specialization.
- They present the topic in written form.
- They are able to give a scientific talk on the topic.

Qualification-goals/Competencies:

- The students have gained experience of familiarizing themselves with the details of a given scientific topic.
- They are able to present the result of their studies in comprehensible written form.
- They are able to supply a coherent overview of a complex scientific area in a comprehensive oral presentation.
- They have gained experience in holding scientific discussions.
- They understand scientific presentations and know how to critically question them in open discussions.

Grading through:

- term paper

Responsible for this module:

- Prof. Dr. rer. nat. Jürgen Prestin

Teacher:

- Institute of Medical Biometry and Statistics
- Institute of Mathematics and Image Computing
- Institute for Mathematics

- Prof. Dr. rer. nat. Jürgen Prestin
- Prof. Dr. rer. nat. Jan Modersitzki
- Prof. Dr. rer. nat. Andreas Rößler
- Nachfolge von Prof. Dr. rer. nat. Karsten Keller
- Prof. Dr. rer. nat. Jan Lellmann
- Prof. Dr. rer. biol. hum. Inke König
- Prof. Dr. rer. nat. Silke Szymczak

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Preparation and presentation of a scientific talk

Module exam(s):
- MA5009-L1: Master's Seminar Mathematics, ungraded seminar, 0 % of module grade, must be passed

MA5990-KP30, MA5990 - Master's thesis in Computational Life Science (MaArbMML)

Duration:	Turnus of offer:	Credit points:
1 Semester	each semester	30

Course of study, specific field and term:

- Master CLS 2023 (compulsory), Interdisciplinary modules, 4th semester
- Master CLS 2016 (compulsory), Interdisciplinary modules, 4th semester
- Master CLS 2010 (compulsory), mathematics, 4th semester

Classes and lectures:

- Master's thesis (supervised self studies, 1 SWS)
- Colloquium (presentation (incl. preparation), 1 SWS)

Workload:

- 870 Hours private studies
- 30 Hours oral presentation (including preparation)

Contents of teaching:

- Investigating a given problem in mathematics or its application areas and developing a good solution
- Writing a Master's Thesis
- Colloquium to present the results including a discussion with the referees

Qualification-goals/Competencies:

- The students are able to solve a complex scientific problem with state-of-the-art methods.
- Experience in writing a scientific thesis within a given time period
- Becoming an expert in a special subfield of mathematics
- Experience in working with scientific literature
- Presentation skills

Grading through:

- Written report
- colloquium

Responsible for this module:

- Prof. Dr. rer. nat. Jürgen Prestin

Teacher:

- Institutes of the Department of Computer Science/ Engineering

- Alle prüfungsberechtigten Dozentinnen/Dozenten des Studienganges

Language:

- thesis can be written in German or English

Notes:

Admission requirements for taking the module:
- The basic prerequisite for starting the master's thesis is the successful completion of 75 credits.

Admission requirements for participation in module examination(s):
- Submission of a master's thesis

Module examination(s):
- MA5990-L1: Master's thesis in Computational Life Science, master's thesis and colloquium, 100% of module grade

LS2300-KP08, LS2301 - Biophysical Chemistry (BPCKP08)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	8

Course of study, specific field and term:

- Master CLS 2023 (compulsory), MML with specialization in Life Science, 2nd semester
- Bachelor Biophysics 2024 (compulsory), biophysics, 4th semester
- Bachelor Molecular Life Science 2024 (compulsory), Chemistry, 4th semester
- Bachelor MLS 2018 (compulsory), Chemistry, 4th semester
- Bachelor MLS 2016 (compulsory), Chemistry, 4th semester
- Master CLS 2016 (compulsory), MML with specialization in Life Science, 2nd semester
- Bachelor Biophysics 2016 (compulsory), biophysics, 4th semester
- Master CLS 2010 (optional subject), computational life science / life sciences, 2nd semester
- Bachelor MLS 2009 (compulsory), life sciences, 4th semester

Classes and lectures:

- Biophysical Chemistry (lecture, 3 SWS)
- Biophysical Chemistry (exercise, 1 SWS)
- Biophysical Chemistry (practical course, 3 SWS)

Workload:

- 160 Hours private studies
- 80 Hours in-classroom work

Contents of teaching:

- Lecture topics:
- What is Biophysical Chemistry?
- Basics of NMR spectroscopy
- Basics of mass spectrometry
- Theoretical calculation of molecules - Quantum mechanics or molecular mechanics?
- Basics of chemical thermodynamics
- Thermodynamics of ligand binding
- Basics of chemical kinetics
- Basics of enzyme kinetics
- Molecular Mechanics
- Practical works:
- NMR, Molecular Modeling, experiments with a focus on thermodynamics and kinetics

Qualification-goals/Competencies:

- Acquire basic knowledge on spectroscopic techniques to analyze (bio)molecules. Focus is on NMR and mass spectrometry techniques
- Insight into properties (e.g. structure, dynamics, spectroscopic properties) of molecules employing theoretical models. Acquisition of basic knowledge to compute molecules
- Application of laws of thermodynamics to describe chemical reactions and biological processes with a focus on binding and recognition reactions in biological systems
- Acquire basic knowledge to analyze time courses of chemical reactions and biological processes
- Acquisition of skills to work independently and self-determined in the laboratory with regard to the roles of GSP of the University of Lübeck and of the DFG-guidelines.
-

Grading through:

- written exam

Requires:

- Organic Chemistry (LS1600-KP10, LS1600-MLS)

Responsible for this module:

- Prof. Dr. rer. nat. Ulrich Günther

Teacher:

- Institute of Chemistry and Metabolomics

- Prof. Dr. rer. nat. Ulrich Günther

- PD Dr. phil. nat. Thomas Weimar

Literature:

- Peter Atkins and Julio de Paula: Physical Chemistry for the Life Sciences - Oxford, University Press, Freeman and Company, 2006, ISBN 0-1992-8095-9
- Thomas Engel und Philip Reid: Physikalische Chemie - Pearson Studium, 2006, ISBN 13: 978-3-8273-7200-0
- van Holde, Johnson & HoPrentice Hall: Principles of Physical Biochemistry - New Jersey, 1998, 2006, ISBN 0-13-720459-0
- Atkins: Physical Chemistry - Oxford University Press, Oxford Mel-bourne Tokyo, 1998, ISBN 0-19-850101-3 Paperback, Deutsche Ausgabe (dritte Auflage) bei Wiley VCH, 2002: ISBN 3-527-30236-0 Wiley-VCH, Weinheim
- Fersht, W. H.: Structure and Mechanism in Protein Science - New York, 1999, ISBN 0-7167-3268-8
- Cantor & Schimmel: Biophysical Chemistry, Parts I-III - Freeman and Company, New York, 1980, ISBN 0-71671188-5 Paperback
- H. Friebolin: Ein- und zweidimensionale NMR-Spektroskopie - Wiley-VCH
- James Keeler and Peter Wothers: Chemical Structure and Reactivity: An integrated approach - Oxford University Press, 2008; second ed. 2013

Language:

- offered only in German

Notes:

Prerequisites for the modul:
- None

Prerequisites for admission to the written examination:
- Successful completion of the excercises as specified at the beginning of the semester

Modul exam(s):
- LS2300-L1: Biophysical Chemistry, written exam, 90 min, 100 % of module grade
- LS2300-L2: Practical course Biophysical Chemistry, ungraded practical course, 0 % of module grade, has to be passed

MML: Optional course in the 2nd semester master program with specialisation in Life Science

Biophysics: some specific practicals

The practical course takes place in September as compact course. Prerequisite LS1600 and LS2600

The module is better understandable if the modules Physics 1 or 2 have been attended before.

(Share of Institute of Physics in practical course is 25%.)

LS2600-KP06, LS2601 - Biological Chemistry (BiolChem06)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	6

Course of study, specific field and term:

- Master CLS 2023 (compulsory), MML with specialization in Life Science, 1st semester
- Bachelor Molecular Life Science 2024 (compulsory), Chemistry, 3rd semester
- Bachelor MLS 2018 (compulsory), Chemistry, 3rd semester
- Bachelor MLS 2016 (compulsory), life sciences, 3rd semester
- Master CLS 2016 (compulsory), MML with specialization in Life Science, 1st semester
- Bachelor MLS 2009 (compulsory), life sciences, 3rd semester

Classes and lectures:

- Biological Chemistry (lecture, 4 SWS)

Workload:

- 120 Hours private studies
- 60 Hours in-classroom work

Contents of teaching:

- Lecture topics:
- What is Biological Chemistry?
- The nature of chemical bonds
- Chemical reactions to modify proteins
- Synthesis of peptides
- Chemical analytics - MS and NMR
- Metabolic labeling
- Chemical reactions to follow the fate of molecules in cells and whole organisms

Qualification-goals/Competencies:

- The nature of chemical bonds - an in depth treatment based on quantum mechanical principles
- How to use synthetic organic chemistry to solve biological questions
- In-depth treatment of reaction mechanisms of chemical reactions important in biological systems
- Analytical techniques to identify and characterize compounds
-
-
-

Grading through:

- written exam

Responsible for this module:

- Prof. Dr. rer. nat. Ulrich Günther

Teacher:

- Institute of Chemistry and Metabolomics

- Prof. Dr. rer. nat. Ulrich Günther
- Dr. Alvaro Mallagaray
- Prof. Dr. rer. nat. Karsten Seeger
- PD Dr. phil. nat. Thomas Weimar

Literature:

- Paula Y. Bruice: Organic Chemistry - Pearson Verlag
- James Keeler and Peter Wothers: Chemical Structure and Reactivity: An integrated approach - Oxford University Press, 2008; second ed. 2013ISBN: 978-0-19-928930-1

Language:

- offered only in German

Notes:

Prerequisites for the module:
- None

Prerequisites for admission to the written examination:
- None

Modul exam(s):
- LS2600-L1: Biological Chemistry, written exam, 90 min, 100 % of module grade

LS4020 A - Module part LS4020A: Crystallography (StrAnaKris)

Duration:	Turnus of offer:	Credit points:	Max. group size:
1 Semester	each winter semester	3	60

Course of study, specific field and term:

- Master CLS 2023 (Module part of a compulsory module), MML with specialization in Life Science, 3rd semester
- Master Infection Biology 2018 (Module part of a compulsory module), Infection Biology, 1st semester
- Master Infection Biology 2012 (Module part of a compulsory module), Infection Biology, 1st semester
- Master Biophysics 2019 (Module part of a compulsory module), biophysics, 1st semester
- Master CLS 2016 (Module part of a compulsory module), MML with specialization in Life Science, 3rd semester
- Master MLS 2018 (Module part of a compulsory module), life sciences, 1st semester
- Master MLS 2016 (Module part of a compulsory module), life sciences, 1st semester

Classes and lectures:

- LS4021-V: Crystallography (lecture, 2 SWS)

Workload:

- 60 Hours private studies
- 30 Hours in-classroom work

Contents of teaching:

- Crystal growth, precipitant and phase diagram, crystal morphology, symmetry and space groups, crystallogenesis
- X-rays, X-ray sources, X-ray diffraction, Bragg's law, reciprocal lattice and Ewald-sphere construction
- X-ray diffraction by electrons, Fourier analysis and synthesis
- Protein structure determination by X-ray diffraction, crystallographic phase problem, Patterson map, molecular replacement (MR), multiple isomorphous replacement (MIR), multi-wavelength anomalous diffraction (MAD)
- Crystallography and the drug discovery process: studying protein-ligand interactions
- Practical exercises employing an X-ray generator (collection of a diffraction image) and the computer (MR; calculation and interpretation of electron density maps)
- Site visit at the Synchrotron DESY (Hamburg)

Qualification-goals/Competencies:

- They have a general scientific competence in macromolecular X-ray diffraction analysis
- They have the methodological competence to grow protein crystals by hanging or sitting drops
- They have the methodological competence to correctly interpret (salt or protein) the diffraction image of a crystal using the Ewald Sphere construction
- They have the methodological competence to tackle the phase problem either by MR, MIR or MAD
- They can calculate and interprete electron density maps
- They have the methodological competence, to apply structure- or fragment-based techniques for lead compound identification
- They have the communication competency to convey the principles of X-ray diffraction theory

Grading through:

- see Notes

Responsible for this module:

- Siehe Hauptmodul

Teacher:

- Institute of Biochemistry

- Dr. math. et dis. nat. Jeroen Mesters

Literature:

- Jan Drenth: Principles of Protein X-ray Crystallography - Science+Business Media, LLC, New York

Language:

- offered only in English

Notes:

Is part of Module:
- LS4021-KP06 (former LS4020-IB) -> Prof. Hübner
- LS4020-KP06 (former LS4020-MLS) and LS4020-KP12 -> Prof. Peters
- LS4026-KP06 start in 2023

4 exercises, 2 hours each, are offered in addition to the lecture. Dates are given at the start of the semester.

It is a compulsory module part for the Master MLS with a focus on structural biology.

LS4020 B - Module part LS4020B: NMR Spectroscopy (StrAnaNMR)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	3

Course of study, specific field and term:

- Master CLS 2023 (Module part of a compulsory module), MML with specialization in Life Science, 3rd semester
- Master MLS 2018 (Module part of a compulsory module), structure biology, 1st semester
- Master Infection Biology 2018 (Module part of a compulsory module), Interdisciplinary modules, 1st semester
- Master Biophysics 2019 (Module part of a compulsory module), biophysics, 1st semester
- Master CLS 2016 (Module part of a compulsory module), MML with specialization in Life Science, 3rd semester
- Master MLS 2016 (Module part of a compulsory module), structure biology, 1st semester
- Master Infection Biology 2012 (Module part of a compulsory module), Interdisciplinary modules, 1st semester
- Master CLS 2010 (module part), computational life science / life sciences, 3rd semester
- Master MLS 2009 (Module part of a compulsory module), structure biology, 1st semester

Classes and lectures:

- NMR-Spectroscopy (lecture, 2 SWS)

Workload:

- 60 Hours private studies
- 30 Hours in-classroom work

Contents of teaching:

- Lecture topics:
- Assignment of NMR spectra
- Description of the NOESY experiment using the vector model
- Chemical Exchange and Transfer-NOEs
- Multidimensional NMR spectroscopy
- Assignment strategy for peptides
- Introduction into the product operator formalism (POF)
- Description of the COSY and of the HSQC experiment using POF
- NMR experiments for the assignment of proteins
- NMR structural analysis of proteins
- Experiments to probe the motions of protein

Qualification-goals/Competencies:

- Students are able to assign and analyze complex NMR spectra
- Understanding of NMR experiments based on the product operator formalism
- Students are able to analyze structure and dynamics of proteins through NMR experiments

Grading through:

- see Notes

Responsible for this module:

- Prof. Dr. rer. nat. Ulrich Günther

Teacher:

- Institute of Chemistry and Metabolomics

- Prof. Dr. rer. nat. Ulrich Günther
- Dr. Alvaro Mallagaray

Literature:

- James Keeler: Understanding NMR Spectroscopy - Wiley
- :
- Malcolm H. Levitt: Spin Dynamics - Basics of Nuclear Magnetic Resonance - Wiley-VCH
- D. Neuhaus & M. P. Williamson: The Nuclear Overhauser Effect in Structural and Conformational Analysis - Wiley-VCH
- Timothy Claridge: High-Resolution NMR Techniques in Organic Chemistry - Pergamon Press
- : Current scientific literature

Language:

- offered only in English

Notes:

This lecture is a part of modules:
- LS4021-KP06 (former LS4020-IB) -> Prof. Hübner
- LS4020-KP06 (former LS4020-MLS) and LS4020-KP12 -> Prof. Peters
- LS4027-KP06 start 2023

Exercises are integrated into the lectures.
It is a compulsory module part for the Master MLS with a focus on structural biology.

LS4020 D - Module part LS4020D: Microscopy: Techniques and Applications (StrAnaMikr)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	3

Course of study, specific field and term:

- Master CLS 2023 (Module part of a compulsory module), MML with specialization in Life Science, 3rd semester
- Master MLS 2018 (Module part of a compulsory module), structure biology, 1st semester
- Master Infection Biology 2018 (Module part of a compulsory module), Interdisciplinary modules, 1st semester
- Master Biophysics 2019 (Module part of a compulsory module), biophysics, 1st semester
- Master CLS 2016 (Module part of a compulsory module), MML with specialization in Life Science, 3rd semester
- Master MLS 2016 (Module part of a compulsory module), structure biology, 1st semester
- Master Infection Biology 2012 (Module part of a compulsory module), Interdisciplinary modules, 1st semester
- Master CLS 2010 (module part), computational life science / life sciences, 3rd semester

Classes and lectures:

- LS4027-V Optical Methods (lecture, 2 SWS)

Workload:

- 60 Hours private studies
- 30 Hours in-classroom work

Contents of teaching:

- Basic principles of optics
- Light sources and detectors
- Classical light microscopy
- Photophysics, fluorescence microscopy
- Confocal microscopy
- Nonlinear microscopy
- Fluorescent dyes; GFP and genetically encoded fluorescent markers; live cell/intravital imaging: important experimental parameters
- Protein-protein interactions in living cells: FRET, FLIM; biosensors
- Photoactivatable/switchable fluorescent proteins; fluorescent timers
- Optogenetics: Cell manipulation by light
- Super-resolution 3D fluorescence microscopy: STED, PALM, STORM
- Optical tweezers as instrument for nanomanipulation
- Visualization and quantitative evaluation; data format and data storage media
- In vivo imaging in tissues and living animals
- Bioluminescence and optoacoustic imaging
- Flow cytometry & fluorescence activated cell sorting
- High-content screening; optical sensor technology
- Technologies under development

Qualification-goals/Competencies:

- Students acquire professional competence in basic principles and concepts of optics.
- Students know the basics of light and fluorescence microscopy.
- They know and understand the most important methods for marking and microscopic visualization of proteins and sub-cellular structures.
- Students know the possible applications of live cell microscopy, intravital imaging, and quantitative fluorescence techniques in biological questions.
- They know basic techniques of 3-dimensional optical imaging of tissues and animals.
- Student are familiar with current research topics in the field of optical methods in the life sciences and are able to evaluate them in terms of their application maturity and potential.
- Students can classify optical methods according to their complexity and outline possible applications.
- The students have the social and communication skills to discuss given questions within group work for lecture preparation and lecture follow-up.

Grading through:

- written exam

Responsible for this module:

- Siehe Hauptmodul

Teacher:

- Institute of Biomedical Optics

- Prof. Dr. rer. nat. Gereon Hüttmann
- Prof. Dr. rer. nat. Sebastian Karpf
- Dr. rer. nat. Norbert Linz
- Prof. Dr. rer. nat. Robert Huber

Literature:

- J. B. Pawley, ed.: Handbook of Biological Confocal Microscopy, Springer
- V. V. Tučin: Handbook of optical biomedical diagnostics, SPIE Press
- L. V. Wang, and H.-i. Wu: Biomedical optics principles and imaging, Wiley
- :
- :
- :

Language:

- offered only in English

Notes:

Is module part of:
- LS4021-KP06 (former LS4020-IB) -> Prof. Hübner
- LS4020-KP06 (former LS4020-MLS) and LS4020-KP12 -> Prof. Peters
- LS4026-KP06 start 2023

(Share of Institute of Biomedical Optics to this lecture is 100%)

LS4020-KP08 - Advanced Topics in Life Science (VertLSKP08)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	8

Course of study, specific field and term:

- Master CLS 2023 (compulsory), MML with specialization in Life Science, 3rd semester
- Master CLS 2016 (compulsory), MML with specialization in Life Science, 3rd semester

Classes and lectures:

- See module part LS4020 A: Crystallography (lecture, 2 SWS)
- See module part LS4020 B: NMR-Spectroscopy (lecture, 2 SWS)
- See module part LS4020 C: Single Molecule Methods (lecture, 2 SWS)
- See module part LS4020 D: Microscopy: techniques and applications (lecture, 2 SWS)

Workload:

- 180 Hours private studies
- 60 Hours in-classroom work

Contents of teaching:

- See module parts LS4020 A to D

Qualification-goals/Competencies:

- See module parts LS4020 A to D

Grading through:

- written exam

Responsible for this module:

- Prof. Dr. rer. nat. Thomas Peters

Teacher:

- Institute of Physics
- Institute for Biology
- Institute of Biochemistry
- Institute of Chemistry and Metabolomics

- Prof. Dr. rer. nat. Thomas Peters
- Prof. Dr. rer. nat. Rolf Hilgenfeld
- Dr. math. et dis. nat. Jeroen Mesters
- Prof. Dr. rer. nat. Karsten Seeger
- Prof. Dr. rer. nat. Christian Hübner
- Prof. Dr. rer nat. Rainer Duden

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Module exam(s):
- LS4020-L1: Advanced Topics in Life Science, 2 written exams (90 min each) or oral exams (30 min each), 2 x 50 % of module grade

The 2 credit points higher workload compared to the two submodules results from the required self-study for CLS students.

Two of the four above-mentioned courses must be selected. Both selected module parts count for 50% of the grade.
There is a separate written exam for each module part. The two chosen module parts must be written on one date, i.e. on the first date at the end of the semester or on the second of the offered dates at the end of the vacations. The date may be spread over two days, as the examinations for different module parts may be offered on different days.
If only the partial exam for one module part is written, the exam is considered failed and will be counted as a failed attempt.

CS4336-KP08 - Artificial intelligence, image analysis and computer graphics (MoKiBiCo)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	8

Course of study, specific field and term:

- Master CLS 2023 (compulsory), MML with specialization in Image Processing, 2nd semester

Classes and lectures:

- Model and AI-based image processing in medicine (lecture, 2 SWS)
- Model and AI-based image processing in medicine (exercise, 1 SWS)
- computer graphics (lecture, 2 SWS)
- computer graphics (exercise, 1 SWS)

Workload:

- 110 Hours private studies and exercises
- 90 Hours in-classroom work
- 40 Hours exam preparation

Contents of teaching:

- Methods and algorithms for the analysis and visualization of medical images including current research activities in the field of medical image computing. The following methods and algorithms are explained:
- Fundamentals of neural networks in medical image processing
- Convolutional Neural Networks and Deep Learning in Medical Image Processing
- U-Nets for image segmentation
- Autoencoder and Generative Adversarial Networks in Medical Image Processing
- Data augmentation techniques
- Random Decision Forests for the segmentation of medical image data
- Statistical shape models: generation and application for image segmentation
- ROI-based segmentation and cluster analysis for the segmentation of multispectral image data
- Live wire segmentation
- Segmentation with active contour models and deformable models
- Non-linear image registration
- Atlas-based segmentation and multi-atlas segmentation using non-linear registration
- 3D Visualization techniques in medicine
- Geometric transformations in 2D and 3D
- Homogeneous coordinates
- Transformations between Cartesian coordinate systems
- Planar and perspective projections
- Polygonal models
- Illumination models and shading methods
- Texture Mapping
- Culling and clipping
- Hidden line and surface removal
- Raster graphics algorithms
- Ray tracing
- Shadows, reflections and transparency
- Basics of graphics programming with OpenGL and GLSL

Qualification-goals/Competencies:

- Students can classify and explain advanced methods for medical image analysis on the basis of their characteristics. They can select these methods based on a given specific application.
- They are able to explain advanced methods of cluster analysis and classification especially with Convolutional Neural Networks and Random Decision Forests and to characterize them by their properties.
- They can explain the conception of neural network architectures of U-Nets, GANs or auto-encoders in detail. They can explain in detail the conception of neural network architectures of U-Nets, GANs or auto-encoders.
- They know prerequisites, problems and limits as well as augmentation techniques for the use of neural networks in medical image processing.
- They know different approaches to model-based segmentation, can describe the different model assumptions made here and are able to explain the optimization strategies and algorithms used here.
- They are able to assess the properties of various non-linear image registration methods and to select and parametrize similarity measures and regularization terms for a specific registration problem.

- They are familiar with methods of multi-atlas segmentation and can explain and exemplify the properties of different label fusion approaches.
- They can differentiate between different medical visualization techniques, classify them according to their specific advantages and disadvantages, and select and apply them in a meaningful way depending on a specific application problem.
- Students know the basic concepts, algorithms and methods in computer graphics
- They are able to implement principle algorithms
- They are able to explain the learned techniques and to assess their possibilities and limitations

Grading through:

- written exam

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)
- Medical Image Computing (CS3310-KP04)

Responsible for this module:

- Prof. Dr. rer. nat. habil. Heinz Handels

Teacher:

- Institute of Medical Informatics

- Prof. Dr. rer. nat. habil. Heinz Handels
- Dr. rer. nat. Jan Ehrhardt

Literature:

- H. Handels: Medizinische Bildverarbeitung - 2. Auflage, Vieweg u. Teubner 2009
- T. Lehmann: Handbuch der Medizinischen Informatik - München: Hanser 2005
- M. Sonka, V. Hlavac, R. Boyle: Image Processing, Analysis and Machine - Elsevier, 2007
- B. Preim, C. Botha: Visual Computing for Medicine - 2nd Edition, Elsevier, 2013
- Foley et. al: Grundlagen der Computergrafik - Addison-Wesley, 1994

Language:

- German and English skills required

Notes:

Admission requirements for taking the module:
- None (the competences of the modules mentioned under "requires" are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of exercise assignments and programming projects as specified at the beginning of the semester

Module Exam(s):
- CS4332-L1: Model- and AI-based Image Processing in Medicine, written exam, 90 min, 50% of module grade
- CS3205-L1: Computer Graphics, written exam, 90 min, 50% of module grade

MA5038-KP08 - Advanced Topics in Image Processing (VertBVKP08)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	8

Course of study, specific field and term:

- Master CLS 2023 (compulsory), MML with specialization in Image Processing, 3rd semester
- Master CLS 2016 (compulsory), MML with specialization in Image Processing, 3rd semester

Classes and lectures:

- Advanced Topics in Image Processing (depends on the chosen courses, 3 SWS)

Workload:

- 240 Hours overall workload, division depending on the chosen courses

Contents of teaching:

- Familiarization with advanced methods in image and signal processing
- Familiarization with the underlying mathematical models and methods
- Practical implementation, critical evaluation and interpretation of the results
- Details as in the description of the chosen courses

Qualification-goals/Competencies:

- Students have advanced knowledge in a special or application area within the field of image and signal processing.
- The have an improved overview of the diversity of the field.
- They can see their prior knowledge in a different context and build new connections.
- Interdisciplinary qualifications:
- Students have advanced skills in modeling.
- They can translate theoretical concepts into practical solutions.
- They are experienced in implementation.
- They can think abstractly about practical problems.

Grading through:

- see Notes

Responsible for this module:

- Prof. Dr. rer. nat. Jan Modersitzki
- Prof. Dr. rer. nat. Jan Lellmann

Teacher:

- Institute of Mathematics and Image Computing

- N.N.

Language:

- German and English skills required

Notes:

The module comprises 8 ECTS credit points, which must be accounted for by combining courses within the area of advanced image and signal processing. Important: The chosen combination must be agreed upon in advance by the person responsible for the module. Please refer to the further information in the Moodle course Registration for

ME4411 T - Module part: Computed Tomography (CT)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	3

Course of study, specific field and term:

- Master CLS 2023 (Module part of a compulsory module), MML with specialization in Image Processing, 1st semester
- Master MES 2020 (Module part of a compulsory module), medical engineering science, 1st semester
- Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester
- Master CLS 2016 (Module part of a compulsory module), MML with specialization in Image Processing, 1st semester
- Master Computer Science 2014 (module part), Module part, Arbitrary semester
- Master Medical Informatics 2014 (module part), Module part, Arbitrary semester
- Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester
- Master MES 2014 (Module part of a compulsory module), medical engineering science, 1st semester

Classes and lectures:

- Computed Tomography (lecture, 2 SWS)

Workload:

- 40 Hours private studies
- 35 Hours in-classroom work
- 15 Hours exam preparation

Contents of teaching:

- Signal processing (recapitulation of fundamental principles in signal processing)
- Mathematical methods in image reconstruction and signal processing
- X-Ray (fundamental principles, quantum statistics)
- Computed Tomography * devices, * current and past technology, * signal processing, * Fourier-based 2D and 3D image reconstruction, * algebraic and statistical image reconstruction, * image artifacts, * technical and clinical applications, * dose.

Qualification-goals/Competencies:

- Students are able to create an overview of the signal chain for medical imaging.
- They are able to explain the mathematical background for the reconstruction of CT images.
- They are able to explain the basics for the creation of X-ray.
- They are able to list all generations of CT devices and explain differences and advances.
- They are able to apply the Fourier transform.
- They are able to explain the mathematical basics for the two-dimensional image reconstruction.
- They are able to create and apply an algebraic approach for the reconstruction of CT images.
- They are able to create and apply an statistical approach for the reconstruction of CT images.
- They are able to outline the differences between two dimensional and three dimensional image reconstruction.
- They are able to transfer methods from two dimensional to three dimensional image reconstruction.

Grading through:

- Oral examination

Responsible for this module:

- Siehe Hauptmodul

Teacher:

- Institute of Medical Engineering
- Prof. Dr. rer. nat. Thorsten Buzug

Literature:

- T. M. Buzug: Computed Tomography, From Photon Statistics to Modern Cone Beam CT - Springer-Verlag, Berlin/Heidelberg, 2008
- T. M. Buzug: Einführung in die Computertomographie, Mathematisch-physikalische Grundlagen der Bildrekonstruktion - Springer-Verlag, Berlin/Heidelberg, 2004

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None

Prerequisites for participation in the exam(s):
- None

Module exam(s):
- ME4411-L1: Computed Tomography, oral exam, 100 % of module grade

(Is module part of CS4512, ME4410-KP12, ME4415-KP06)

ME4412 T - Module part: Magnetic Resonance Imaging (MRT)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	3

Course of study, specific field and term:

- Master CLS 2023 (Module part of a compulsory module), MML with specialization in Image Processing, 1st semester
- Master MES 2020 (Module part of a compulsory module), medical engineering science, 1st semester
- Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester
- Master Medical Informatics 2019 (module part), Module part, Arbitrary semester
- Master CLS 2016 (Module part of a compulsory module), MML with specialization in Image Processing, 1st semester
- Master Computer Science 2014 (module part), Module part, Arbitrary semester
- Master Medical Informatics 2014 (module part), Module part, Arbitrary semester
- Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester
- Master MES 2014 (Module part of a compulsory module), medical engineering science, 1st semester

Classes and lectures:

- Magnetic Resonance Imaging (lecture, 2 SWS)

Workload:

- 40 Hours private studies
- 30 Hours in-classroom work
- 15 Hours exam preparation

Contents of teaching:

- Physical fundamentals of magnetic resonance imaging: nuclear magnetic resonance, relaxation mechanisms, principles of position encodingprinciples of spatial encoding, relaxation)
- Construction of basic imaging sequences, weighting
- Concept of k-space
- Coherence pathways
- Hardware components of a clinical MR system
- Possible sources of hazard for patients
- Influence of measurement parameters on signal-to-noise ratio
- Causes of image artefacts

Qualification-goals/Competencies:

- The students can explain the physical principles of NMR and MRI.
- They can explain the idea behind important imaging sequences, using a pulse sequence diagram.
- They can recognise the causes of important image artefacts.
- The can list advantages and disadvantages of MRT, compared to other imaging techniques.
- They can list possible sources of hazard for patients, explain their causes and point out strategies for avoiding these.

Grading through:

- Oral examination

Responsible for this module:

- Siehe Hauptmodul

Teacher:

- Institute of Medical Engineering
- Prof. Dr. rer. nat. Martin Koch

Literature:

- Liang, Z.-P., Lauterbur, P. C.: Principles of Magnetic Resonance Imaging: A Signal Processing Perspective - IEEE Press, New York 2000

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None

Prerequisites for participation in the exam(s):
- None

Module exam(s):
- ME4412-L1: Magnetic Resonance Imaging, oral exam, 30 min, 100 % of module grade

(Is module part of CS4512, ME4410-KP12, ME4415-KP06, ME4414-KP06)

ME4415-KP06 - Imaging (BildgbKP06)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	6

Course of study, specific field and term:

- Master CLS 2023 (compulsory), MML with specialization in Image Processing, 1st semester
- Bachelor CLS 2016 (optional subject), mathematics, 5th semester
- Master CLS 2016 (compulsory), MML with specialization in Image Processing, 1st semester

Classes and lectures:

- ME4411 T: Modul part: Computed Tomography (lecture, 2 SWS)
- ME4412 T: Modul part: Magnetic Resonance Imaging (lecture, 2 SWS)

Workload:

- 80 Hours private studies
- 70 Hours in-classroom work
- 30 Hours exam preparation

Contents of teaching:

- as described for the module parts

Qualification-goals/Competencies:

- as described for the module parts

Grading through:

- Oral examination

Responsible for this module:

- Prof. Dr. rer. nat. Thorsten Buzug

Teacher:

- Institute of Medical Engineering

- Prof. Dr. rer. nat. Thorsten Buzug
- Prof. Dr. rer. nat. Martin Koch

Literature:

- T. M. Buzug:

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None

Prerequisites for participation in the exam(s):
- None

Module exam(s):
- ME4415-L1: Imaging, oral exam, 30 min, 100 % of module grade

(Consists of module parts ME4411 T, ME4412 T)

MA4661-KP08, MA4661 - Genetic Epidemiology 2 (GenEpi2)

Duration:	Turnus of offer:	Credit points:	Max. group size:
1 Semester	each summer semester	8	20

Course of study, specific field and term:

- Master CLS 2023 (compulsory), MML with specialization in Genetic Statistics, 2nd semester
- Bachelor CLS 2023 (optional suject), mathematics, 6th semester
- Bachelor CLS 2016 (optional subject), mathematics, 6th semester
- Master CLS 2016 (compulsory), MML with specialization in Genetic Statistics, 2nd semester
- Bachelor CLS 2010 (optional subject), mathematics, 6th semester
- Master CLS 2010 (optional subject), mathematics, Arbitrary semester

Classes and lectures:

- Genetic Epidemiology 2 (lecture, 2 SWS)
- Genetic Epidemiology 2 (exercise, 1 SWS)
- Genetic Epidemiology 2 (practical course, 2 SWS)

Workload:

- 135 Hours private studies
- 75 Hours in-classroom work
- 30 Hours exam preparation

Contents of teaching:

- Classical methods of genetic epidemiology: - Familial aggregation and heritability - Model-based linkage analysis - Model-free linkage analysis - Linkage analysis for quantitative phenotypes - Linkage analyses for quantitative phenotypes - Family-based association tests
- Current topics in genetic epidemiology, e.g.: - Association tests for rare variants - Analysis of Omics data - Polygenic scores - Mendelian randomization
- Analysis of genetic data using specialized software packages (such as PLINK and MERLIN): - Genome-wide association studies - Family studies (linkage and association analyses)

Qualification-goals/Competencies:

- Students will be able to name and describe the most important procedures for linkage and association analysis in family studies.
- They know current analysis methods in genetic epidemiology.
- They can perform elementary tests by hand and interpret the results.
- They will be able to use software for more complex testing procedures and interpret the results.

Grading through:

- Written or oral exam as announced by the examiner

Is requisite for:

- Seminar Genetic Epidemiology (MA5129-KP04, MA5129)

Requires:

- Biostatistics 2 (MA2600-KP07)
- Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)
- Genetic Epidemiology 1 (MA3200-KP04, MA3200)

Responsible for this module:

- Prof. Dr. rer. nat. Silke Szymczak

Teacher:

- Institute of Medical Biometry and Statistics

- Prof. Dr. rer. nat. Silke Szymczak
- MitarbeiterInnen des Instituts

Literature:

- Ziegler, Andreas; König Inke R (2010): A Statistical Approach to Genetic Epidemiology. Concepts and Applications - 2nd ed., Wiley-VCH: Weinheim
- Bickeböller, Heike; Fischer, Christine (2007): Einführung in die Genetische Epidemiologie - Springer: New York
- Recent review articles: (to be announced in lecture)

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Module exam(s):
- MA4661-L1: Genetic Epidemiology 2, written exam (90 min) or oral exam (30 min), 100 % of module grade
- MA4661-L2: Practical Course Genetic Epidemiology 2, ungraded practical course, 0 % of module grade, must be passed

(Share of Institute of Medical Biometry and Statistics in V is 100%)
(Share of Institute of Medical Biometry and Statistics in Ü is 100%)
(Share of Institute of Medical Biometry and Statistics in P is 100%)

MA5129-KP04, MA5129 - Seminar Genetic Epidemiology (SemGenEpi)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4 (Typ B)

Course of study, specific field and term:

- Master CLS 2023 (compulsory), MML with specialization in Genetic Statistics, 3rd semester
- Master CLS 2016 (compulsory), MML with specialization in Genetic Statistics, 3rd semester
- Master CLS 2010 (optional suject), mathematics, 3rd semester
- Master CLS 2010 (compulsory), computational life science / biostatistics, 3rd semester

Classes and lectures:

- Seminar Genetic Epidemiology (seminar, 2 SWS)

Workload:

- 90 Hours work on an individual topic with written and oral presentation
- 30 Hours in-classroom work

Contents of teaching:

- Become acquainted with current topics in genetic epidemiology overall and in detail, typically using a current scientific publication, in written and oral form

Qualification-goals/Competencies:

- The students have the methodological competence to master the thorough analysis of a circumscribed scientific topic and to put it into scientific perspective.
- They are competent to present their results comprehensively in written form.
- They have the communication competence to orally present a scientifically complex topic in a coherent way.
- They have the communication competence to take an active part in a scientific discussion.

Grading through:

- Oral presentation and written report

Requires:

- Genetic Epidemiology 2 (MA4661-KP08, MA4661)
- Genetic Epidemiology 1 (MA3200-KP04, MA3200)

Responsible for this module:

- Prof. Dr. rer. nat. Silke Szymczak

Teacher:

- Institute of Medical Biometry and Statistics

- Prof. Dr. rer. nat. Silke Szymczak

Language:

- English, except in case of only German-speaking participants

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Module exam(s):
- MA5129-L1: Seminar Genetic Epidemiology, ungraded seminar, 0 % of module grade, must be passed

Specialized literature will be named in class.

MZ4010-KP04, MZ4010 - Clinical Epidemiology (KlinEpi)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Master CLS 2023 (compulsory), MML with specialization in Genetic Statistics, 3rd semester
- Bachelor Medical Informatics 2019 (optional subject), medical computer science, 4th to 6th semester
- Master CLS 2016 (compulsory), MML with specialization in Genetic Statistics, 3rd semester
- Bachelor Medical Informatics 2014 (compulsory), medical computer science, 5th semester
- Bachelor Medical Informatics 2011 (compulsory), medical computer science, 3rd semester
- Master CLS 2010 (compulsory), computational life science / biostatistics, 1st semester
- Master Computer Science 2012 (compulsory), specialization field medical informatics, 3rd semester

Classes and lectures:

- Clinical Epidemiology (lecture, 2 SWS)
- Clinical Epidemiology (exercise, 1 SWS)

Workload:

- 55 Hours private studies and exercises
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Introduction to epidemiology
- Diagnosis
- Frequencies
- Registers and data sources
- Geographical epidemiology
- Study designs (RCT, cohort study, case control study, cross sectional study)
- Effect measures
- Causality
- Chance, bias and confounding
- Control of errors
- Outbreak investigation

Qualification-goals/Competencies:

- Students are able to explain technical terms such as disease register, incidence, prevalence, mortality, lethality, standardization.
- They are able to explain and interpret epidemiological measures.
- They are able to assess which study design is appropriate for a certain research question.
- They are able to identify possible sources of error, bias and confounding and how they affect the study results.
- They are able to assess causal inferences in the context of different study types.
- They are able to critically appraise data, results, and epidemiological research methods as well as scientific literature in the context of medicine and epidemiology.

Grading through:

- written exam

Responsible for this module:

- Prof. Dr. med. Alexander Katalinic

Teacher:

- Institute for Social Medicine and Epidemiology

- Prof. Dr. med. Alexander Katalinic
- MitarbeiterInnen des Instituts

Literature:

- L. Gordis: Epidemiology - Oxford: Elsevier; 5th edition 2013
- R. H. Fletcher: Clinical Epidemiology. The Essentials. - Lippincott Williams & Wilki; 5th rev. edition 2012
- :

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None

Prerequisites for participation in the exam(s):
- None

Module exam(s):
- MZ4010-L1, Clinical Epidemiology, written exam, 90 min, 100 % of module grade

MZ4373-KP03, MZ4373 - Human Genetics (HumGen)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	3

Course of study, specific field and term:

- Master CLS 2023 (compulsory), MML with specialization in Genetic Statistics, 1st semester
- Master Medical Informatics 2019 (optional subject), bioinformatics, 1st or 2nd semester
- Master Medical Informatics 2014 (optional subject), bioinformatics, 1st or 2nd semester
- Master CLS 2016 (compulsory), MML with specialization in Genetic Statistics, 1st semester
- Master CLS 2010 (compulsory), computational life science / biostatistics, 1st semester
- Master CLS 2010 (optional suject), mathematics, Arbitrary semester

Classes and lectures:

- Human Genetics for MML (lecture, 2 SWS)

Workload:

- 40 Hours private studies
- 30 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Human genome
- Heredity
- Genetics of mitochondria
- Mutations, detection and nomenclature of sequence variations
- Polymorphisms and SNP
- Linkage analyses
- Repetitive sequences
- Methods: isolation, amplification, screening, and analysis of nucleic acids
- Data bases
- Epigenetics

Qualification-goals/Competencies:

- Students are able to explain basic principles of heredity, the organization of the human genome, the relevance of sequence variations, and their application for medical biometrics.

Grading through:

- written exam

Responsible for this module:

- Prof. Dr. rer. nat. Martin Kircher

Teacher:

- Institute of Human Genetics

- Prof. Dr. rer. nat. Martin Kircher
- Dr. Andreas Dalski
- MitarbeiterInnen des Instituts

Literature:

- Tom Strachan & Andrew P. Read: Molekulare Humangenetik - 3. Auflage (2005)

Language:

- German or English

Notes:

Prerequisites for attending the module:
- None

Prerequisites for participation in the exam(s):
- None

Module exam(s):
- MZ4373-L1: Human Genetics, written exam, 90 min, 100 % of module grade

MZ4374-KP03, MZ4374 - Molecular Human Genetics (MolHumGen)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	3 (Typ B)

Course of study, specific field and term:

- Master CLS 2023 (compulsory), MML with specialization in Genetic Statistics, 1st semester
- Master Medical Informatics 2019 (optional subject), bioinformatics, 1st or 2nd semester
- Master CLS 2016 (compulsory), MML with specialization in Genetic Statistics, 1st semester
- Master Medical Informatics 2014 (optional subject), bioinformatics, 1st or 2nd semester
- Master CLS 2010 (compulsory), computational life science / biostatistics, 1st semester

Classes and lectures:

- Molecular Human Genetics (practical course, 2 SWS)

Workload:

- 60 Hours private studies
- 30 Hours in-classroom work

Contents of teaching:

- Safety instructions
- Isolation of nucleic acids
- Preparation and separation of nucleic acids
- Amplification of nucleic acids (PCR)
- Restriction of nucleic acids
- Theoretical consideration of pedigrees
- Data base search

Qualification-goals/Competencies:

- Students can perform fundamental molecular genetic experiments, they get basic knowledge in laboratory work

Grading through:

- continuous, successful participation in practical course, >80%

Requires:

- Human Genetics (MZ4373-KP03, MZ4373)

Responsible for this module:

- Prof. Dr. rer. nat. Martin Kircher

Teacher:

- Institute of Human Genetics

- Prof. Dr. rer. nat. Martin Kircher
- Dr. Andreas Dalski

Literature:

- Lecture notes: -

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None (The competences of the required modules are required for this module, but the modules are not a prerequisite for admission.)

Prerequisites for the exam:
- Regular and successful participation in the practical course, at least 80%

Module exam(s):
- MZ4374-L1: Molecular Human Genetics, ungraded practical course, 0 % of module grade, must be passed

MA3111-KP07 - Numerics (NumKP07)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	7

Course of study, specific field and term:

- Master CLS 2023 (compulsory), 1st, 2nd, or 3rd semester
- Master CLS 2016 (compulsory), 1st, 2nd, or 3rd semester

Classes and lectures:

- Numerics (lecture, 2 SWS)
- Numerics (exercise, 2 SWS)

Workload:

- 100 Hours private studies and exercises
- 60 Hours in-classroom work
- 30 Hours additional private studies computational life science
- 20 Hours exam preparation

Contents of teaching:

- Round-off errors and condition
- Direct solvers for linear equations
- LR decomposition
- Perturbation theory
- Cholesky decomposition
- QR decomposition, least squares fit

Qualification-goals/Competencies:

- Basic understanding of numeric tasks
- Mastering the modern programming language MATLAB
- Experience in the implementation of theoretical algorithms
- Ability to judge the quality of a method (accuracy, stability, complexity)

Grading through:

- written exam

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Linear Algebra and Discrete Structures 1 (MA1000-KP08, MA1000)
- Analysis 2 (MA2500-KP09)
- Analysis 1 (MA2000-KP08, MA2000)

Responsible for this module:

- Prof. Dr. rer. nat. Andreas Rößler

Teacher:

- Institute for Mathematics

- Prof. Dr. rer. nat. Andreas Rößler

Literature:

- W. Dahmen, A. Reusken: Numerische Mathematik für Ingenieure und Naturwissenschaftler - 2. Auflage, Springer (2008)
- P. Deuflhard, A. Hohmann: Numerische Mathematik I - 4. Auflage, De Gruyter (2008)
- P. Deuflhard, F. Bornemann: Numerische Mathematik II - 4. Auflage, De Gruyter (2013)
- M. Hanke-Bourgeois: Grundlagen der Numerischen Mathematik und des Wissenschaftlichen Rechnens - 3. Auflage, Teubner (2009)
- H. R. Schwarz, N. Köckler: Numerische Mathematik - 8. Auflage, Teubner (2011)
- J. Stoer: Numerische Mathematik I - 10. Auflage, Springer (2007)
- J. Stoer, R. Bulirsch: Numerische Mathematik II - 6. Auflage, Springer (2011)
- A. M. Quarteroni, R. Sacco, F. Salieri: Numerical Mathematics - 2. Auflage, Springer (2007)

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Module exam(s):
- MA3111-L1: Numerics, written exam, 90 min, 100 % of module grade

MA4021-KP07 - Stochastics (StochKP07)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	7

Course of study, specific field and term:

- Master CLS 2023 (compulsory), 1st, 2nd, or 3rd semester

Classes and lectures:

- Stochastics (lecture, 3 SWS)
- Stochastics (exercise, 2 SWS)

Workload:

- 115 Hours private studies and exercises
- 75 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Lebesgue integral und Riemann integral
- transformations of measures and integrals
- product measures and Fubini's theorem
- moments and dependency measures
- normally distributed random vectors and distributions closely related to the normal distribution
- characteristic functions
- conditional expectations
- basis ideas of information theory

Qualification-goals/Competencies:

- Studends get insights into basic stochastic structures
- They master techniques of integration being relevant to stochastics
- They master the treatment of (particularly normally distributed) random vectors and their distributions
- They acquire a basic understanding of information theory approaches
- They are able to formalize complex stochastic problems

Grading through:

- written exam

Requires:

- Analysis 2 (MA2500-MML)

Responsible for this module:

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Teacher:

- Institute for Mathematics

- Nachfolge von Prof. Dr. rer. nat. Karsten Keller

Literature:

- J. Elstrodt: Maß- und Integrationstheorie - Springer
- M. Fisz: Wahrscheinlichkeitsrechnung und mathematische Statistik - Deutscher Verlag der Wissenschaften

Language:

- offered only in German

Notes:

Admission requirements for taking the module:
- None (The competencies of the modules listed under 'Requires' are needed for this module, but are not a formal prerequisite)

Admission requirements for participation in module examination(s):
- Successful completion of homework assignments during the semester

Module exam(s):
- MA4021-L1: Stochastics, written exam, 90 min, 100 % of module grade

The lecture is identical to the one in module MA4020.

MA4031-KP08 - Optimization (Advanced Mathematics) (OptiKP08)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	8

Course of study, specific field and term:

- Master CLS 2023 (compulsory), 1st, 2nd, or 3rd semester
- Master CLS 2016 (compulsory), 1st, 2nd, or 3rd semester

Classes and lectures:

- Optimization (lecture, 4 SWS)
- Optimization (exercise, 2 SWS)

Workload:

- 130 Hours private studies and exercises
- 90 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Linear optimization (simplex method)
- Unconstrained nonlinear optimization (gradient descent, conjugate gradients, Newton method, Quasi-Newton methods, globalization)
- Equality- and inquality-constrained nonlinear optimization (Lagrange multipliers, active set methods)
- Stochastic methods for machine learning

Qualification-goals/Competencies:

- Students can model real-life problems as optimization problems.
- They understand central optimization techniques.
- They can explain central optimization techniques.
- They can compare and assess central optimization techniques.
- They can implement central optimization techniques.
- They can assess numerical results.
- They can select suitable optimization techniques for practical problems.
- Interdisciplinary qualifications:
- Students can transfer theoretical concepts into practical solutions.
- They are experienced in implementation.
- They can think abstractly about practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Is requisite for:

- Non-smooth Optimization and Analysis (MA5035-KP05)

Requires:

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Analysis 2 (MA2500-KP09)

Responsible for this module:

- Prof. Dr. rer. nat. Jan Modersitzki

Teacher:

- Institute of Mathematics and Image Computing

- Prof. Dr. rer. nat. Jan Lellmann
- Prof. Dr. rer. nat. Jan Modersitzki

Literature:

- J. Nocedal, S. Wright: Numerical Optimization - Springer
- F. Jarre: Optimierung - Springer
- C. Geiger: Theorie und Numerik restringierter Optimierungsaufgaben - Springer

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None (Familiarity with the topics of the required modules is assumed, but the modules are not a formal prerequisite for attending the course).

Prerequisites for the exam:
- Exercises and their presentation are ungraded preliminary examinations. These must have been completed and positively evaluated before the first examination.

Examination:
- MA4031-L1: Optimization, written examination (90 min) or oral examination (30 min) as decided by examiner, 100% of final mark

Variant of MA4030, MA4030-KP08 for students who did not attend a course on optimization in their Bachelor s program.

CS5260-KP04, CS5260SJ14 - Speech and Audio Signal Processing (SprachAu14)

Duration:	Turnus of offer:	Credit points:
1 Semester	every second semester	4

Course of study, specific field and term:

- Master CLS 2023 (optional subject), Elective, Arbitrary semester
- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, Arbitrary semester
- Master MES 2020 (optional subject), medical engineering science, Arbitrary semester
- Master Media Informatics 2020 (optional subject), computer science, Arbitrary semester
- Master Medical Informatics 2019 (optional subject), Medical Data Science / Artificial Intelligence, 1st or 2nd semester
- Master MES 2014 (optional subject), medical engineering science, Arbitrary semester
- Master CLS 2010 (optional suject), computer science, Arbitrary semester
- Master Medical Informatics 2014 (optional subject), computer science, 1st or 2nd semester
- Master Media Informatics 2014 (optional subject), computer science, Arbitrary semester

Classes and lectures:

- Speech and Audio Signal Processing (lecture, 2 SWS)
- Speech and Audio Signal Processing (exercise, 1 SWS)

Workload:

- 55 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Speech production and human hearing
- Physical models of the auditory System
- Dynamic compression
- Spectral analysis: Spectrum and cepstrum
- Spectral perception and masking
- Vocal tract models
- Linear prediction
- Coding in time and frequency domains
- Speech synthesis
- Noise reduction and echo compensation
- Source localization and spatial reproduction
- Basics of automatic speech recognition

Qualification-goals/Competencies:

- Students are able to describe the basics of human speech production and the corresponding mathematical models.
- They are able to describe the process of human auditory perception and the corresponding signal processing tools for mimicing auditory perception.
- They are able to present basic knowledge of statistical speech modeling and automatic speech recognition.
- They can describe and use signal processing methods for source separation and room-acoustic measurements.

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr.-Ing. Markus Kallinger

Teacher:

- Institute for Signal Processing

- Prof. Dr.-Ing. Markus Kallinger

Literature:

- L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition - Upper Saddle River: Prentice Hall 1993
- J. O. Heller, J. L. Hansen, J. G. Proakis: Discrete-Time Processing of Speech Signals - IEEE Press

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of assignments during the semester.

Modul exam:
- CS5260-L1: Speech and Audio Signal Processing, written or oral exam, 100% of modul grade

Mentioned in SGO MML under CS5260 (without SJ14).