UNIVERSITÄT ZU LÜBECK

Module Guide for the Study Path

# Master Biophysics 2023

Version from 1. October 2025

## 1st and 2nd semester



## 1st or 2nd semester



## 1st semester



## 2nd semester

## 3rd semester



## 4th semester



## Arbitrary semester

# BP4300-KP12 - Elective consolidation courses (BPVertfg12)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 2 Semester | each semester | 12 |

**Course of study, specific field and term:**

- Master Biophysics 2023 (advanced module), biophysics, 1st and 2nd semester

**Classes and lectures:**

- see the list (seminar / practical course / exercise, 12 SWS)

**Workload:**

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

**Contents of teaching:**

- See the description of the courses

**Qualification-goals/Competencies:**

- Consolidation course, one our of six different areas to be chosen (See the list below).

**Grading through:**

- as announced by examiner

**Responsible for this module:**

- Prof. Dr. rer. nat. Christian Hübner

**Teacher:**

- All institutes of the MINT-Section
- Alle Dozentinnen/Dozenten der UzL

**Literature:**

- Individual selection will be provided:

**Language:**

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

**Notes:**

Elective consolidation courses:
CS4510-KP12
CS4511-KP12
LS4031-KP12
MA4300-KP12
MA4310-KP12
MZ4110-KP12

## CS5260SJ14 T - Module part: Speech and Audio Signal Processing (SprachA14a)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 1 Semester | normally each year in the summer semester | 4 |

**Course of study, specific field and term:**

- Master Computer Science 2019 (module part), Module part, Arbitrary semester
- Master Biophysics 2023 (module part), advanced curriculum, 1st and 2nd semester
- Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester
- Master Biophysics 2019 (module part), advanced curriculum, 1st or 2nd semester
- Master IT-Security 2019 (module part), Module part, Arbitrary semester
- Master Computer Science 2014 (Module part of a compulsory module), Module part, Arbitrary semester
- Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester
- Master MES 2014 (module part), computer science / electrical engineering, 1st or 2nd 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:**

- exam type depends on main module

**Responsible for this module:**

- Siehe Hauptmodul

**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.

Module examination(s):
- see superordinate module

(Is modul part of CS4290, CS4510, RO4290-KP04)
(Is the same as CS5260SJ14)

## ME4420-KP12, ME4420 - Biomedical Optics (BMO)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 2 Semester | each winter semester | 12 |

**Course of study, specific field and term:**

- Master Biophysics 2023 (compulsory), biophysics, 1st and 2nd semester
- Master MES 2020 (compulsory), medical engineering science, 1st and 2nd semester
- Master Entrepreneurship in Digital Technologies 2020 (advanced module), specific, Arbitrary semester
- Master Biophysics 2019 (compulsory), biophysics, 1st and 2nd semester
- Master Entrepreneurship in Digital Technologies 2014 (advanced module), specific, 1st and 2nd semester
- Master MES 2014 (compulsory), medical engineering science, 1st and 2nd semester

**Classes and lectures:**

- ME4421 T: Module part: Biomedical Optics 1 (lecture, 2 SWS)
- ME4422 T: Module part: Biomedical Optics 2 (lecture, 2 SWS)
- ME4423 T: Module part: Laser physics and -technologies (lecture, 2 SWS)
- Seminar Biomedical Optics (seminar, 2 SWS)

**Workload:**

- 135 Hours private studies
- 120 Hours in-classroom work
- 55 Hours exam preparation
- 30 Hours oral presentation (including preparation)
- 20 Hours written report

**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. Robert Huber

**Teacher:**

- Institute of Biomedical Optics

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

**Literature:**

- as listed for the module parts:

**Language:**

- German and English skills required

**Notes:**

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Examination requirement is the successful participation in one of the three module seminars (BMO1, BMO2, or Laser Physics). This includes mandatory attendance and a 20 minute scientific presentation followed by discussion.

Exam:
- A 30 minutes oral exam about the content of the lectures BMO1, BMO2 and laser physics.

## MZ4110-KP12 - Neurowissenschaften (Neuro)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 2 Semester | starts every winter semester | 12 |

**Course of study, specific field and term:**

- Master Biophysics 2023 (advanced module), advanced curriculum, 1st and 2nd semester
- Master Biophysics 2019 (advanced module), advanced curriculum, 1st and 2nd semester

**Classes and lectures:**

- Molecular Neuroscience (lecture, 2 SWS)
- Molecular Neuroscience (seminar, 2 SWS)
- Clinical Neurobiology (lecture, 2 SWS)
- Clinical Neurobiology (seminar, 2 SWS)

**Workload:**

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

**Contents of teaching:**

- Electrical activity of neurons
- Electrical activity of neurons
- Channels and transporters in neurons
- Synaptic transmission
- Neurotransmitters and their receptors
- Intracellular signaling in neurons
- Plasticity and memory
- Circadian rhythms and sleep
- The visual system
- Development of the nervous system
- Alzheimer's disease
- Infections of the CNS
- Neural stem cells and neurodegenerative disease
- Neural stem cells and tumor stem cells in brain tumors
- Neurobiology of cerebral ischemia
- Brain channelopathies: epilepsy and ataxia
- Neurogenetic disorders
- Neuroimmunology of multiplesclerosis
- Neurometabolic disorders
- Neuropathies
- Molecular basis of Parkinson disease and other movement disorders
- Schizophrenia

**Qualification-goals/Competencies:**

- Similar to moduls MZ4115 und MZ4125:Understanding basics of neuroscience
- Understanding the structure and development of the brain
- Understanding neuronal excitation and signal transmission
- Introduction to examples of behavior and plasticity
- Introduction to neuronal stem cells
- Introduction to various neuropathological diseases
- Understanding molecular mechanisms of neuropathological diseases

**Grading through:**

- written exam

**Responsible for this module:**

- Prof. Dr. rer. nat. Olaf Jöhren

**Teacher:**

- Department of Neurology
- Medical Clinic I
- Department of Neurosurgery
- Institut of Physiology

- Institute of Experimental and Clinical Pharmacology and Toxicology

- Prof. Dr. rer. nat. Olaf Jöhren
- Prof. Dr. med. Cor de Wit
- Prof. Dr. rer. nat. Henrik Oster
- Prof. Dr. med. Markus Schwaninger
- PD Dr. rer. nat. Christina Zechel
- Prof. Dr. rer. nat. Katja Lohmann
- PD Dr. Sc. Ana Westenberger
- Prof. Dr. rer. nat. Enrico Leipold
- Dr. rer. nat. Markus Krohn
- Dr. rer. nat. Violetta Pilorz

**Literature:**

- Nicholls: From Neuron to Brain: A Cellular and Molecular Approach to the Function of the Nervous System - ISBN-10: 0878936092, 679 Seiten, Palgrave Macmillan; 5th edition (2012
- Purves D, Augustine G, Fitzpatrick D, Hall W, LaMantia A: Neuroscience - Oxford University Press; 6. Edition (25. September 2018) - ISBN-10: 160535841X
- Brady: Basic Neurochemistry: Principles of Molecular, Cellular, and Medical Neurobiology - ISBN-10: 0123749476, 1096 Seiten, Academic Press; 8th Edition (2011)
- : Original publications and Reviews
- Purves: Neuroscience - ISBN-10: 0878936955, Palgrave Macmillan; 5th edition. (2011)

**Language:**

- offered only in German

**Notes:**

Similar to MZ5115 and MZ4125

## BP4110-KP08 - theoretical biophysics (ThBP)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 2 Semester | starts every winter semester | 8 |

**Course of study, specific field and term:**

- Master Biophysics 2019 (compulsory), biophysics, 1st and 2nd semester
- Master Biophysics 2023 (compulsory), biophysics, 1st or 2nd semester

**Classes and lectures:**

- theoretical biophysics (exercise, 1 SWS)
- theoretical biophysics (lecture, 2 SWS)
- molecular dynamics (lecture, 2 SWS)
- molecular dynamics (exercise, 1 SWS)

**Workload:**

- 150 Hours private studies
- 90 Hours in-classroom work

**Contents of teaching:**

- Basic concepts of quantum mechanics
- Intra- and intermolecular interactions
- Description of molecules by classical models
- Simulation of the dynamics of molecules by means of Newtonian mechanics
- Description of molecular dynamics with the help of thermodynamics
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**Qualification-goals/Competencies:**

- Students can explain how the existence of atoms and molecules can be explained from the fundamental assumptions of quantum mechanics.
- They can explain, within what limits can be described by classical models the interactions between atoms.
- They can sketch an algorithm with which the dynamics of molecules can be simulated.
- They can list, which thermodynamic concepts are to describe the molecular dynamics.
- They can classify common simulation programs for large biomolecules according to categories and recognize their basics.

**Grading through:**

- Oral examination

**Requires:**

- Module part: Biophysik 1 (ME4600 C)

**Responsible for this module:**

- PD Dr. rer. nat. Hauke Paulsen

**Teacher:**

- Institute of Physics
- PD Dr. rer. nat. Hauke Paulsen
- Prof. Dr. rer. nat. Christian Hübner

**Literature:**

- V. Schünemann: Biophysik - Berlin: Springer 2004
- M. Daune: Molekulare Biophysik - Braunschweig: Vieweg 1997
- Andrew R Leach: Molecular Modelling: Principles and Applications - Prentice Hall, 2nd edition 2001

**Language:**

- German and English skills required

## BP4200-KP04 - Elective Master Biophysics (WpfBP)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 1 Semester | normally each term | 04 |

**Course of study, specific field and term:**

- Master Biophysics 2023 (optional subject), biophysics, 1st or 2nd semester

**Classes and lectures:**

- Elective Biophysics (lecture, 2 SWS)

**Workload:**

- 120 Hours work on an individual topic with written and oral presentation or group work

**Contents of teaching:**

**Grading through:**

- see Notes

**Responsible for this module:**

- Dr. Young-Hwa Song

**Teacher:**

- All institutes of the University of Lübeck

**Language:**

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## CS4510-KP12, CS4510 - Signal Analysis (SignalAna)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 2 Semester | each year, can be started in winter or summer semester | 12 |

**Course of study, specific field and term:**

- Master Biophysics 2023 (advanced module), advanced curriculum, 1st or 2nd semester
- Master MES 2020 (advanced module), computer science / electrical engineering, Arbitrary semester
- Master Entrepreneurship in Digital Technologies 2020 (advanced module), specific, Arbitrary semester
- Master Computer Science 2019 (optional subject), advanced module, Arbitrary semester
- Master Biophysics 2019 (advanced module), advanced curriculum, 1st and 2nd semester
- Master IT-Security 2019 (advanced module), Elective Computer Science, 1st or 2nd semester
- Master MES 2014 (advanced module), computer science / electrical engineering, 1st and/or 2nd semester
- Master Entrepreneurship in Digital Technologies 2014 (advanced module), specific, 2nd and/or 3rd semester
- Master Computer Science 2014 (advanced module), advanced curriculum, 2nd and/or 3rd semester

**Classes and lectures:**

- CS5260SJ14 T: Speech and Audio Signal Processing (lecture with exercises, 3 SWS)
- CS5275 T: Selected Topics of Signal Analysis and Enhancement (lecture with exercises, 3 SWS)
- CS5194 T: Lab course (project work, 3 SWS)

**Workload:**

- 150 Hours private studies
- 90 Hours in-classroom work
- 60 Hours group work
- 40 Hours exam preparation
- 20 Hours written report

**Contents of teaching:**

- Introduction to statistical signal analysis
- Principles of feature extraction and pattern recognition
- Linear optimum filters
- Adaptive filters
- Spectrum analysis
- Basic concepts of multirate signal processing
- Applications in speech and image processing
- Realization of signal processing tasks for typical application scenarios in teamwork

**Qualification-goals/Competencies:**

- Students are able to explain the basic elements of stochastic signal processing and optimum filtering.
- They are able to describe and apply linear estimation theory.
- Students are able to describe the concepts of adaptive signal processing.
- They are able to explain theconcepts of feature extraction and pattern recognition.
- They are able to analyze and design multirate systems.
- Students are able to explain various practical applications of signal processing algorithms.
- They are able to create and implement signal processing systems on their own and in teamwork.

**Grading through:**

- Oral examination

**Responsible for this module:**

- Prof. Dr.-Ing. Markus Kallinger

**Teacher:**

- Institute for Signal Processing
- Prof. Dr.-Ing. Markus Kallinger

**Literature:**

- : See description of module parts

**Language:**

- German and English skills required

**Notes:**

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.

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- CS4510-L3 (all exept Master Biophysics since 2023): Successful completion of the project assignment, seminar presentation and exercise assignments as specified at the beginning of the semester
- CS4510-L1 (only Master Biophysics since 2023): Successful completion of the exercise assignments as specified at the beginning of the semester
- CS4510-L2 (only Master Biophysics since 2023): Successful completion of the project assignment as specified at the beginning of the semester

Module Exam(s):
- CS4510-L3 (all exept Master Biophysics since 2023): Signal Analysis, oral exam, 100% of module grade
- CS4510-L1 (only Master Biophysics since 2023): partial exam Signal Analyse, oral exam, 100% of module grade
- CS4510-L2 (only Master Biophysics since 2023): partial exam Lab course Signal- and image processing, project, ungraded

(Consists of CS4220 T, CS5275 T, CS5194 T)

## CS4511-KP12, CS4511 - Learning Systems (LernSys)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 2 Semester | irregularly | 12 |

**Course of study, specific field and term:**

- Master Biophysics 2023 (advanced module), advanced curriculum, 1st or 2nd semester
- Master Computer Science 2019 (optional subject), Canonical Specialization Bioinformatics and Systems Biology, Arbitrary semester
- Master MES 2020 (advanced module), computer science / electrical engineering, Arbitrary semester
- Master Computer Science 2019 (optional subject), Canonical Specialization Data Science and AI, Arbitrary semester
- Master Entrepreneurship in Digital Technologies 2020 (advanced module), specific, Arbitrary semester
- Master Computer Science 2019 (optional subject), advanced module, Arbitrary semester
- Master Biophysics 2019 (advanced module), advanced curriculum, 1st and 2nd semester
- Master IT-Security 2019 (advanced module), Elective Computer Science, 1st or 2nd semester
- Master MES 2014 (advanced module), computer science / electrical engineering, 1st and 2nd semester
- Master Entrepreneurship in Digital Technologies 2014 (advanced module), specific, 2nd and 3rd semester
- Master Computer Science 2014 (advanced module), advanced curriculum, 2nd and 3rd semester

**Classes and lectures:**

- CS4405 T: Neuro Informatics (lecture with exercises, 3 SWS)
- CS5450 T: Machine Learning (lecture with exercises, 3 SWS)
- CS5430 T: Seminar Machine Learning (seminar, 2 SWS)

**Workload:**

- 180 Hours private studies
- 120 Hours in-classroom work
- 40 Hours exam preparation
- 20 Hours work on an individual topic with written and oral presentation

**Contents of teaching:**

- see module parts

**Qualification-goals/Competencies:**

- see module parts

**Grading through:**

- Oral examination

**Responsible for this module:**

- Prof. Dr. rer. nat. Thomas Martinetz

**Teacher:**

- Institute for Neuro- and Bioinformatics

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

**Literature:**

- : see module parts

**Language:**

- German and English skills required

**Notes:**

Admission requirements for taking the module:
- None

Admission requirements for participation in module examination(s):
- Successful completion of exercises and project tasks as specified at the beginning of the semester.
- Seminar lecture and elaboration according to the requirements at the beginning of the semester.

Module Exam(s):
- CS4511-L1: Learning Systems, oral exam, 100% of module grade.

(Consists of CS4405 T, CS5450 T, CS5430 T)

Only for computer science students with the application subject Bioinformatics, the course CS4405 T Neuroinformatics is replaced by CS5204 T Artificial Intelligence 2, because this group of participants must already complete Neuroinformatics as part of a required module.

## CS5194 T - Module part: Practical Project in Signal and Image Processing (PrSigBildv)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 1 Semester | every second semester | 4 (Typ B) |

**Course of study, specific field and term:**

- Master Biophysics 2023 (module part), advanced curriculum, 1st or 2nd semester
- Master Computer Science 2019 (module part), Module part, Arbitrary semester
- Master MES 2020 (module part), computer science / electrical engineering, Arbitrary semester
- Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester
- Master Biophysics 2019 (module part), advanced curriculum, 1st or 2nd semester
- Master IT-Security 2019 (module part), Module part, 1st or 2nd semester
- Master MES 2014 (module part), computer science / electrical engineering, 1st or 2nd semester
- Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester
- Master Computer Science 2014 (module part), Module part, Arbitrary semester

**Classes and lectures:**

- iRoom (practical course, 3 SWS)

**Workload:**

- 60 Hours group work
- 40 Hours private studies
- 20 Hours written report

**Contents of teaching:**

- Planning and realization of typical signal processing applications in a team

**Qualification-goals/Competencies:**

- Students will have comprehensive knowledge of using signal and image processing algorithms in practice.
- They are able to realize signal processing systems in teamwork and in a self-directed manner.
- They have the communication competency to document and present project results.

**Grading through:**

- exam type depends on main module

**Requires:**

- Signal processing (CS3100-KP04)
- Image processing (CS3203)

**Responsible for this module:**

- Siehe Hauptmodul

**Teacher:**

- Institute for Signal Processing
- Prof. Dr.-Ing. Markus Kallinger
- MitarbeiterInnen des Instituts

**Language:**

- offered only in German

**Notes:**

(Part of Module CS4510)

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- The project must be completed in order to take the exam in the module CS4510

Modul Exam:
- CS4510-L1: Signal Analysis, oral exam consisting out of Pattern Recognition, Selected Topics of Signal Analysis and Enhancement and

this project, 100% of module grade

## LS4031-KP12 - Zell- und molekularbiologische Pathomechanismen und Therapieansätze (ZMolPath)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 2 Semester | starts every winter semester | 12 |

**Course of study, specific field and term:**

- Master Biophysics 2023 (advanced module), advanced curriculum, 1st or 2nd semester
- Master Biophysics 2019 (advanced module), advanced curriculum, 1st and 2nd semester

**Classes and lectures:**

- Pharmakologie und Toxikologie (= LS4110 A) (lecture, 2 SWS)
- Drug Design ( = LS4110 B) (lecture, 2 SWS)
- Cell Biology (= LS4010 A) (lecture, 2 SWS)
- General virology and biosafety (= LS4040) (lecture, 2 SWS)

**Workload:**

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

**Contents of teaching:**

- Similar to LS4110A, LS4110B, LS4010A, LS4040:Introduction into Pharmacology
- Pharmacodynamic
- Pharmacokinetics
- Oral Antidiabetics
- Pharmacology of the Renin-Angiotensin-Aldosterone-System
- Cerebrovascular Pharmacology
- Reverse Pharmacology
- Pharmacology of the Blood-Brain-Barrier
- Anxiolytics, Hypnotics and Sedatives
- Antiepileptic Drugs
- Gene Therapy of neurological diseases
- Pain physiology and analgetic therapies
- Concepts in Drug Design
- NMR experiments for Drug Design
- Case Study: Omeprazole vs. Tamiflu
- Chemical Synthesis of Drugs - Combinatorial Approaches
- Drug Discovery - An Overview
- Target Identification and Validation
- X-ray Crystallography in Drug Design
- Structure-based drug design - Principles and Methods
- Secretion in pro- and eukaryotes
- Structure, function biogenesis and stasis of membraneouse compartments of eukaryotes
- Cellular fusion, cytokinesis and organellar inheritence
- RNA-metabolism
- History of virology
- Virus taxonomy and structure
- Virus morphology in overview
- Viral life cycles (entry, assembly, budding)
- Replication mechanisms
- Viral evolution
- Basic techniques in virology and methods of virus diagnostics
- Blood-borne viruses and safety of blood products
- Biosafety classification of viruses according to Gentechnikrecht and Biostoffverordnung
- Pharmacology of Thyroid Homones
- Serendipity in the age of rational drug design: a case study

**Qualification-goals/Competencies:**

- Similar to the moduls LS4110A, LS4110B, LS4010A, LS4040:Students are able to explain the effects of therapeutic drugs on the organism (Pharmacodynamics).
- The are able to explain the time course of therapeutic drug concentrations in the organism (Pharmacokinetics).
- The are able to explain the mechanisms of action of various substance classes.
- The are able to explain the experimental methods in pharmacology
- The are able to explain the basic strategies of Drug Design.

- The are able to explain the the way from the target discovery to the drug. Techniques of rational Drug Design
- The are able to explain the the relationship between chemical structure and effect and the techniques for theoretical prognosis and experimental tests, particular x-ray crystallography and NMR-experiments
- The students should explain the borders of x-ray crystallography and NMR-experiments.
- Ability to link the newly communicated detailed cell biology knowledge with the already acquired knowledge and to apply it in the context of other modules.
- Ability, to recognize the connection between the cell biology of hosts and the molecular strategies of viral and other microbiological parasites.
- They can categorize viruses systematically.
- They can explain and compare viral life cycles and replication strategies.
- They can list basic practices and protocols for the virological safety of blood products.
- They can apply basics knowledge according to Gentechnikrecht and Biostoffverordnung .

**Grading through:**

- written exam

**Responsible for this module:**

- Prof. Dr. rer. nat. Enno Hartmann
- Prof. Dr. rer. nat. Thomas Peters

**Teacher:**

- Institute of Virology and Cell Biology
- Institute for Biology
- Institute of Chemistry and Metabolomics
- Institute of Experimental and Clinical Pharmacology and Toxicology
- Institute of Molecular Medicine
- Institute of Biochemistry

- Prof. Dr. rer. nat. Thomas Peters
- Prof. Dr. rer. nat. Olaf Jöhren
- Dr. rer. nat. Jan Wenzel
- Prof. Dr. rer. nat. Tobias Restle
- Prof. Dr. rer. nat. Rolf Hilgenfeld
- Prof. Dr. med. Markus Schwaninger
- Dr. med. Dirk Ridder
- Prof. Dr. rer. nat. Walter Raasch
- Prof. Dr. rer. nat. Norbert Tautz
- Dr. rer. nat. Olaf Isken
- Prof. Dr. rer. nat. Enno Hartmann
- Prof. Dr. rer. medic. Lisa Marshall
- Dr. rer. nat. Dipl.-Psych. Sonja Binder
- Prof. Dr. rer. nat. Enrico Leipold
- Dr. rer. nat. Marietta Zille
- Dr.rer.nat Sonja Petkovic
- Prof. Dr. Lars Redecke
- Dr. math. et dis. nat. Jeroen Mesters
- Dr. rer. hum. biol. Helge Müller-Fielitz

**Literature:**


- Brunton L, Knollmann B: Goodman & Gilman's The Pharmacologic Basis of Therapeutics - McGraw-Hill Education; 14. Edition (1. November 2022) - ISBN-10: 1264258070
- Lüllmann H, Mohr K, Hein L, Ziegler A, Bieger D: Color Atlas of Pharmacology - Thieme; 5. Edition (15. November 2017) - ISBN-10: 9783132410657
- G. Klebe: Wirkstoffdesign - Spektrum-Verlag Heidelberg, 2009. ISBN 978-3-8274-2046-6
- A. Hillisch & R. Hilgenfeld, Birkhäuser: Modern Methods in Drug Discovery - Basel, Boston, Berlin 2003, ISBN 3-7643-6081-X
- : Grundlagen- und Übersichtsartikel für beide Veranstaltungen
- Lodish: Molecular Cell Biology
- Alberts: Molecular Biology of the Cell
- S.J. Flint et al.: Principles of Virology: Molecular Biology, Pathogenesis, and Control of Animal Viruses - American Society Microbiology, February 2009, 3rd Ed., ISBN: 978-1-55581-443-4

**Language:**

- offered only in English

**Notes:**

Similar to LS4110 A, LS4110 B, LS4010 A und LS4040-KP04 without practical course

## MA4300-KP12, MA4300 - Modellierung und Analyse zeitabhängiger biologischer Prozesse und Daten (MAPD)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 2 Semester | starts every winter semester | 12 |

**Course of study, specific field and term:**

- Master MES 2020 (advanced module), mathematics / natural sciences, Arbitrary semester
- Master Biophysics 2019 (advanced module), advanced curriculum, 1st and 2nd semester
- Master MES 2014 (advanced module), mathematics / natural sciences, 1st and 2nd semester
- Master Biophysics 2023 (advanced module), advanced curriculum, 1st or 2nd semester

**Classes and lectures:**

- MA4330 T: Module part: Biosignalanalyse (4ECTS) (course, 3 SWS)
- MA4450 T: Module part: Modellierung Biologischer Systeme (8 ECTS) (course, 4 SWS)

**Workload:**

- 225 Hours private studies and exercises
- 105 Hours in-classroom work
- 30 Hours exam preparation

**Contents of teaching:**

- see description of module parts

**Qualification-goals/Competencies:**

- see description of module parts

**Grading through:**

- Oral examination

**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:**

- see literature of module parts:

**Language:**

- offered only in German

**Notes:**

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- The module includes an oral examination with duration and scope according to PVO. Exercises are preliminary examinations.

## CS5450 T - Module part: Machine Learning (MaschLerna)

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

**Course of study, specific field and term:**

- Master Biophysics 2023 (module part), advanced curriculum, 1st semester
- Master Computer Science 2019 (module part), Module part, Arbitrary semester
- Master MES 2020 (module part), computer science / electrical engineering, Arbitrary semester
- Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester
- Master Biophysics 2019 (module part), advanced curriculum, 1st semester
- Master IT-Security 2019 (module part), Module part, 1st or 2nd semester
- Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester
- Master MES 2014 (module part), computer science / electrical engineering, 1st or 2nd semester
- Master Computer Science 2014 (module part), Module part, Arbitrary 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:**

- exam type depends on main module

**Responsible for this module:**

- Siehe Hauptmodul

**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
- Tom Mitchell: Machine Learning - McGraw Hill. ISBN 0-07-042807-7

**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 assignments as specified at the beginning of the semester.

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

(Is part of the module CS4290, CS4511, CS5400, CS4251-KP08)

## LS4026-KP06 - Bioanalytics A (BioanalyA)

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

**Course of study, specific field and term:**

- Master Infection Biology 2023 (optional subject), life sciences, 1st semester
- Master Biophysics 2023 (compulsory), biophysics, 1st semester
- Master Molecular Life Science 2023 (compulsory), life sciences, 1st semester

**Classes and lectures:**

- LS4021-V: Crystallography (lecture, 2 SWS)
- LS4027-V: Optical Methods (lecture, 2 SWS)

**Workload:**

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

**Contents of teaching:**

- Lecture Crystallography: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)
- Lecture Optical Methods: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 developmen

**Qualification-goals/Competencies:**

- Lecture Crystallography: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
- Lecture Optical Methods: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.
- 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.

**Grading through:**

- written exam

**Responsible for this module:**

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

**Teacher:**

- Institute of Biomedical Optics
- Institute of Biochemistry

- Dr. math. et dis. nat. Jeroen Mesters
- Prof. Dr. rer. nat. Gereon Hüttmann
- Prof. Dr. rer. nat. Sebastian Karpf
- Dr. rer. nat. Norbert Linz
- Dr. rer. nat. Fred Reinholz

**Literature:**

- Jan Drenth: Principles of Protein X-ray Crystallography - Science+Business Media, LLC, New York
- 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 part of Module, too:
- LS4030-KP12 -> Prof. Hübner
- LS4021-KP06 -> Prof. Hübner

Prerequisites for the module:
- nothing

Prerequisites for admission to the written examination:
- nothing.

Module exam:
- LS4026-L1: Bioanalytics A, written exam, 120 min, 100 % module grade (Content of both lectures Crystallographie and Optical Methods)

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

## LS4027-KP06 - Bioanalytics B (BioanalyB)

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

**Course of study, specific field and term:**

- Master Infection Biology 2023 (optional subject), life sciences, 1st semester
- Master Biophysics 2023 (compulsory), biophysics, 1st semester
- Master Molecular Life Science 2023 (optional subject), structure biology, 1st semester

**Classes and lectures:**

- Single Molecule Methods (lecture, 2 SWS)
- NMR-Spectroscopy (lecture, 2 SWS)

**Workload:**

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

**Contents of teaching:**

- Lecture Singel Molecule Methods: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
- NMR-Spectroscopy:
- Assignment of NMR spectra
- Description of the NOESY experiment using the vector modelChemical 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:**

- Lecture Singel Molecule Methods:
- 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
- Lecture NMR-Spectroscopy:
- 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:**

- written exam

**Responsible for this module:**

- Prof. Dr. rer. nat. Ulrich Günther

**Teacher:**

- Institute of Chemistry and Metabolomics
- Institute of Physics

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

**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
- James Keeler: Understanding NMR Spectroscopy
- Horst Friebolin: Ein- und zweidimensionale NMR-Spektroskopie. Eine Einführung
- Malcolm H. Levitt: Spin Dynamics - Basics of Nuclear Magnetic Resonance
- D. Neuhaus & M. P. Williamson: The Nuclear Overhauser Effect in Structural and Conformational Analysis

**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

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

Prerequisites for the module:
- nothing

Prerequisites for admission to the written examination:
- snothing

Module exam:
- LS4027-L1: Bioanalytics B, written exam, 90 min, 100 % module grade(included content of LS4022-V Single Molecule Methods und LS4024-V NMR-Spectroscopy)

## MA4450 T - Module part: Modeling Biological Systems (MoBST)

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

**Course of study, specific field and term:**

- Master Biophysics 2023 (module part), advanced curriculum, 1st semester
- Master MES 2020 (module part), mathematics / natural sciences, Arbitrary semester
- Master Biophysics 2019 (module part), advanced curriculum, 1st semester
- Master MES 2014 (module part), mathematics / natural sciences, 1st semester

**Classes and lectures:**

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

**Workload:**

- 160 Hours private studies and exercises
- 60 Hours in-classroom work
- 20 Hours exam preparation

**Contents of teaching:**

- Elementary time-discrete deterministic models
- Structured time-discrete population dynamics
- Generating functions, 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
- exam type depends on main module

**Requires:**

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Stochastics 1 (MA2510-KP04, MA2510)
- Analysis 2 (MA2500-MML)

**Responsible for this module:**

- Siehe Hauptmodul

**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:**

The lecture is identical to that in module
MA4450.

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:
- Preliminary examinations can be determined at the beginning of the semester. If preliminary work has been defined, it must have been completed and positively assessed before the initial examination.

## ME4421 T - Module part: Biomedical Optics 1 (BioMedOp1)

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

**Course of study, specific field and term:**

- 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 Biophysics 2019 (Module part of a compulsory module), biophysics, 1st 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
- Master Biophysics 2023 (Module part of a compulsory module), biophysics, 1st semester

**Classes and lectures:**

- Lecture Biomedical Optics 1 (lecture, 2 SWS)

**Workload:**

- 40 Hours private studies and exercises
- 30 Hours in-classroom work
- 20 Hours exam preparation

**Contents of teaching:**

- Tissue optics
- Photophysics of molecules, fluorescent markers, and targeting
- Photochemistry, photobiology, and photodynamic therapy
- Spectroscopic tissue characterization and diagnosis
- Raman spectroscopy and imaging
- Coherence of light, and implications for biomedical optics
- Generation, steering, and detection of light
- Thermal action of light on biomolecules and tissue, rate processes
- Selective treatment of ocular structures, guided by online-dosimetry
- Mechanisms of pulsed laser ablation
- Laser ablation at tissue surfaces and inside the body & surgery by high-intensity focused ultrasound
- Nonlinear interactions of light and matter
- Plasma-mediated surgery, exemplified on refractive corneal surgery and cataract surgery
- Optical manipulation of microstructures (Laser scissors, tweezers, and catapults)
- Plasmonic systems, nano-optics, and optical bio-sensors

**Qualification-goals/Competencies:**

- The students are able to describe, illustrate and compare the fundamental diagnostic and therapeutic optical techniques in biomedicine.
- They are able to assess advantages and disadvantages of these techniques and to draw conclusions for their implementation into possible applications.
- They can explain light and tissue interactions and relate them to the optical techniques in which they are used.
- The students are able to understand and classify complex optical techniques as a whole and to analyze their constitutents.
- They have a profound understanding of scientific optical techniques in biomedicine, can apply it independently, and are able to transfer their knowledge to related tasks.

**Grading through:**

- exam type depends on main module

**Is requisite for:**

- Module part: Biomedical Optics 2 (ME4422 T)

**Responsible for this module:**

- Siehe Hauptmodul

**Teacher:**

- Institute of Biomedical Optics
- Prof. Dr. rer. nat. Robert Huber
- Prof. Dr. rer. nat. Gereon Hüttmann

- Dr. rer. nat. Ralf Brinkmann
- Dr. rer. nat. Norbert Linz

**Literature:**

- P.N. Prasad: Introduction to Biophotonics - Wiley 2003
- J. Popp, V. Tuchin, A. Chiou, S.H. Heinemann: Handbook of Biophotonics Vol 1 & 2 - Wiley-VCH 2011
- A.J. Welch, M. van Gemert: Optical-Thermal Response of Laser-Irradiated Tissue - Plenum 1995 (zweite Auflage 2011)

**Language:**

- offered only in German

**Notes:**

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Preliminary examinations can be determined at the beginning of the semester. If preliminary work has been defined, it must have been completed and positively assessed before the initial examination.

## ME4423 T - Module part: Laserphysics and -technologies (LaPhyTec)

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

**Course of study, specific field and term:**

- 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 Biophysics 2019 (Module part of a compulsory module), biophysics, 1st 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
- Master Biophysics 2023 (Module part of a compulsory module), biophysics, 1st semester

**Classes and lectures:**

- Lecture laser physics and -technologies (lecture, 2 SWS)

**Workload:**

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

**Contents of teaching:**

- Understanding the laser (What is a laser, the laser history, laser parameters)
- Basic properties of light, light propagation (Gaussian beam resonators, stability conditions, wavelength selective elements)
- Light and matter (radiation interactions, stimulated and spontaneous emission light amplification)
- Laser (Broad laser theory, rate equations, laser threshold, laser dynamics)
- Types of lasers (gas lasers, ion lasers, solid state lasers, fiber lasers, semiconductor lasers)
- nonlinear optics (frequency doubling and conversion)
- Ultrashort light pulses

**Qualification-goals/Competencies:**

- Students can assess what types of lasers are suitable for which applications.
- They can implement concepts for new laser applications.
- They can list the most important types of lasers.
- They can explain the basic concepts of laser physics.
- They can analyze laser formally.
- They can assess the potential of laser radiation on the basis of the parameters.

**Grading through:**

- exam type depends on main module

**Responsible for this module:**

- Siehe Hauptmodul

**Teacher:**

- Institute of Biomedical Optics
- Prof. Dr. rer. nat. Robert Huber
- Dr. rer. nat. Ralf Brinkmann
- Prof. Dr. rer. nat. Sebastian Karpf

**Literature:**

- Dieter Meschede: Optics, Light and Lasers - Wiley-VCH 2007
- Walter Koechner: Solid State Laser Engineering - Springer 1999
- Saleh/Teich: Grundlagen der Photonik - Wiley-VCH 2008

**Language:**

- offered only in German

**Notes:**

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Preliminary examinations can be determined at the beginning of the semester. If preliminary work has been defined, it must have been completed and positively assessed before the initial examination.

## BP4510-KP12 - experimental biophysics (ExpBP)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 1 Semester | each summer semester | 12 |

**Course of study, specific field and term:**

- Master Biophysics 2019 (compulsory), biophysics, 2nd semester
- Master Biophysics 2023 (compulsory), biophysics, 2nd semester

**Classes and lectures:**

- Proteinbiophysics (exercise, 1 SWS)
- Proteinbiophysics (lecture, 2 SWS)
- Basics of Membrane Biophysics (lecture, 2 SWS)
- Basics of Membrane Biophysics (exercise, 1 SWS)
- Instrumentation in Biophysics (exercise, 1 SWS)
- Instrumentation in Biophysics (lecture, 2 SWS)

**Workload:**

- 225 Hours private studies
- 135 Hours in-classroom work

**Contents of teaching:**

- Protein structure
- Energy landscapes
- Thermodynamics of protein folding
- Thermodynamics of protein folding
- Kinetics of protein folding
- Thermodynamics of enzymatic reactions
- Kinetics of enzymatic reactions
- Importance and function of cell membranes: structure, physical function and dynamic models
- Basics of the membrane components
- Thermodynamic self-assembling of lipids and reconstitution techniques
- Transmembrane and intrinsic membrane potentials
- Mechanical properties of lipid membranes
- Physical basics of membrane transport mechanisms
- Investigations using lipid monolayer
- Electrical and optical experiments using planar lipid bilayers
- Examples for interaction mechanisms between peptides/ proteins and planar membranes
- Spectroscopic methods on membranes and membrane proteins
- Light and force microscopy on membranes and membrane proteins
- UV-VIS spectroscopy
- Atomic force microscopy
- Fluorescence spectroscopy
- Film balance
- Patch clamp

**Qualification-goals/Competencies:**

- Students will understand and be able to apply the physical principles of protein folding, protein dynamics and protein interaction.
- They can name the components of biological membranes and explain their structure.
- They can name and explain the role and function of membrane lipids and proteins.
- They can name and explain the mechanical and electrical properties of membranes.
- They can select and apply appropriate methods for the investigation of artificial and natural membranes.
- They can identify the appropriate instrumentation for a particular question of biophysics.
- They can further develop instruments of biophysics
- They can use the instruments of biophysics optimally

**Grading through:**

- Oral examination

**Requires:**

- Introduction into Biophysics (LS2200-KP04, LS2200)

**Responsible for this module:**

- Prof. Dr. rer. nat. Christian Hübner

**Teacher:**

- Research Center Borstel, Leibniz Lung Center
- Institute of Physics

- Prof. Dr. rer. nat. Christian Hübner
- PD Dr. rer. nat. Hauke Paulsen
- Prof. Dr. rer. nat. Thomas Gutsmann
- Prof. Dr. rer. nat. Andra Schromm
- Dr. Christian Nehls

**Literature:**

- Hans Frauenfelder, Shirley Chan und Winnie Chan: Physics of Proteins: An Introduction to Molecular Biophysics (Biological and Medical Physics, Biomedical Engineering) - von Springer, Berlin (Gebundene Ausgabe - 30. Dezember 2010)
- Alan Fersht: Structure & Mechanism in Protein Science: Guide to Enzyme Catalysis and Protein Folding - W H Freeman & Co (Gebundene Ausgabe - 15. Februar 1999)
- Meyer B. Jackson: Molecular and Cellular Biophysics - ISBN: 978-0-521-62470-1
- G. Adam, P. Läuger, G. Stark: Physikalische Chemie und Biophysik - Springer-Verlag, 4. Auflage 2003
- W. Hanke, R. Hanke: Methoden der Membranphysiologie - Spektrum Akademischer Verlag, Auflage 1997
- Ole G. Mouritsen: Life - As a Matter of Fat - Springer 2005, ISBN 987-3-540-23248-3
- Thomas Heimburg: Thermal Biophysics of Membranes - Whiley-VCH 2007, ISBN 978-3-527-40471-1
- Lukas K. Buehler: Cell Membranes - Garland Science 2016, ISBN 978-0-8153-4196-3
- Yves Dufrene (Ed.): Life at the Nanoscale - Pan Stanford Publishing 2011, ISBN 978-981-4267-96-0

**Language:**

- German and English skills required

## CS4405 T - Module part: NeuroInformatics (NeuroInfa)

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

**Course of study, specific field and term:**

- Master Biophysics 2023 (module part), advanced curriculum, 2nd semester
- Master Computer Science 2019 (module part), Module part, Arbitrary semester
- Master MES 2020 (module part), computer science / electrical engineering, Arbitrary semester
- Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester
- Master Medical Informatics 2019 (module part), Module part, Arbitrary semester
- Master Biophysics 2019 (module part), advanced curriculum, 2nd semester
- Master IT-Security 2019 (module part), Module part, 1st or 2nd 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), computer science / electrical engineering, 2nd semester
- Master Computer Science 2014 (module part), Module part, Arbitrary 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
- Unxupervised 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:**

- exam type depends on main module

**Responsible for this module:**

- Siehe Hauptmodul

**Teacher:**

- Institute for Neuro- and Bioinformatics
- Prof. Dr. rer. nat. Thomas Martinetz

**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:**

Examination prerequisites can be defined at the beginning of the semester. If prerequisite courses are defined, they must have been completed and positively evaluated before the first examination.

(Is module part of CS4410, CS4511)
(Is equal to CS4405)

Admission requirements for the module:
- None

Admission requirements for the examination:
- Successful completion of exercises during the semester.

Translated with www.DeepL.com/Translator (free version)

## CS5275 T - Module part: Selected Topics of Signal Analysis and Enhancement (AMSAVa)

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

**Course of study, specific field and term:**

- Master Robotics and Autonomous Systems 2019 (module part), Module part Current Issues Robotics and Automation, 1st and/or 2nd semester
- Master Biophysics 2023 (module part), advanced curriculum, 2nd semester
- Master Computer Science 2019 (module part), Module part, Arbitrary semester
- Master MES 2020 (module part), computer science / electrical engineering, Arbitrary semester
- Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester
- Master Biophysics 2019 (module part), advanced curriculum, 2nd semester
- Master IT-Security 2019 (module part), Module part, 1st or 2nd semester
- Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester
- Master MES 2014 (module part), computer science / electrical engineering, 1st or 2nd semester
- Master Computer Science 2014 (module part), Module part, Arbitrary semester

**Classes and lectures:**

- Selected Topics of Signal Analysis and Enhancement (lecture, 2 SWS)
- Selected Topics of Signal Analysis and Enhancement (exercise, 1 SWS)

**Workload:**

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

**Contents of teaching:**

- Introduction to statistical signal analysis
- Autocorrelation and spectral estimation
- Linear estimators
- Linear optimal filters
- Adaptive filters
- Multichannel signal processing, beamforming, and source separation
- Compressed sensing
- Basic concepts of multirate signal processing
- Nonlinear signal processing algorithms
- Application scenarios in auditory technology, enhancement, and restauration of one- and higher-dimensional signals, Sound-field measurement, noise reduction, deconvolution (listening-room compensation), inpainting

**Qualification-goals/Competencies:**

- Students are able to explain the basic elements of stochastic signal processing and optimum filtering.
- They are able to describe and apply linear estimation theory.
- Students are able to describe the concepts of adaptive signal processing.
- They are able to describe and apply the concepts of multichannel signal processing.
- They are able to describe the concept of compressed sensing.
- They are able to analyze and design multirate systems.
- Students are able to explain various applications of nonlinear and adaptive signal processing.
- They are able to create and implement linear optimum filters and nonlinear signal enhancement techniques on their own.

**Grading through:**

- exam type depends on main module

**Responsible for this module:**

- Siehe Hauptmodul

**Teacher:**

- Institute for Signal Processing
- Prof. Dr.-Ing. Markus Kallinger

**Literature:**

- A. Mertins: Signaltheorie: Grundlagen der Signalbeschreibung, Filterbänke, Wavelets, Zeit-Frequenz-Analyse, Parameter- und

Signalschätzung - Springer-Vieweg, 3. Auflage, 2013
- S. Haykin: Adaptive Filter Theory - Prentice Hall, 1995

**Language:**
- offered only in German

**Notes:**

(Part of modules CS4290, CS4510, CS5400, RO4290-KP04, CS5274-KP08)
(Is equal to CS5275)

For Details see main module.

Prerequisites for attending the module:
- None

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

Modul exam in Main module:
- CS5275-L1: Selected Topics of Signal Analysis and Enhancement, written or oral exam, 100% of modul grade

## CS5430 T - module part: Seminar Machine Learning (SemMaschLa)

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

**Course of study, specific field and term:**

- Master Biophysics 2023 (module part), advanced curriculum, 2nd semester
- Master Computer Science 2019 (module part), Module part, Arbitrary semester
- Master MES 2020 (module part), computer science / electrical engineering, Arbitrary semester
- Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester
- Master Biophysics 2019 (module part), advanced curriculum, 2nd semester
- Master IT-Security 2019 (module part), Module part, 1st or 2nd semester
- Master MES 2014 (module part), computer science / electrical engineering, 1st or 2nd semester
- Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester
- Master Computer Science 2014 (module part), Module part, Arbitrary semester

**Classes and lectures:**

- Seminar Machine Learning (seminar, 2 SWS)

**Workload:**

- 70 Hours private studies
- 30 Hours in-classroom work
- 20 Hours work on an individual topic with written and oral presentation

**Contents of teaching:**

- Independent study of a specific field of machine learning

**Qualification-goals/Competencies:**

- Students can read and understand scientific articles in the field of machine learning.
- Students can present the contents of scientific articles in the field of machine learning in a talk.

**Grading through:**

- exam type depends on main module

**Responsible for this module:**

- Siehe Hauptmodul

**Teacher:**

- Institute for Neuro- and Bioinformatics
- Prof. Dr.-Ing. Erhardt Barth
- MitarbeiterInnen des Instituts

**Language:**

- German and English skills required

**Notes:**

Admission requirements for the module:
- None

Admission requirements for the examination:
- Examination prerequisites may be defined at the beginning of the semester. If prerequisites are defined, they must have been completed and positively evaluated prior to the initial examination.

(Is part of the module CS4511)

## LS4131-KP04 - Basics of Membrane Biophysics (Membiop04)

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

**Course of study, specific field and term:**

- Master Biophysics 2023 (Module part of a compulsory module), life sciences, 2nd semester
- Master Molecular Life Science 2023 (optional subject), structure biology, 2nd semester
- Master MLS 2018 (optional subject), structure biology, 2nd semester
- Master MLS 2016 (optional subject), structure biology, 2nd semester

**Classes and lectures:**

- Basics of Membrane Biophysics (lecture, 2 SWS)
- Basics of Membrane Biophysics (exercise, 1 SWS)

**Workload:**

- 75 Hours private studies
- 45 Hours in-classroom work

**Contents of teaching:**

- Importance and function of cell membranes: structure, physical function and dynamic models
- Basics of the membrane components
- Thermodynamic self-assembling of lipids and reconstitution techniques
- Transmembrane and intrinsic membrane potentials
- Mechanical properties of lipid membranes
- Physical basics of membrane transport mechanisms
- Investigations using lipid monolayer
- Electrical and optical experiments using planar lipid bilayers
- Examples for interaction mechanisms between peptides/ proteins and planar membranes
- Spectroscopic methods on membranes and membrane proteins
- Light and force microscopy on membranes and membrane proteins
-

**Qualification-goals/Competencies:**

- Constituents and composition of biological membranes
- Physical role and function of membrane lipids and proteins
- Mechanical and electrical properties of membranes
- Various methods to investigate reconstituted and natural membranes

**Grading through:**

- written exam

**Responsible for this module:**

- Prof. Dr. rer. nat. Thomas Gutsmann

**Teacher:**

- Research Center Borstel, Leibniz Lung Center

- Prof. Dr. rer. nat. Thomas Gutsmann
- Prof. Dr. rer. nat. Andra Schromm
- Dr. Christian Nehls

**Literature:**

- Adam, P. Läuger, G. Stark: Physikalische Chemie und Biophysik - Springer-Verlag, 4. Auflage 2003
- W. Hanke, R. Hanke: Methoden der Membranphysiologie - Spektrum Akademischer Verlag, Auflage 1997
- Ole G. Mouritsen: Life - As a Matter of Fat - Springer 2005, ISBN 987-3-540-23248-3
- Thomas Heimburg: Thermal Biophysics of Membranes - Whiley-VCH 2007, ISBN 978-3-527-40471-1
- Lukas K. Buehler: Cell Membranes - Garland Science 2016, ISBN 978-0-8153-4196-3

**Language:**

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

**Notes:**

Prerequisites for the module:
- nothing

Prerequisites for admission to the written examination:
- succesful participation in the exercises

Module exam:
- LS4131-L1: Membrane-Biophysics, written exam, 90 min, 100 % module grade

## LS4135-KP04 - Protein biophysics (ProtBiop04)

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

**Course of study, specific field and term:**

- Master Molecular Life Science 2023 (optional subject), structure biology, 2nd semester
- Master MLS 2018 (optional subject), structure biology, 2nd semester
- Master MLS 2016 (optional subject), structure biology, 2nd semester
- Master Biophysics 2023 (Module part of a compulsory module), life sciences, 2nd semester

**Classes and lectures:**

- Physics of Proteins (lecture, 2 SWS)
- Physics of Proteins (exercise, 1 SWS)

**Workload:**

- 75 Hours private studies
- 45 Hours in-classroom work

**Contents of teaching:**

- Protein structure
- Energy landscapes
- Thermodynamics of protein folding
- Kinetics of protein folding
- Thermodynamics of enzymatic reactions
- Kinetics of enzymatic reactions

**Qualification-goals/Competencies:**

- Understanding of physical principles of:
- protein folding
- protein dynamics
- protein interactions

**Grading through:**

- written exam

**Requires:**

- Introduction into Biophysics (LS2200-KP04, LS2200)

**Responsible for this module:**

- Prof. Dr. rer. nat. Christian Hübner

**Teacher:**

- Institute of Physics

- Prof. Dr. rer. nat. Christian Hübner
- PD Dr. rer. nat. Hauke Paulsen

**Literature:**

- Hans Frauenfelder, Shirley Chan und Winnie Chan: Physics of Proteins: An Introduction to Molecular Biophysics (Biological and Medical Physics, Biomedical Engineering) - von Springer, Berlin (Gebundene Ausgabe - 30. Dezember 2010)
- Alan Fersht: Structure & Mechanism in Protein Science: Guide to Enzyme Catalysis and Protein Folding - W H Freeman & Co (Gebundene Ausgabe - 15. Februar 1999)
- Meyer B. Jackson: Molecular and Cellular Biophysics - ISBN: 978-0-521-62470-1

**Language:**

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

**Notes:**

Prerequisites for the module:
- nothing

Prerequisites for admission to the written examination:
- succesful participation in the exercises.

Module exam:
- LS4135-L1: Protein-Biophysics, written exam, 90 min, 100 % module grade

## MA4030 T - Module part: Optimization (OptiT)

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

**Course of study, specific field and term:**

- Master Biophysics 2023 (module part), advanced curriculum, 2nd semester
- Master MES 2020 (module part), mathematics / natural sciences, Arbitrary semester
- Master Biophysics 2019 (module part), advanced curriculum, 2nd semester
- Master MES 2014 (module part), mathematics / natural sciences, 2nd 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:**

- exam type depends on main module

**Is requisite for:**

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

**Requires:**

- Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500)
- Analysis 2 (MA2500-KP04, MA2500)

**Responsible for this module:**

- Siehe Hauptmodul

**Teacher:**

- Institute of Mathematics and Image Computing
- Prof. Dr. rer. nat. Jan Modersitzki
- Prof. Dr. rer. nat. Jan Lellmann

**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:**

(Sub-module of MA4310)

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:
- Preliminary examinations can be determined at the beginning of the semester. If preliminary work has been defined, it must have been completed and positively assessed before the first examination.

## MA4310-KP12, MA4310 - Numerical Optimization (NumOpt)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 1 Semester | each summer semester | 12 |

**Course of study, specific field and term:**

- Master MES 2020 (advanced module), mathematics / natural sciences, Arbitrary semester
- Master Biophysics 2019 (advanced module), advanced curriculum, 2nd semester
- Master MES 2014 (advanced module), mathematics / natural sciences, 2nd semester
- Master Biophysics 2023 (advanced module), advanced curriculum, 2nd semester

**Classes and lectures:**

- MA4030 T: Module part: Optimization (lecture, 4 SWS)
- MA5034 T: Module part: Calculus of Variations and Partial Differential Equations (4ECTS) (course, 3 SWS)
- MA5032 T: Module part: Numerical Methods for Image Computing (4ECTS) (course, 3 SWS)
- MA4030 T: Module part: Optimization (exercise, 2 SWS)

**Workload:**

- 195 Hours private studies and exercises
- 135 Hours in-classroom work
- 30 Hours exam preparation

**Contents of teaching:**

- as stated in module parts

**Qualification-goals/Competencies:**

- as stated in module parts

**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:**

- as stated in module parts:

**Language:**

- German and English skills required

**Notes:**

The module MA4310: Numerical Optimization consists of the module MA4030: Optimization and annually alternating of the module MA5034: Calculus of Variations and Partial Differential Equations or the module MA5032: Numerical Methods for Image Computing.

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- The module includes an oral examination with duration and scope according to PVO. Exercises and presentation are preliminary examinations.

## MA4330 T - Module part: Biosignal analysis (BioSAT)

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

**Course of study, specific field and term:**

- Master Biophysics 2023 (module part), advanced curriculum, 2nd semester
- Master MES 2020 (module part), mathematics / natural sciences, Arbitrary semester
- Master Biophysics 2019 (module part), advanced curriculum, 2nd semester
- Master MES 2014 (module part), mathematics / natural sciences, 2nd semester

**Classes and lectures:**

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

**Workload:**

- 65 Hours private studies and exercises
- 45 Hours in-classroom work
- 10 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 deepened knowledges of the mathematical background of signal analysis
- They master different methods of 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:**

- exam type depends on main module

**Requires:**

- Analysis 2 (MA2500-KP04, MA2500)

**Responsible for this module:**

- Siehe Hauptmodul

**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:**

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:
- Preliminary examinations can be determined at the beginning of the semester. If preliminary work has been defined, it must have been

completed and positively assessed before the initial examination.

## MA5032 T - Module part: Numerical Methods for Image Computing (NumerikBVT)

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

**Course of study, specific field and term:**

- Master Biophysics 2023 (module part), advanced curriculum, 2nd semester
- Master MES 2020 (module part), mathematics / natural sciences, Arbitrary semester
- Master Biophysics 2019 (module part), advanced curriculum, 2nd semester
- Master MES 2014 (module part), mathematics / natural sciences, 2nd semester

**Classes and lectures:**

- Numerical Methods for Image Computing (lecture, 2 SWS)
- Numerical Methods for Image Computing (exercise, 1 SWS)

**Workload:**

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

**Contents of teaching:**

- Imaging process an imaging modalities
- Grids and image representation
- Operators in spatial and frequency domain
- Discrete Fourier Transform/FFT und Anwendungen
- JPEG
- Poisson equation and finite differences discretization
- Splitting methods
- Multigrid methods

**Qualification-goals/Competencies:**

- The students are familiar with fundamental numerical concepts in image computing.
- They have experience in realizing practical solutions.
- They can implement numerical algorithms on a computer.
- They understand selected methods for solving large linear systems.
- They can implement selected methods for solving large linear systems.
- 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:**

- exam type depends on main module

**Responsible for this module:**

- Siehe Hauptmodul

**Teacher:**

- Institute of Mathematics and Image Computing
- Prof. Dr. rer. nat. Jan Modersitzki
- Prof. Dr. rer. nat. Jan Lellmann

**Language:**

- German and English skills required

**Notes:**

(Sub-module of MA4310)

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:
- Preliminary examinations can be determined at the beginning of the semester. If preliminary work has been defined, it must have been completed and positively assessed before the first examination.

## MA5034 T - Module part: Calculus of Variations and Partial Differential Equations (VariPDET)

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

**Course of study, specific field and term:**

- Master Biophysics 2023 (module part), advanced curriculum, 2nd semester
- Master MES 2020 (module part), mathematics / natural sciences, Arbitrary semester
- Master Biophysics 2019 (module part), advanced curriculum, 2nd semester
- Master MES 2014 (module part), mathematics / natural sciences, 2nd 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
- 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:**

- exam type depends on main module

**Responsible for this module:**

- Siehe Hauptmodul

**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:**

(Sub-module of MA4310)

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:
- Preliminary examinations can be determined at the beginning of the semester. If preliminary work has been defined, it must have been completed and positively assessed before the first examination.

## ME4422 T - Module part: Biomedical Optics 2 (BioMedOp2)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 1 Semester | each summer semester | 3 |

**Course of study, specific field and term:**

- Master MES 2020 (Module part of a compulsory module), medical engineering science, 2nd semester
- Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester
- Master Biophysics 2019 (Module part of a compulsory module), biophysics, 2nd 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, 2nd semester
- Master Biophysics 2023 (Module part of a compulsory module), biophysics, 2nd semester

**Classes and lectures:**

- Biomedical Optics 2 (lecture, 2 SWS)

**Workload:**

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

**Contents of teaching:**

- Light microscopy: geometrical optics, wave optics, Fourier optics
- Effects of incoherent and coherent microscope-illumination & technical realization
- Phase contrast and differential interference contrast (DIC)
- Marker and targeting techniques, GFP, quantum dots, FRET
- Deconvolution & optical sectioning via structured illumination, confocal microscopy, 2-photon imaging
- Nanoscopy beyond the Abbe-limit: principles and biological applications
- Optical coherence tomography (OCT): principles, technical realization, and clinical applications
- Opto-acoustic tomography and microscopy
- Electron microscopy: principles and biological applications of TEM, REM, and Cryo-EM

**Qualification-goals/Competencies:**

- The students have a profound understanding and knowledge of modern optical imaging techniques in biomedicine, are able to describe and illustrate them, and to relate them to applications.
- They can explain the light-tissue interaction relevant for the different techniques, describe them mathematically and predict their effects.
- The students are able to understand and classify complex optical imaging techniques as a whole and to analyze their constitutents.
- They are able to transfer and adopt their knowledge to related problems and to develop new concepts.

**Grading through:**

- exam type depends on main module

**Requires:**

- Module part: Biomedical Optics 1 (ME4421 T)

**Responsible for this module:**

- Siehe Hauptmodul

**Teacher:**

- Institute of Biomedical Optics

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

**Literature:**


- D. B. Murphy: Fundamentals of Light Microscopy and Electronic Imaging - Wiley-Liss 2001
- J. Mertz: Optical Microscopy - Roberts & Co. Publ. 2010
- J.B. Pawley (ed): Handbook of Confocal Microscopy - Springer 2006

- W. Drexler, J.G. Fujimoto (eds.): Optical Coherence Tomography - Springer 2008
- L. Wang (ed): Photoacoustic Imaging and Spectroscoy - CRC Press 2009

**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:
- Talk and participation in discussion

## BP5100-KP12 - Internship Biophysics 1 (ProPrakBP1)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 1 Semester | each semester | 12 (Typ B) |

**Course of study, specific field and term:**

- Master Biophysics 2019 (compulsory), biophysics, 3rd semester
- Master Biophysics 2023 (compulsory), biophysics, 3rd semester

**Classes and lectures:**

- Internship I (September-November) (block practical course, 12 SWS)

**Workload:**

- 320 Hours work on project
- 40 Hours written report

**Contents of teaching:**

- Project management in a concrete research context
- Documentation, presentation, motivation in heterogeneous environments
- Strategies of literature research
- Analysis and curation of complex experimental data

**Qualification-goals/Competencies:**

- Students can name and explain selected aspects of biophysics
- They can plan and implement experiments in selected areas of biophysics
- They can document and present project results.
- They can respond to special audiences or time restrictions in a presentation.
- They can plan and implement projects in concrete application scenarios.
- They can manage projects.

**Grading through:**

- B-Certificate (not graded)

**Responsible for this module:**

- Studiengangsleitung

**Teacher:**

- All Institutes and Clinics of the Universität zu Lübeck
- Scientific facilities at the Universität zu Lübeck or abroad with mandatory supervision by an university lecturer
- Alle Dozentinnen/Dozenten der UzL

**Literature:**

- is selected individually:

**Language:**

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

**Notes:**

The internships can be completed in auditorytechnology companies or scientific facilities outside the university as well. It is recommended to seek a place abroad.
One of the two internships can be completed in a medical institution or a clinic.
Both internships can be merged into one large internship.

## BP5200-KP12 - Internship Biophysics 2 (ProPrakBP2)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 1 Semester | each semester | 12 (Typ B) |

**Course of study, specific field and term:**

- Master Biophysics 2019 (compulsory), biophysics, 3rd semester
- Master Biophysics 2023 (compulsory), biophysics, 3rd semester

**Classes and lectures:**

- Internship I (September-November) (block practical course, 12 SWS)

**Workload:**

- 320 Hours work on project
- 40 Hours written report

**Contents of teaching:**

- Project management in a concrete research context
- Documentation, presentation, motivation in heterogeneous environments
- Strategies of literature research
- Analysis and curation of complex experimental data

**Qualification-goals/Competencies:**

- Students can name and explain selected aspects of biophysics
- They can plan and implement experiments in selected areas of biophysics.
- They can document and present project results.
- They can respond to special audiences or time restrictions in a presentation.
- They can plan and implement projects in concrete application scenarios.
- They can manage projects.

**Grading through:**

- B-Certificate (not graded)

**Responsible for this module:**

- Studiengangsleitung

**Teacher:**

- All Institutes and Clinics of the Universität zu Lübeck
- Scientific facilities at the Universität zu Lübeck or abroad with mandatory supervision by an university lecturer
- Alle Dozentinnen/Dozenten der UzL

**Literature:**

- is selected individually:

**Language:**

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

**Notes:**

The internships can be completed in auditorytechnology companies or scientific facilities outside the university as well. It is recommended to seek a place abroad.
One of the two internships can be completed in a medical institution or a clinic.
Both internships can be merged into one large internship.

## PS5000-KP06, PS5000 - Student Conference (ST)

| Duration: | Turnus of offer: | Credit points: |
|---|---|---|
| 1 Semester | each winter semester | 6 (Typ B) |

**Course of study, specific field and term:**

- Master Psychology - Cognitive Systems 2022 (compulsory), psychology, 3rd semester
- Master Biophysics 2023 (compulsory), biophysics, 3rd semester
- Master Auditory Technology 2022 (compulsory), Auditory Technology, 3rd semester
- Master MES 2020 (compulsory), interdisciplinary competence, 3rd semester
- Master Medical Informatics 2019 (compulsory), interdisciplinary competence, 3rd semester
- Master Biophysics 2019 (compulsory), biophysics, 3rd semester
- Master Auditory Technology 2017 (compulsory), Auditory Technology, 3rd semester
- Master Interdisciplinary Courses (optional subject), Interdisciplinary modules, Arbitrary semester
- Master Robotics and Autonomous Systems 2019 (compulsory), Compulsory courses, 3rd semester
- Master Medical Informatics 2014 (compulsory), interdisciplinary competence, 3rd semester
- Master MES 2014 (compulsory), interdisciplinary competence, 3rd semester
- Master Psychology - Cognitive Systems 2027 (compulsory), psychology, 3rd semester

**Classes and lectures:**

- Student Conference (seminar, 4 SWS)

**Workload:**

- 155 Hours work on an individual topic (research and development) and written elaboration
- 25 Hours in-classroom work

**Contents of teaching:**

- Preparation of a scientific publication in English based on the results of at least one of the project internships
- Preparation of a scientific poster in English based on the results of at least one of the project internships
- Presentation of a scientific poster in German or English, based on the results of at least one of the project internships
- Talk in English based on the results of at least one of the project internships
- Active participation in scientific discussions
- Active participation in a scientific peer-review process

**Qualification-goals/Competencies:**

- Students have experience in a comprehensive review of a scientific topic
- They are able to get an extensive overview of a complex scientific area
- They have the experience and ability to take an active part in scientific discussions
- They are able to defend one's work successfully in a scientific discourse
- They have knowledge of the peer-review process of publications
- They are able to constructively criticize in a blind peer-review process
-

**Grading through:**

- continuous, successful participation in course

**Responsible for this module:**

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

**Teacher:**

- All Institutes and Clinics of the Universität zu Lübeck

**Literature:**

- is selected individually:

**Language:**

- offered only in English

**Notes:**

Admission requirements for the module:
- Successful completion of at least one project internship.
- Registration for at least one project internship is required.

Admission requirements for the examination:
- Regular and successful participation

Since the content of the presentation should reflect the results of at least one of the project internships, the students will be supervised by the same university lecturer that supervised the internships. Internships can be carried out at home or abroad in medical technology companies, audiology companies and IT companies in the healthcare industry as well as hospitals and scientific institutions. The supervision by an university lecturer is obligatory.

Students for whom this course is a compulsory module have priority.

(The share of the Institute of Medical Technology in all is 75%)
(Share of medical informatics in all is 25%)

## BP5990-KP30 - Master Thesis Auditory Technology (BPMArbeit)

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

**Course of study, specific field and term:**

- Master Biophysics 2023 (compulsory), biophysics, 4th semester
- Master Biophysics 2019 (compulsory), biophysics, 4th semester

**Classes and lectures:**

- Authoring of the Master 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:**

- Independent scientific work on a complex task in biophysics and its application
- Scientific presentation of the problem at hand and the solutions developed

**Qualification-goals/Competencies:**

- Ability to solve a preformulated more complex scientific problem in a defined period of time and to present and defende theexperimental results within the rules of the UzL for GSP and the DFG-guidelines.
- They can plan, organise and implement a complex, innovative project.
- They can present complex information in written and oral form.

**Grading through:**

- Written report

**Responsible for this module:**

- Studiengangsleitung

**Teacher:**

- All institutes of the University of Lübeck
- Alle prüfungsberechtigten Dozentinnen/Dozenten des Studienganges

**Literature:**

- is selected individually:

**Language:**

- thesis can be written in German or English

**Notes:**

Prerequisites for the module:
- Minimum of 82 ECTS

Prerequisites for admission to the written examination:
- succesful work on the subject

Module exam:
- BP5990-L1: Master Thesis in BP, written thesis, 66,66 % module grade
- BP5990-L2: Colloquium about the thesis in BP, oral defend, 60 min (20 min oral presentation), 33,33 % module grade (the arithmetic mean of the two examinators)

If the Master thesis is done externally (outside our university) the student has to choose a licensed lecturer (see PO) of our university as a second instructor who will be First Examiner in the examination.

## CS4295-KP04 - Deep Learning (DEEPL)

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

**Course of study, specific field and term:**

- Master Computer Science 2019 (optional subject), Elective, Arbitrary semester
- Master Psychology 2016 (optional subject), Elective, Arbitrary semester
- Master Biophysics 2023 (optional subject), Elective, Arbitrary semester
- Master Media Informatics 2020 (optional subject), Elective, Arbitrary semester
- Master MES 2020 (optional subject), Elective, Arbitrary semester
- Master Entrepreneurship in Digital Technologies 2020 (optional subject), specific, Arbitrary semester
- Master Psychology - Cognitive Systems 2027 (optional subject), psychology, Arbitrary semester
- Master Psychology - Cognitive Systems 2022 (optional subject), psychology, Arbitrary semester

**Classes and lectures:**

- CS4295-V: Deep Learning (lecture, 2 SWS)
- CS4295-Ü: Deep Learning (exercise, 2 SWS)

**Workload:**

- 75 Hours private studies
- 45 Hours in-classroom work

**Contents of teaching:**

- Foundations and Deep Learning Basics (Learning Paradigms, Classification and Regression, Underfitting and Overfitting)
- Shallow Neural Networks (Basic Neuron Model, Multilayer Perceptions, Backpropagation, Computational Graphs, Universal Approximation Theorem, No-Free Lunch Theorems, Inductive Biases)
- Optimization (Stochastic Gradient Descent, Momentum Variants, Adaptive Optimizer)
- Convolutional Neural Networks (1D Convolution, 2D Convolution, 3D Convolution, ReLUs and Variants, Down and Up Sampling Techniques, Transposed Convolution)
- Regularization (Early Stopping, L1 and L2 Regularization, Label Smoothing, Dropout Strategies, Batch Normalization)
- Very Deep Networks (Highway Networks, Residual Blocks, ResNet Variants, DenseNets)
- Dimensionality Reduction (PCA, t-SNE, UMAP, Autoencoder)
- Generative Neural Networks (Variational Autoencoder, Generative Adversarial Networks, Diffusion Models)
- Graph Neural Networks (Graph Convolutional Networks, Graph Attention Networks)
- Fooling Deep Neural Networks (Adversarial Attacks, White Box and Black Box Attacks, One-Pixel Attacks)
- Physics-Aware Deep Learning (Physical Knowledge as Inductive Bias, PINN, PhyDNet, Neural ODE, FINN)

**Qualification-goals/Competencies:**

- Students get a fundamental understanding deep learning basics such as backpropagation, computational graphs, and auto-differentiation
- Students understand the implications of inductive biases
- Students get a comprehensive understanding of most relevant deep learning approaches
- Students learn to analyze the challenges in deep learning tasks and to identify well-suited approaches to solve them
- Students will understand the pros and cons of various deep learning models
- Students know how to analyze the models and results, to improve the model parameters, and to interpret the model predictions and their relevance

**Grading through:**

- Written or oral exam as announced by the examiner

**Responsible for this module:**

- Prof. Dr. Sebastian Otte

**Teacher:**

- Institute for Robotics and Cognitive Systems
- MitarbeiterInnen des Instituts
- Prof. Dr. Sebastian Otte

**Literature:**


- Goodfellow, I., Bengio, Y., & Courville, A. (2016): Deep Learning - MIT Press. ISBN 978-0262035613
- Prince, S. J. D. (2023): Understanding Deep Learning - The MIT Press. ISBN 978-0262048644

- Deisenroth, M. P., Faisal, A. A., & Ong, C. S. (2020): Mathematics for Machine Learning - Cambridge University Press, 2020. ISBN 978-1108470049
- Bishop, C. M. (2006): Pattern Recognition and Machine Learning - Springer. ISBN 978-0387310732
- Recent publications on the related topics:

**Language:**

- offered only in English

**Notes:**

Admission requirements for taking the module:
- None

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

Module Exam(s):
- CS4295-L1: Deep Learning, exam, 90 min

According to the decision of the examination board of computer science of 19.8.2024 this module can be chosen by students Master Computer Science SGO from 2019 in the area of 5th elective.

## CS4440 T - Module part: Molecular Bioinformatics (MolBioInfa)

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

**Course of study, specific field and term:**

- Master Biophysics 2023 (module part), advanced curriculum, Arbitrary semester
- Master Biophysics 2019 (module part), advanced curriculum, Arbitrary semester
- Master Computer Science 2019 (module part), Module part, Arbitrary semester
- Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester
- Master Medical Informatics 2019 (module part), Module part, Arbitrary semester
- Master MLS 2009 (Module part of a compulsory module), interdisciplinary competence, 1st semester
- Master Medical Informatics 2014 (module part), Module part, Arbitrary semester
- Master Computer Science 2014 (module part), Module part, Arbitrary semester

**Classes and lectures:**

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

**Workload:**

- 45 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:**

- exam type depends on main module

**Requires:**

- Introduction to Bioinformatics (CS1400-KP04, CS1400)

**Responsible for this module:**

- Siehe Hauptmodul

**Teacher:**

- Institute for Neuro- and Bioinformatics
- Prof. Dr. Bernhard Haubold
- Prof. Dr. rer. nat. Thomas Martinetz
- Prof. Lars Bertram
- MitarbeiterInnen des Instituts

**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:**

- 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:
- Preliminary examinations can be determined at the beginning of the semester. If preliminary work has been defined, it must have been completed and positively assessed before the initial examination.

This modul is for Master MLS the Modulpart B of Modul LS4060 with 5 credit points.

## CS4575-KP04 - Sequence Learning (SEQL)

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

**Course of study, specific field and term:**

- Master Computer Science 2019 (optional subject), Elective, Arbitrary semester
- Master Medical Informatics 2019 (optional subject), Medical Data Science / Artificial Intelligence, 1st or 2nd semester
- Master Psychology 2016 (optional subject), Elective, Arbitrary semester
- Master Biophysics 2023 (optional subject), Elective, Arbitrary semester
- Master Media Informatics 2020 (optional subject), Elective, Arbitrary semester
- Master MES 2020 (optional subject), Elective, Arbitrary semester
- Master Entrepreneurship in Digital Technologies 2020 (optional subject), specific, Arbitrary semester
- Master Psychology - Cognitive Systems 2022 (optional subject), psychology, Arbitrary semester
- Master Psychology - Cognitive Systems 2027 (optional subject), psychology, Arbitrary semester

**Classes and lectures:**

- CS4575-V: Sequence Learning (lecture, 2 SWS)
- CS4575-Ü: Sequence Learning (exercise, 1 SWS)

**Workload:**

- 75 Hours private studies
- 45 Hours in-classroom work

**Contents of teaching:**

- Introduction to Sequence Learning (Formalisms, Metrics, Recapitulation of Relevant Machine Learning Techniques)
- Recurrent Neural Networks (Simple RNN Models, Backpropagation Through Time)
- Gated Recurrent Networks (Vanishing Gradient Problem in RNNs, Long Short-Term Memories, Gated Recurrent Units, Stacked RNNs)
- Important Techniques for RNNs (Teacher Forcing, Scheduled Sampling, h-Detach)
- Bidirectional RNNs and related concepts
- Hierarchical RNNs and Learning on Multiple Time Scales
- Online Learning and Learning without BPTT (Real-Time Recurrent Learning, e-Prop, Forward Propagation Through Time)
- Reservoir Computing (Echo State Networks, Deep ESNs)
- Spiking Neural Networks (Spiking Neuron Models, Learning in SNNs, Neuromorphic Computing, Recurrent SNNs)
- Temporal Convolution Networks (Causal Convolution, Temporal Dilation, TCN-ResNets)
- Introduction to Transformers (Sequence-to-Sequence Learning, Basics on Attention, Self-Attention and the Query-Key-Value Principle, Large Language Models)
- State Space Models (Structured State Space Sequence Models, Mamba)

**Qualification-goals/Competencies:**

- Students get a comprehensive understanding of most relevant sequence learning approaches
- Students learn to analyze the challenges in sequence learning tasks and to identify well-suited approaches to solve them
- Students will understand the pros and cons of various sequence learning models
- Students can implement common and custom sequence learning models for time series analysis, classification, and forecasting
- Students know how to analyze the models and results, to improve the model parameters, and to interpret the model predictions and their relevance

**Grading through:**

- Written or oral exam as announced by the examiner

**Responsible for this module:**

- Prof. Dr. Sebastian Otte

**Teacher:**

- Institute for Robotics and Cognitive Systems
- MitarbeiterInnen des Instituts
- Prof. Dr. Sebastian Otte

**Literature:**


- Goodfellow, I., Bengio, Y., & Courville, A. (2016): Deep Learning - MIT Press. ISBN 978-0262035613
- Prince, S. J. D. (2023): Understanding Deep Learning - The MIT Press. ISBN 978-0262048644
- Deisenroth, M. P., Faisal, A. A., & Ong, C. S. (2020): Mathematics for Machine Learning - Cambridge University Press, 2020. ISBN

978-1108470049
- Nakajima, K., & Fischer, I. (2021): Reservoir Computing: Theory, Physical Implementations, and Applications - Cambridge University Press, 2020. ISBN 978-1108470049
- Sun, R., & Giles, C. (2001): Sequence Learning: Paradigms, Algorithms, and Applications - Springer Berlin Heidelberg. ISBN 978-3540415978
- Bishop, C. M. (2006): Pattern Recognition and Machine Learning - Springer. ISBN 978-0387310732
- Recent publications on the related topics:

**Language:**

- offered only in English

**Notes:**

Admission requirements for taking the module:
- None, but it is recommended to complete the course Deep Learning (CS4295-KP04) first

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

Module Exam(s):
- CS4575-L1: Sequence Learning, exam, 90 min

According to the decision of the examination board of computer science of 19.8.2024 this module can be chosen by students Master Computer Science SGO from 2019 in the area of 5th elective.