Brandenburgische Technische Universität Cottbus - Senftenberg
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Brandenburgische
Technische Universität
Cottbus - Senftenberg

Modulhandbuch für den Studiengang Mathematical Data Science (universitäres Profil), Master of Science, Prüfungsordnung 2025

Inhaltsverzeichnis

Module 13639 Mathematical Foundations of Data Science

assign to: Mathematical Compulsory Modules

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13639	Mandatory

Modul Title	**Mathematical Foundations of Data Science** Mathematische Grundlagen der Datenwissenschaft
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Hartmann, Carsten
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	8
Learning Outcome	After completing the course, the students are able to apply statistical learning methods to justify conclusions drawn from data. They are familiar with fundamental properties, assumptions, limitations of the considered methods and their derivation.
Contents	• Linear Regression • Empirical Risk Minimization • Model Assessment and Model Selection • Bias-Variance Decomposition • Bayesian Decision Theory • Naïve Bayes Classifier • Linear Classifiers
Recommended Prerequisites	Good command of basic linear algebra, analysis and probability theory is recommended, e.g. as taught in the modules • 11103: Analysis I • 11104: Analysis II • 11101: Lineare Algebra und analytische Geometrie I • 11217: Wahrscheinlichkeitstheorie or 11917: Mathematik W-3 (Statistik) or 11212: Statistics
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours

Teaching Materials and Literature	• Trevor Hastie, Robert Tibshirani, Jerome Friedman: The elements of statistical learning: data mining, inference, and prediction. Springer, 2009. • Philippe Rigollet, Jan-Christian Hütter: High-Dimensional Statistics, Lecture Notes, MIT, 2023. • Stefan Richter. Statistical analysis of machine learning algorithms, Lecture Notes, Universität Heidelberg, 2020.
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • successful completion of a homework **Final module examination:** • written exam, 90 min.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematical Data Science M.Sc.: Mandatory module • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Stochastics“
Module Components	• Lecture: Mathematical Foundations of Data Science • Accompanying exercises • Related examination
Components to be offered in the Current Semester	**130830** Lecture Mathematical Foundations of Data Science - 4 Hours per Term **130831** Exercise Mathematical Foundations of Data Science - 2 Hours per Term **130832** Examination Mathematical Foundations of Data Science

Module 13798 Seminar Mathematical Data Science

assign to: Mathematical Compulsory Modules

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13798	Mandatory

Modul Title	**Seminar Mathematical Data Science** Seminar Mathematische Datenwissenschaft
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Hartmann, Carsten
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every semester
Credits	4
Learning Outcome	On completion of the course, students will have • acquired in-depth technical knowledge of a topic • developed their skills in modeling and in the use and further development of mathematical solution methods • learned how to narrow down and precisely formulate scientific problems as well as effective time management • improved their oral communication skills by speaking freely in front of an audience and in group discussions • improved their skills in the use of scientific word processing systems (LaTeX).
Contents	Selected topics from the field of mathematical data science
Recommended Prerequisites	Good command of basic linear algebra, analysis and probability theory is recommended, e.g. as taught in the modules • 11103: Analysis I • 11104: Analysis II • 11101: Lineare Algebra und analytische Geometrie I • 11217: Wahrscheinlichkeitstheorie or 11917: Mathematik W-3 (Statistik) or 11212: Statistics
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Seminar - 2 hours per week per semester Self organised studies - 90 hours

Teaching Materials and Literature	• Leo Breiman: Statistical Modeling: The Two Cultures. Statistical Science, Vol. 16, No. 3, 199-215, 2001. • Brad Efron: Prediction, Estimation and Attribution, Journal of the American Statistical Association, 115(530), 636–655, 2020 • David B. Dunson: Statistics in the big data era: Failures of the machine. Statistics & Probability Letters, Vol. 136, 4-9, 2018. Additional literature will be provided at the beginning of the semester.
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• Seminar presentation (30-45 min.) including report (8-10 pages), depending on subject (70 %) • Active participation throughout the semester (30%) The module is passed if 75% of the examination requirements are met.
Evaluation of Module Examination	Study Performance – ungraded
Limited Number of Participants	40
Remarks	• Study programme Mathematical Data Science M.Sc.: Mandatory module
Module Components	• Seminar Mathematical Data Science
Components to be offered in the Current Semester	No assignment

Module 14261 Master Seminar

assign to: Mathematical Compulsory Modules

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	14261	Mandatory

Modul Title	**Master Seminar** Master-Seminar
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wunderlich, Ralf
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every semester
Credits	4
Learning Outcome	The students • have acquired advanced special knowledge to a topic of mathematics that is at the level of research • have further developed capacities of modelling and applying mathematical methods • are able to specify and precisely formulate scientific problems • have gained further experience in effective time management • are able to demonstrate the progress of knowledge independently acquired for the master thesis • have improved skills of preparing a topic for a talk • have improved oral communication skills by speaking to the public and by discussions in groups • have gained more experience in teamwork • have further improved their ability in using the common text processing software (LaTeX) • come to a decision on how to continue preparations for the master thesis evaluating the seminar discussions
Contents	depends on the area of the master thesis
Recommended Prerequisites	• all necessary credit points in the complexe Mathematics-Specialization • at least 60 credit points
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Seminar - 2 hours per week per semester

	Self organised studies - 90 hours
Teaching Materials and Literature	depend on the chosen topic
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• Seminar talk (30-60 min.) and handout (10-15 pages), depending on the topic (70%) • Active participation in seminar course (30%) 75% of the exam is required to pass the module.
Evaluation of Module Examination	Study Performance – ungraded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Mandatory module
Module Components	• Master Seminar
Components to be offered in the Current Semester	No assignment

Module 14262 Master Thesis

assign to: Mathematical Compulsory Modules

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	14262	Mandatory

Modul Title	**Master Thesis** Master-Arbeit
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wunderlich, Ralf
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every semester
Credits	30
Learning Outcome	The students are able to: • successfully elaborate a research-oriented subject on their own and within the specified time period, • make a scientificly founded contribution to the theoretical or practical solution of a particular problem. In particular, this means that they: • have enhanced and developed their knowledge and skills from prior modules, • have autonomously acquired relevant knowledge from the literature; • have found open problems and have developed concepts to their solution, • are able to define and narrow down a problem in such a way that it can be solved in the time available; • know how to appropriately apply the needed mathematical methods and techniques; • have further improved their ability in using the common text processing software (LaTeX), • have increased their proficiency for scientific dispute in the defense of their thesis.
Contents	depends on the subject of the thesis
Recommended Prerequisites	none
Mandatory Prerequisites	Students are admitted to the Master's thesis if they have earned at least 78 credit points at the time of registration.

Forms of Teaching and Proportion	Self organised studies - 900 hours
Teaching Materials and Literature	To be named and provided by the supervisor. Some of the literature will be researched by the students themselves.
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• Master thesis, written (75%), • marked defense, oral, 60 min. (25%)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Mandatory module The working time for the master thesis is 24 weeks.
Module Components	• Consultations as needed • Defense
Components to be offered in the Current Semester	No assignment

Module 11847 Neural Networks and Learning Theory

assign to: Advanced Mathematical Methods in Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	11847	Compulsory elective

Modul Title	**Neural Networks and Learning Theory** Neuronale Netze und Lerntheorie
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil Meer, Klaus
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Each summer semester even year
Credits	8
Learning Outcome	Students will get insight into different network architectures and their principles of operation. Notions like artificial intelligence and automatic learning will be made precise during the course. A central issue is the understanding of mathematical ideas underlying different network learning algorithms. This includes both positive solutions of problems and knowledge about limits of the approaches studied.
Contents	Some central network architectures are treated. These architectures differ in the way they manipulate input data, the way they perform learning tasks and the analysis of corresponding algorithms by mathematical means. More precisely, the following types of networks are covered: • General aspects of architecures, in particular feedforward nets, recurrent nets • Perceptron network, perceptron learning algorithm • Backpropagation algorithm • Radial basis function networks • Support Vector Machines • Learning theory and Vapnik-Chervonenkis dimension • Self-organizing networks • Hopfield networks Special emphasis will be given to the mathematical analysis of algorithms. This will make it necessary to study some basic facts of optimization and probability theory.

Recommended Prerequisites	Basic knowledge both concerning optimality criteria in differentiable optimization and probability theory are advisable, but will be treated briefly in the course. Solid knowledge of the content of module • 11213: Mathematik IT -3 (Analysis)
Mandatory Prerequisites	No successful participation in associated phase-out module 12450 *Neuronale Netze und Lerntheorie*.
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• E. Alpaydin: Maschinelles Lernen, Oldenbourg Verlag München, 2008 • M. Anthony, N.Biggs: Computational Learning Theory, Cambridge University Press 1997 • N. Christiani, J. Shawe-Taylor: An Introduction to Support Vector Machines and kernel-based Learning Methods, Cambridge Univ. Press, 2003 • A.C.C Coolen, R. Kühn, P. Sollich: Theory of Neural Information Processing Systems, Oxford University Press 2005 • P. Fischer: Algorithmisches Lernen, Teubner 1999 • P. Flach: Machine Learning: The Art and Science of Algorithms that Make Sense of Data, Cambridge University Press 2012 • F. M. Ham, I. Kostanic: Principles of Neurocomputing for Science & Engineering, McGraw Hill 2001 • S. Haykin: Neural Networks, Prentice Hall, 1999 • R. Rojas: Theorie der neuronalen Netze, Springer 1996 • S. Shalev-Shwartz, S. Ben-David: Understanding Machine Learning, Cambridge University Press 2014.
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Written examination, 90 min. **OR** • Oral examination, 30-45 min. (with small number of participants) In the first lecture it will be announced, if the examination will be offered in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	100
Remarks	• Study programme Informatik M.Sc.: Compulsory elective module in complex „Grundlagen der Informatik" (level 400) • Study programme Cyber Security M.Sc.: Compulsory elective module in complex „Computer Science" • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Learning and Reasoning“ • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Kognitions- und Neurowissenschaft“

- Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“
- Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend
- Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend
- Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“
- Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“

Module Components

- Lecture: Neural Networks and Learning Theory
- Accompanying exercise
- Related examination

Components to be offered in the Current Semester

120162 Examination
Neural Networks and Learning Theory (Wiederholung)

Module 13843 Scientific Computing

assign to: Advanced Mathematical Methods in Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13843	Compulsory elective

Modul Title	**Scientific Computing** Methoden des Scientific Computing
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Breuß, Michael Prof. Dr.-Ing. Oevermann, Michael
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students will have extended the knowledge and skills acquired in the previous numerical modules. They will have acquired advanced knowledge for understanding modern simulation methods in a wide variety of areas of science and technology.
Contents	The aim of the module is to introduce advanced methods used in scientific computing. The main part of the course is devoted to the discretization of partial differential equations. Among the topics are: The variety of discrete grid types used in discretizations, Finite-Element-Methods, Finite-Volume-Methods, special Finite-Difference-Methods, a variety of time stepping methods for time-dependent partial differential equations, TVD-Schemes for hyperbolic conservation laws, iterative solvers for sparse linear systems of equations.
Recommended Prerequisites	Knowledge of the content of the modules: • 11925 *Grundlagen der Numerischen Mathematik* • 11943 *Grundlagen des Wissenschaftlichen Rechnens* • 11414 *Funktionentheorie und Partielle Differentialgleichungen* as well as programming skills, typically Matlab and C / Fortran
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester

	Practical training - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	The literature in use may change over time and will be announced at the first class meeting.
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of homework **Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30 min. In the first lecture it will be anounced, if the examination will be offered in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Numerics“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Specialisation“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Specialisation“, in limited extend • Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“ • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanded Methods“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Numerics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“
Module Components	• Lecture: „Scientific Computing“ • Accompanying exercise • Accompanying laboratory • Related examination
Components to be offered in the Current Semester	**130320** Lecture Scientific Computing - 4 Hours per Term **130321** Exercise/Practical training Scientific Computing - 2 Hours per Term **130323** Examination Scientific Computing

Module 13863 Mathematical Statistics

assign to: Advanced Mathematical Methods in Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13863	Compulsory elective

Modul Title	**Mathematical Statistics** Mathematische Statistik
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wunderlich, Ralf Prof. Dr. rer. nat. Hartmann, Carsten
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	The students • are skilled in probability theory, • know the basic statistical models and learn how to correctly use statistical methods • can study advanced topics in stochastics • understand statistical methods thoroughly to avoid biased and false conclusions • are experienced in autonomously doing research based on specific applications.
Contents	• Descriptive statistics (central tendency and variation, quantiles, linear regression) • Parameter estimation (point estimates, confidence intervals, Bayesian estimastion, sufficient statistic) • Hypothesis testing (statistical tests, Neyman-Pearsonlemma, one- and two-sided tests) • Linear models (regression and variance analysis, linear classification, Gauss-Markov theorem) • Applications and use of statistical software
Recommended Prerequisites	Knowledge of the content of module • 11217: Probability Theory
Mandatory Prerequisites	No successful participation in module *11331 - Mathematische Statistik*.
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester

	Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• G. Casella, R.L. Berger. Statistical Inference. Duxbury, 2002 • W.R. Pestman. Mathematical Statistics. De Gruyter 1998 • Jun Shao, Mathematical Statistics, Springer, 2003, DOI: 10.1007/b97553 • H.-O. Georgii, Stochastics: Introduction to Probability and Statistics, De Gruyter, 2008 (DOI: 10.1515/9783110206760)
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of homework **Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30 min. In the first lecture it will introduced, if the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematik B.Sc.: Compulsory elective module in complex „Specialisation“ • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Specialisation“ • Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“ • Study programme Informatik B.Sc.: Compulsory elective module in „Applied Mathematics“ or in field of application „Mathematics“ • Study programme Informatik M.Sc.: Compulsory elective module in „Mathematics“ or in field of application „Mathematics“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Stochastics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“
Module Components	• Lecture: Mathematical Statistics • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 13889 Stochastic Processes

assign to: Advanced Mathematical Methods in Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13889	Compulsory elective

Modul Title	**Stochastic Processes** Stochastische Prozesse
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wunderlich, Ralf Prof. Dr. rer. nat. Hartmann, Carsten
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Each summer semester odd year
Credits	8
Learning Outcome	After successfully completing the module, students • are familiar with the basic concepts and ideas behind random processes, • know models and methods for time-dependent random phenomena, • are prepared for studying advanced topics in stochastics • have experience in autonomously doing research based on specific applications.
Contents	• Markov processes, discrete and continuous in time, • communication classes and asymptotic behaviour of Markov chains • processes with independent and stationary increments, martingales • stopping times and stopping theorems, optimal stopping • applications from finance, science and engineering
Recommended Prerequisites	Knowledge of the contents of module • 11217 Wahrscheinlichkeitstheorie
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Self organised studies - 180 hours
Teaching Materials and Literature	• P. Bremaud. Markov Chains, Springer, 1999. • K.L Chung. Markov Chains: With Stationary Transition Probabilities. Springer, 2012. • J.L. Doob: Stochastic Processes. Wiley, 1990.

- R. Durrett. Essentials of Stochastic Processes. Springer, 1999.
- S.R.S. Varadhan. Stochastic Processes. AMS, 2007.

Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Written examination, 90 min. **OR** • Oral examination, 30 min. In the first lecture it will be anounced, if the examination will be offered in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in the complex „Stochastik“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Specialisation“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Specialisation“, in limited extend • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“ • Study programme Informatik B.Sc.: Compulsory elective module in field of application „Mathematik“ • Study programme Informatik M.Sc.: Compulsory elective module in field of application „Mathematik“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Stochastics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“
Module Components	• Lecture: Stochastic Processes • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 13911 Algebra: Structures and Algorithms

assign to: Advanced Mathematical Methods in Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13911	Compulsory elective

Modul Title	**Algebra: Structures and Algorithms** Algebra: Strukturen und Algorithmen
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Averkov, Gennadiy
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students are able to work with basic algebraic concepts and know basic algebraic facts and constructions. They are able to use this knowledge to solve algebraic problems, with our without the assistance of computer-algebra systems. Students understand the basic algebraic algorithmic machinery of computational algebra.
Contents	• Commutative rings and ideals • Affine varieties • Groebner basis and the Hilbert basis theorem • Elimination of variables with Groebner bases and resultsants • Hilbert's Nullstellensatz • Selected applications (e.g. global optimization, solution of kinematic problems, automated theory proving)
Recommended Prerequisites	Knowledge of the content of the modules • 11101: *Lineare Algebra und analytische Geometrie I* or • 11112: *Mathematik IT-1 (Diskrete Mathematik)*, and • 11113: *Mathematik IT-2 (Lineare Algebra)*
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 120 hours

Teaching Materials and Literature	• D. Cox, J. Little, and D. O'Shea: Ideals, Varieties, and Algorithms–An Introduction to Computational Algebraic Geometry and Commutative Algebra, Springer Publishing Company, 2010 • D. Cox, J. Little, and D. O'Shea: Using Algebraic Geometry, Springer Publishing Company, 2005 • S. Lang: Algebra, Springer Publishing Company, 2002
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	**Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30 - 45 min. (with small number of participants) In the first lecture it will introduced, if the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“ • Studiengang Mathematics M.Sc.: Wahlpflichtmodul im Komplex „Analysis / Algebra / Combinatorics“ • Studiengang Mathematical Data Science M.Sc.: Wahlpflichtmodul im Komplex „Advanced Mathematical Methods in Data Science“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanded Methods“ • Study programme Informatik B.Sc.: Compulsory elective module in „Praktische Mathematik" or in field of application „Mathematics" • Study programme Informatik M.Sc.: Compulsory elective module in „Mathematik" or in field of application „Mathematik" • Study programme Cyber Security M.Sc.: Compulsory elective module in complex „Computer Science“
Module Components	• Lecture *Algebra: Structures and Algorithms*, with integrated exercise • Related examination
Components to be offered in the Current Semester	**130220** Lecture/Exercise Algebra: Structures and Algorithms - 4 Hours per Term **130222** Examination Algebra: Structures and Algorithms

Module 13912 Coding Theory

assign to: Advanced Mathematical Methods in Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13912	Compulsory elective

Modul Title	**Coding Theory** Datenkodierung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Averkov, Gennadiy
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students will know and understand the problems and basics of data coding. They can transfer known facts and procedures of linear algebra to this application field and have learned further concepts of algebra. They know linear codes and understand the meaning of the parameters. They know simple decoding algorithms, can apply them and show their correctness.
Contents	• Basics of coding theory • Theory of linear codes • Examples of linear codes, in particular, Reed-Solomon codes • General and specific decoding algorithms • Simple Goppa codes
Recommended Prerequisites	Knowledge of the content of the modules • 11101: *Lineare Algebra und analytische Geometrie I* or • 11112: *Mathematik IT-1 (Diskrete Mathematik)*, and • 11113: *Mathematik IT-2 (Lineare Algebra)*
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• van Lint, J., van der Geer, G., Introduction to Coding Theory and Algebraic Geometry

	• J.I. Hall, Notes on Coding Theory • Willems, Wolfgang, Codierungstheorie und Kryptographie
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	**Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30 - 45 min. (with small number of participants) In the first lecture it will introduced, if the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“ • Study programme Informatik B.Sc.: Compulsory elective module in „Praktische Mathematik" or in field of application „Mathematics" • Study programme Informatik M.Sc.: Compulsory elective module in „Mathematik" or in field of application „Mathematik" • Study programme Cyber Security M.Sc.: Compulsory elective module in complex „Computer Science“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“
Module Components	• Lecture *Coding Theory*, with integrated exercise • Related examination
Components to be offered in the Current Semester	**130251** Examination Coding Theory (Wiederholung)

Module 14085 Graph Theory

assign to: Advanced Mathematical Methods in Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	14085	Compulsory elective

Modul Title	**Graph Theory** Graphentheorie
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Köhler, Ekkehard
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Each winter semester odd year
Credits	8
Learning Outcome	The students • Know the most important terms and connections of graph theory • Are able to apply graph theoretical concepts to solve practical problems • Used the example of graph theroretic topics to attain experience in self-contained scientific working
Contents	• Basic concepts, graphs, connectivity, trees • Matchings, colorings, flows • Hall's theorem, König's theorem, chromatic number, Menger's theorem • Planar graphs, Euler characteristic, Kuratowski's theorem, duality, cycle bases • Ethical responsibility in the application of models, algorithms and results
Recommended Prerequisites	Knowledge of the content of the modules • 11101: Lineare Algebra und analytische Geometrie I • 11102: Lineare Algebra und analytische Geometrie II or • 11112: Mathematik IT-1 (Diskrete Mathematik) • 11113: Mathematik IT-2 (Lineare Algebra)
Mandatory Prerequisites	• No successful participation in module 11415 Graphtheorie
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester

	Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• D.B. West: Introduction to Graph Theory. (Prentice Hall, 1996) • R. Diestel: Graphentheorie. (Springer,1996)
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of homework **Final module examination:** • Written examination, 90 min.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“ • Study programme Mathematics M.Sc.:Compulsory elective module in complex „Analysis / Algebra / Combinatorics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Informatik B.Sc.: Compulsory elective module in „Praktische Mathematik“ or in field of application „Mathematik“ • Study programme Informatik M.Sc.: Compulsory elective module in „Mathematik“ or in field of application „Mathematik“ • Study programme Künstliche Intelligenz B.Sc.: Compulsory elective module in complex „Wissensakquise, -repräsentation und -verarbeitung“ • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Software-basierte Systeme“ • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“ • Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“
Module Components	• Lecture: Graph Theory • Accompanying exercises • Related examination
Components to be offered in the Current Semester	**130410** Lecture Graph Theory - 4 Hours per Term **130411** Exercise Graph Theory - 2 Hours per Term **130413** Examination Graph Theory - 2 Hours per Term

Module 14114 High-Dimensional Statistics

assign to: Advanced Mathematical Methods in Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	14114	Compulsory elective

Modul Title	**High-Dimensional Statistics** Hochdimensionale Statistiken
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Hartmann, Carsten
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students have deepened their knowledge of stochastics acquired in the basic modules. They know the mathematical and statistical methods from data analysis. They have acquired basic skills for in-depth modules in stochastics or optimization. They also have experience in doing independent research.
Contents	Variety of the following topics: • Concentration of random vectors in high dimensions • Concentration inequalities • Linear and nonlinear principal component analysis (PCA) • Random matrices • Sparse recovery (compressed sensing) and LASSO regression • Introduction to statistical learning • Kernel methods and Gaussian processes • Applications in signal and image processing, random networks, …
Recommended Prerequisites	Knowledge of the content of the modules • 11103: Analysis I • 11104: Analysis II • 11101: Lineare Algebra und analytische Geometrie I • 11217: Wahrscheinlichkeitstheorie or very good knowledge of the content of the modules • 11113: Mathematics IT-2 (Linear Algebra) • 11213: Mathematics IT-3 (Analysis) • as well as of the content one of the modules - 11917: Mathematik W-3 (Statistik)

	- 11926: Statistik für Anwender - 11212: Statistics
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• C.M. Bishop. Pattern Recognition and Machine Learning. Springer, 2006. • D.P. Dubhashi, A. Panconesi. Concentration of Measure for the Analysis of Randomized Algorithms, Cambridge University Press, 2009. • R. van Handel. Probability in High Dimension. Lecture Notes, Princeton University, 2016. • R. Vershynin. High-Dimensional Probability: An Introduction with Applications in Data Science, Cambridge University Press, 2018
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite for Final Module Examination:** • Successful completion of a semester project **Final Module Examination:** • Project presentation, 45 min.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Stochastics“ or in complex „Optimization“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Specialisation“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Specialisation“, in limited extend • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Learning and Reasoning“ • Study programme Informatik B.Sc.: Compulsory elective module in „Applied Mathematics“ or in field of application „Mathematics“ • Study programme Informatik M.Sc.: Compulsory elective module in „Mathematics“ or in field of application „Mathematics“ • Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“
Module Components	• Lecture: High-Dimensional Statistics • Accompanying exercise
Components to be offered in the Current Semester	No assignment

Module 14263 Mixed-Integer Programming

assign to: Advanced Mathematical Methods in Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	14263	Compulsory elective

Modul Title	**Mixed-Integer Programming** Gemischt-ganzzahlige Programmierung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Fügenschuh, Armin
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students know the basic concepts (definitions, theorems and proofs) in the field of mixed-integer programming. They are able to formalize an applied optimization problem and solve it with mathematical means.
Contents	Polyhedron theory, estimations in integer optimization, complexity theory, totally unimodular matrices, integer polyhedra and total dual integrity, cutting planes, branch-and-bound, Lagrange Relaxations, Benders decomposition, dynamic programming, stochastic programming, column generation methods, heuristics, nonlinear mixed-integer programming, applications
Recommended Prerequisites	Knowledge in linear and mixed-integer optimization, e.g. knowledge of the content of modules • 13862 *Optimierung und Operations Research* • 11322 *Optimierungsmethoden des Operations Research* Knowledge of the simplex algorithm is implied.
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	Current literature will be announced or handed out in the first lecture.
Module Examination	Continuous Assessment (MCA)

Assessment Mode for Module Examination	• 4 intermediate tests, written during the lecture period, 30 minutes each The best 3 count 1/3 each for the final grade.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Optimization“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend
Module Components	• Lecture: Mixed-Integer Programming • Accompanying exercise
Components to be offered in the Current Semester	No assignment

Module 14726 Mathematical Optimization Techniques and Applications

assign to: Advanced Mathematical Methods in Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	14726	Compulsory elective

Modul Title	**Mathematical Optimization Techniques and Applications** Mathematische Optimierungstechniken und Anwendungen
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Fügenschuh, Armin
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	Upon successful completion of the module, students will have acquired an understanding of core mathematical tools used in modern optimization. They will be able to identify optimization structures in real-world problems, formalize these problems in mathematical terms, and apply suitable algorithms to obtain and interpret solutions.
Contents	Foundations of optimization theory, global vs. local optimality, geometry of optimization, optimization for graph problems, fundamentals of linear programming, duality principles, advanced simplex methods, discrete optimization, interior point and ellipsoid methods, nonlinear optimization, applied modeling. Emphasis is placed both on theoretical insights and algorithmic implementation.
Recommended Prerequisites	Knowledge of subject matters of the modules • 11103: Analysis I • 11104: Analysis II • 11101: Lineare Algebra und analytische Geometrie I or of the modules • 11112: Mathematik IT-1 (Diskrete Mathematik) • 11113: Mathematik IT-2 (Lineare Algebra) • 11213: Mathematik IT-3 (Analysis)
Mandatory Prerequisites	• No successful participation in module 13862 Optimierung und Operations Research.

Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 90 hours
Teaching Materials and Literature	• V. Chvatal, Linear Programming, Bedford St Martins Pr 3PL, 2016 • R.J. Vanderbei: Linear Programming - Foundations and Extensions, 5th Edition, Springer, 2020
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• 4 intermediate tests of 30 minutes each, written during the lecture period. The best 3 count 1/3 each for the final grade.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Optimierung" • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Optimization" • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Advanced Mathematical Methods in Data Science" • Study programme Artificial Intelligence Science M.Sc.: Compulsory elective module in complex „Advanced Methods" • Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject"
Module Components	• Lecture: Optimization and Operations Research • Accompanying exercise
Components to be offered in the Current Semester	**130710** Lecture Mathematical Optimization Techniques and Applications - 4 Hours per Term **130711** Exercise Mathematical Optimization Techniques and Applications - 2 Hours per Term

Module 11859 Cryptography

assign to: Fundamentals of Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	11859	Compulsory elective

Modul Title	**Cryptography** Kryptographie
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil Meer, Klaus Prof. Dr. rer. nat. Averkov, Gennadiy
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	8
Learning Outcome	The students should • know relevant symmetric and asymmetric crypto systems • understand the mathematics relevant for desgining and analyzing crypto systems • be able to explain and use the most important approaches to cryptography • gain the ability to understand state-of-the-art scientific work in the area of cryptography
Contents	• Mathematical Foundations relevant in the context of cryptography, including basic number theory, finite fields, polynomial rings, factorization • elementary crypto systems • Symmetric Cryptosystems DES and AES • public key cryptography, RSA - discrete logarithm, elliptic curve systems • secure signature and authentication methods • security of crypto systems • zero knowledge proofs • complexity theoretic aspects
Recommended Prerequisites	Basic knowledge about discrete mathematics and linear algebra, for example as covered by the modules • 11101: Lineare Algebra und analytische Geometrie I • 11102: Lineare Algebra und analytische Geometrie II

	or • 11112: Mathematik IT-1 (Diskrete Mathematik) • 11113: Mathematik IT-2 (Lineare Algebra)
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	**Books in English** • G. Baumslag, B. Fine, M. Kreuzer, G. Rosenberger: A Course in Mathematical Cryptography, De Gruyter, 2015 • J. Hoffstein, J. Pipher, J.H. Silverman: An Introduction to Mathematical Cryptography, 2nd Edition, Springer 2014. • D.R. Stinson: Cryptography: Theory and Practice, CRC, 1995 **Books in German** • V. Diekert, M. Kufleitner, G. Rosenberger: Diskrete Algebraische Methoden, De Gruyter 2013
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of homework (fortnightly) and/or successful completion of tests (approx. 4 tests of 15-30 minutes each, written during the lecture period) **Final module examination:** • Written examination, 90 minutes, **OR** • Oral examination, 30 - 45 minutes, (in case of a small number of participants) In the first lecture it will be anounced, if the examination will be offered in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	80
Remarks	• Study programme Cyber Security M.Sc.: Mandatory module in complex „Cyber Security Basics“ • Study programme Informatik M.Sc.: Compulsory elective module in complex „Mathematik“ or in field of application „Mathematik“ • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanced Methods“ • Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Physics M. Sc.: Compulsory elective module in complex „Minor Subject"

	• Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“
Module Components	• Lecture: Cryptography • Accompanying exercises • Related examination
Components to be offered in the Current Semester	**120164** Examination Cryptography (Wiederholung)

Module 11881 Foundations of Data Mining

assign to: Fundamentals of Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	11881	Compulsory elective

Modul Title	**Foundations of Data Mining** Grundlagen des Data Mining
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. habil. Schmitt, Ingo
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	Acquaintance with the statistical and learning-theoretical foundations of knowledge extraction from large data sets; knowledge of specific notions and of mathematical background in order to understand current publications and software concerning the field; ability of transfer to concrete problems; knowledge of algorithms and their usage.
Contents	• Foundation of statistics • Clustering (partition-based, density-based, hierarchical, ...) • Classification (decision trees, support vector machines, deep learning on convolution neural networks, ...) • Association rules (frequent itemsets) • further data mining approaches Acquired knowledge will be applied within a project.
Recommended Prerequisites	The module cannot be successfully completed without knowledge of the content of • 11112 *Mathematik IT-1 (Diskrete Mathematik)* • 11113 *Mathematik IT-2 (Lineare Algebra)*
Mandatory Prerequisites	• No successful participation in module 12351 *Grundlagen des Data Mining*.
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 1 hours per week per semester Practical training - 1 hours per week per semester Self organised studies - 120 hours

Teaching Materials and Literature	• James, Gareth; Witten, Daniela; Hastie, Trevor; Tibshirani, Robert: An Introduction to Statistical Learning with Applications in R. Springer, New York 2013. • Aloaydin, Ethem: Machine Learning. The MIT Press, Massachusetts Institute of Technology, 2004. • Mitchell, Tom M.: Machine Learning. McGraw-Hill, 1997.
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of practical training tasks and exercises tasks **Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30-45 min. (with small number of participants) In the first lecture it will be annunced, if the examination will offered in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	80
Remarks	• Study programme Informatik B.Sc.: Compulsory elective module in complex „Grundlagen der Informatik“ (level 300) • Study programme eBusiness M.Sc.: Compulsory elective module in main focus „Entwicklung und Aufbau von eBusiness-Systemen" • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“ • Study programme Cyber Security M.Sc.: Compulsory elective module in complex „Computer Science“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Anwendungen“, field „Informatik“ • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Anwendungen“, field „Informatik“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“ If there is no need that the module is taught in English, alternatively the german version 12351 „Grundlagen des Data Mining“ may be offered instead. Module 11881 „Foundations of Data Mining“ and 12351 „Grundlagen des Data Mining“ can not be combined.
Module Components	• Lecture Foundations of Data Mining • Accompanying exercise with laboratory • Related examination
Components to be offered in the Current Semester	**120230** Lecture Grundlagen des Data Mining / Foundations of Data Mining - 2 Hours per Term **120231** Exercise

Grundlagen des Data Mining / Foundations of Data Mining - 2 Hours per Term
120234 Examination
Grundlagen des Data Mining / Foundations of Data Mining

Module 13500 Introduction to Neural Signal Analysis

assign to: Fundamentals of Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13500	Compulsory elective

Modul Title	**Introduction to Neural Signal Analysis** Einführung in die neuronale Signalanalyse
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. habil. Glasauer, Stefan
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students will demonstrate a comprehensive understanding of neural signaling and EEG signal acquisition. They will possess the ability to apply basic time and frequency domain analyses for processing EEG signals.
Contents	• Introduction to Neural Signaling • EEG Signal Acquisition • Artifacts and preprocessing techniques • Time Domain Analysis • Evoked potentials • Frequency Domain and EEG signals spectral analysis • Applications in Computational Neuroscience • Ethical aspects of brain wave measurements
Recommended Prerequisites	Knowledge of the topics of the modules • 11112 Mathematik IT-1 (Diskrete Mathematik) • 11113 Mathematik IT-2 (Lineare Algebra) • 11213 Mathematik IT-3 (Analysis) • 11756 Algorithmen und Datenstrukturen
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours

Teaching Materials and Literature	• Biomedical Signal Analysis (IEEE Press Series on Biomedical Engineering), Rangaraj M. Rangayyan, Wiley-IEEE Press, ISBN:9780470911396
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of homework **Final Module Examinatio:** • Written exam, 120 minutes **OR** • Oral examination, 30-45 minutes In the first lecture it will be announced, if the examination will be offered in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	100
Remarks	• Study programme Medizininformatik B.Sc.: Compulsory elective module in complex „Medizininformatik" • Study programme Informations- und Medientechnik B. Sc.: Complex „Informatik", compulsory elective module module in the field of study „Kognitive Systeme" • Study programme Informatik B.Sc.: Compulsory elective module in complex „Praktische Informatik" (level 300) • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“
Module Components	• Lecture: Introduction to neural signal analysis • Accompanying exercise • Related examination
Components to be offered in the Current Semester	**140340** Lecture Introduction to Neural Signal Analysis - 2 Hours per Term **140341** Exercise Introduction to Neural Signal Analysis - 2 Hours per Term **140344** Examination Introduction to Neural Signal Analysis

Module 13813 Logic in Databases

assign to: Fundamentals of Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13813	Compulsory elective

Modul Title	**Logic in Databases** Logik in Datenbanken
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. habil. Schmitt, Ingo
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	After successfully completing the module, students will will be able expressions of different kinds of logic for data modeling and querying as well as for information extraction.
Contents	Predicate logic, Herbrand model, datalog, fuzzy logic, quantum mechanics and logic, query language CQQL, probabilistic databases, algorithms for evaluating logical expressions.
Recommended Prerequisites	none
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Practical training - 2 hours per week per semester Self organised studies - 150 hours
Teaching Materials and Literature	• Foundations of Databases“, Abiteboul, Hull, Vianu, Addison Wesley, 1996 • „Multimedia-Kurs Datenbanksysteme“, Werner Kießling, Springer-Verlag, 1998 • „Quantenlogik für Ingenieure und Informatiker“, Günther Wirsching, Ingo Schmitt, Matthias Wolff, Springer-Verlag • Script
Module Examination	Prerequisite + Final Module Examination (MAP)

Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of practical training tasks and exercise tasks **Final module examination:** • Written examination, 90 min. OR • Oral examination, 30-45 min. (with small number of participants) In the first lecture it will announced, wheter the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	80
Remarks	• Study programme Informatik M.Sc.: Compulsory elective module in complex "Grundlagen der Informatik" (level 400) • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“
Module Components	• Lecture: Logic in Databases • Accompanying exercise • Accompanying laboratory • Related examination
Components to be offered in the Current Semester	**120220** Lecture Logic in Databases - 2 Hours per Term **120221** Exercise Logic in Databases - 2 Hours per Term **120223** Examination Logic in Databases

Module 13838 Information Retrieval

assign to: Fundamentals of Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13838	Compulsory elective

Modul Title	**Information Retrieval** Information Retrieval
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. habil. Schmitt, Ingo
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	Students know about problems, models and methods of information retrieval. This includes understanding the concepts of search engines and implementation with their advantages and disadvantages.
Contents	The goal of information retrieval is the search for text documents. With the growth of the internet this goal gained much importance. The course introduces several information retrieval models and algorithms. Furthermore, concepts of how to evaluate retrieval results will be discussed. The content of the course is: • Motivation and introduction to the search of textual documents • Evaluation of IR systems • Vagueness in languages • Simple IR models and their implementations • Vector Space Model • Format of document management • Alternatives to global search • Search engines in WWW Acquired knowledge will be applied within a project.
Recommended Prerequisites	The module cannot be successfully completed without knowledge of the content of • 12330 *Datenbanken*
Mandatory Prerequisites	No successful participation in module 14460 Information Retrieval.

Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 1 hours per week per semester Laboratory training - 1 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• "Information Retrieval", van Rijsbergen (as HTML on the Web) • "Information Retrieval 1: Grundlagen, Modelle und Anwendungen", Andreas Henrich (as PDF on the Web)
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • successful completion in practical training tasks and in exercises tasks **Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30-45 min. (with small number of participants) In the first lecture it will announced, whether the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	80
Remarks	• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Acquisition, Representation, and Processing“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“
Module Components	• Lecture: Information Retrieval • Accompanying exercises (with integrated laboratory) • Related examination
Components to be offered in the Current Semester	**120278** Examination Information Retrieval (Wiederholung)

Module 13842 Virtual Reality and Agents

assign to: Fundamentals of Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13842	Compulsory elective

Modul Title	**Virtual Reality and Agents** Virtual Reality und Agenten
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. habil. Cunningham, Douglas
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students have acquired knowledge of approaches, trends and applications of virtual and mixed environments (virtual and mixed reality). Among other things, they are familiar with tracking, display systems, interaction, input options, scene graphs and collision detection.
Contents	The course focuses on a particular form of Human-Computer Interaction: virtual environments and embodied virtual agents. With the help of tracking and advanced computer graphics, users can be embedded in a virtual environment and allowed to interact with it. Specific topics that will be covered include registration and tracking, perception and Virtual Reality, Display and input systems, interaction techniques, scene graphs, rendering for virtual and mixed environments, collision detection, complete virtual reality systems, applications, knowledge of approaches, trends and applications of virtual and mixed environments (virtual and mixed reality) as well as of embodied virtual agents.
Recommended Prerequisites	Knowledge of the content of module • 12311 *Grundzüge der Computergrafik*
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Practical training - 2 hours per week per semester Study project - 1 hours per week per semester

	Self organised studies - 75 hours
Teaching Materials and Literature	• Doug Bowman, et al.: 3D User Interfaces. Theory and Practice, Addison Wesley, 2004 • Grigore Burdea, Philippe Coiffet: Virtual Reality Technology, 2. Auflage, Wiley & Son, 2003 • William Sherman, Alain Craig: Understanding Virtual Reality. Interfaces, Applications and Design, Morgan Kaufman, 2002 • Roy Kalawsky: The Science of Virtual Reality and Virtual Environments, Addison-Wesley, 1993 Suggestions for further literature can be found on the department's website.
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Written examination, 120 min. **OR** • Oral examination, 30-40 min. (with small number of participants) In the first lecture it will be announced, wheter the examination will be organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	100
Remarks	• Study programme Informatik M.Sc.: Compulsory elective module in complex „Praktische Informatik“(level 400) • Study programme Informations- und Medientechnik B.Sc.: Compulsory elective module in complex: „Informatik“, all fields of study • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“
Module Components	• Lecture: Virtual Reality and Agents • Accompanying exercises • Accompanying laboratory • Related examination
Components to be offered in the Current Semester	**120970** Examination Virtual Reality and Agents (Wiederholung)

Module 13844 Functional Analysis

assign to: Fundamentals of Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13844	Compulsory elective

Modul Title	**Functional Analysis** Funktionalanalysis
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Wachsmuth, Gerd
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	8
Learning Outcome	The students have • expanded and intensified their knowledge from previous modules of Analysis and Algebra • competently mastered definitions and interrelations within abstract spaces • become acquainted with applications in Numerics, Optimization, and Physics • acquired basic knowledge for advanced modules • became familiar with fundamental techniques of proof • improved their logical way of thinking by solving problems in abstract spaces • further developed their abilities for independent scientific work by treating themes from Functional Analysis
Contents	• **Normed spaces** completion, separable spaces, Lebesgue spaces, spaces of continuous and differentiable functions, Sobolev spaces • **Linear and continuous operators** Projection and adjoint operators, topological dual spaces, completely continuous operators, weak convergence and reflexivity • **Main theorems** Weierstrass, Hahn-Banach, Schauder, the openmapping, the closed graph • **Hilbert spaces** Spectral theorem for selfadjoint, completely continuous operators
Recommended Prerequisites	Knowledge of the content of the modules

- 11103 *Analysis I*
- 11104 *Analysis II*
- 11201 *Analysis III*

Mandatory Prerequisites

No successful participation in module *11303 - Funktionalanalysis*.

Forms of Teaching and Proportion

Lecture - 4 hours per week per semester
Exercise - 2 hours per week per semester
Self organised studies - 150 hours

Teaching Materials and Literature

- Aubin, J.-P.: Applied Functional Analysis, Wiley, 2000, https://doi.org/10.1002/9781118032725
- Brezis, H.: Functional Analysis, Sobolev Spaces and Partial Differential Equations, Springer, 2011, https://doi.org/10.1007/978-0-387-70914-7
- Rudin, W.: Functional Analysis, McGraw Hill, 1991

Module Examination

Prerequisite + Final Module Examination (MAP)

Assessment Mode for Module Examination

Prerequisite:
- Successful completion of homework

Final module examination:
- Written examination, 90 min. **OR**
- Oral examination, 30 min. (with small number of participants)

In the first lecture it will introduced, if the examination will organized in written or oral form.

Evaluation of Module Examination

Performance Verification – graded

Limited Number of Participants

none

Remarks

- Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“
- Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend
- Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend
- Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“
- Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanded Methods“
- Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics“
- Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“

If there is no need that the module is taught in English, alternatively the german version 11303 „Funktionalanalysis“ may beread instead.

Module Components

- Lecture: Functional Analysis
- Accompanying exercises
- Related examination

Components to be offered in the Current Semester	**130910** Lecture Functional Analysis / Funktionalanalysis - 4 Hours per Term **130911** Exercise Functional Analysis / Funktionalanalysis - 2 Hours per Term **130912** Examination Functional Analysis / Funktionalanalysis

Module 13874 Introduction to Numerical Linear Algebra

assign to: Fundamentals of Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13874	Compulsory elective

Modul Title	**Introduction to Numerical Linear Algebra** Einführung in die Numerische Lineare Algebra
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. Oevermann, Michael
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	After successful completion of the course the students know and understand classic and state of the art numerical methods and algorithms for solving linear systems of equations and to compute eigenvalues and eigenvectors. Through programming exercises they have acquired the practical skills to implement and validate numerical methods for scientific computing applications. The students have learned to use the programming language Python and common Python libraries/toolboxes (Numpy, Scipy) for an efficient and performant implementation methods used in scientific computing.
Contents	The module focuses on methods and algorithms suitable for solving linear sets of equations as they typically arise in many applications such as solving/discretzising partial differential equations in engineering sciences or machine learning algorithms. In particular we will cover: • Classic iterative methods for solving linear systems of equations (Jacobi, Gauß-Seidel, SOR) • Projection type methods for solving linear systems of equations (CG, GMRES) • Direct methods for sparse linear systems of equations • Jacobi eigenvalue algorithm, power iteration, QR iteration Additionally, we will address practical issues of solving large sparse systems of linear equations such as storage schemes and parallelisation strategies.

Recommended Prerequisites	Basic knowledge of mathematics as conveyed by mathematical courses in computer science or engineering from the first three to four semesters, e.g.: • Module 11101 *Lineare Algebra und analytische Geometrie I*, and • Module 11103 *Analysis I* or • Module 11112 *Mathematik IT-1 (Diskrete Mathematik)* • Module 11113 *Mathematik IT-2 (Lineare Algebra)* • Module 11213 *Mathematik IT-3 (Analysis)* or • Module *Höhere Mathematik - T1* • Module 11108 *Höhere Mathematik - T2* • Module 11206 *Höhere Mathematik - T3*
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• G. H. Golub, C. F. van Loan: Matrix Computations • L. N. Trefethen, D. Bau: Numerical Linear Algebra, SIAM • Y. Saad: Iterative Methods for Sparse Linear Systems • T. A. Davis: Direct Methods for Sparse Linear Systems
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• three written examinations during the lecture or exercise period, 30 minutes each (1/3 each; 70% in total) • three programming tasks (1/3 each; 30% in total)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Numerics“ • Study programme Informatik B.Sc.: Compulsory elective module in complex „Mathematik“ or in field of application „Mathematik“ • Study programme Informatik M.Sc.: Compulsory elective module in complex „Mathematik“ or in field of application „Mathematik“ • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanded Methods“ • Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Numerics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“

	Change from MAP to MCA. Registration for repitition of the MAP module only possible via Student Services.
Module Components	• Lecture: Introduction to Numerical Linear Algebra • Accompanying exercise
Components to be offered in the Current Semester	**131130** Examination Introduction to Numerical Linear Algebra (Wiederholung)

Module 13949 Differential Geometry

assign to: Fundamentals of Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13949	Compulsory elective

Modul Title	**Differential Geometry** Differentialgeometrie
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Breuß, Michael
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students are familiar with the basic concepts and techniques of differential geometry and able to apply the appropriate techniques.
Contents	• Euclidean geometry • Curve geometry • Classic planar theory • Inner planar geometry • Connection of geometry with calculus and topology
Recommended Prerequisites	Knowledge of the content of the modules • 11103: *Analysis I* • 11104: *Analysis II* • 11101: *Lineare Algebra und analytische Geometrie I*
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 3 hours per week per semester Exercise - 1 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• Martin Lipschutz, Schaum's Outline of Differential Geometry, Schaum Outline Series
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of homework (50% of points must be reached)

	Final module examination: • Written examination, 90 min.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Angewandte Mathematik M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Kombinatorik“ • Study programme Mathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Wirtschaftsmathematik B.Sc.: Compulsory elective module in complex „Vertiefung“, in limited extend • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“ • Study programme Physics M.Sc.: Compulsory elective module in complex „Minor Subject“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Analysis / Algebra / Combinatorics“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“
Module Components	• Lecture: Differential Geometry • Accompanying exercise • Related examination
Components to be offered in the Current Semester	**130330** Lecture/Exercise Differential Geometry / Differentialgeometrie - 4 Hours per Term **130332** Examination Differential Geometry / Differentialgeometrie

Module 14186 Image Processing and Computer Vision

assign to: Fundamentals of Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	14186	Compulsory elective

Modul Title	**Image Processing and Computer Vision** Bildverarbeitung und Computer Vision
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. habil. Breuß, Michael
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students are acquainted with basic and advanced techniques and mathematical models for processing digital image data and dealing with various computer vision tasks.
Contents	In the lectures theory and methods are presented. The material is illustrated in the tutorial at hand of typical problems in the field. In a study project the students deepen their knowledge about given techniques. Main topics are: • Mathematical description of images and basic as well as advanced image filtering operations • Algorithms and theory for selected image transformations, e.g. Fourier transform and morphological filters • Introduction into a selection of important computer vision tasks and methods, e.g. in optical flow, object detection, object tracking, segmentation
Recommended Prerequisites	Knowledge of the content of modules • 11113 Mathematik IT-2 (Lineare Algebra) • 11213 Mathematik IT-3 (Analysis)
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Study project - 60 hours

	Self organised studies - 60 hours
Teaching Materials and Literature	none
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of study project tasks **Final module examination:** • Written examination, 90 min.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Fundamentals of Data Science“
Module Components	none
Components to be offered in the Current Semester	**130390** Examination Image Processing and Computer Vision (Wiederholung)

Module 14440 Causal Data Science

assign to: Fundamentals of Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	14440	Compulsory elective

Modul Title	**Causal Data Science** Kausale Datenanalyse
Department	Faculty 5 - Business, Law and Social Sciences
Responsible Staff Member	Prof. Dr. Urbig, Diemo
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	Students have a basic understanding of data science in the context of the identification of causal relationships. They are familiar with a verbal and graphical language to communicate about causality, and with key concepts, such as counterfactuals, outcome equivalence, and confounding effects. They know about typical classes of problems that do not allow causal interpretations of observed associations as well as typical solutions for these problems by means of data analytic and data collection methods. Moreover, students understand the tight interdependency of data analytics and the design of data collection to generate high-quality evidence and high-quality predictions.
Contents	1. *Counterfactuals, Potential Outcomes, Causal Graphs, and typical problems (i.e., omitted relevant variables, measurement error, reverse causality, endogenous selection, endogenous treatment)* 2. *Data analytic solutions: control variables, matching, weighting* 3. *Data analytic solutions: instrumental variables, selection instruments* 4. *Data collection solutions: real experiments* 5. *Assumed experiments as mixed solutions: natural experiments, quasi-experiments, regression discontinuity* 6. *Times series data as a mixed solution: diff-in-diff and related methods* 7. *Reflections on moderation and mediation analyses, respectively, structural equation modeling* *The module focuses on applications in business and economics, but the underlying theories and methods generalize beyond these fields. The course complements more traditional data science modules with*

	a stronger focus on implementing data-scientific algorithms. Tutorials also apply these methods to the analysis of real-world problems with simulated and real datasets. Currently, the freely available software [R] is used in the practical parts of the tutorials.
Recommended Prerequisites	• Basics of statistics, especially estimation and testing and simple regression analysis
Mandatory Prerequisites	None
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	The lecture is based on selected chapters mostly from Morgan & Winship (2015). A few other articles or chapters will be provided during the module. Pearl, J. (2009) has become a classic reference in computer science. A more accessible introduction is found in Morgan & Winship (2015), the book on which most of the module is based. An accessible econometric perspective on some aspects of the module is offered by Angrist & Pischke (2014). More details on experiments can be found in Gerber & Green (2012). • Pearl, J. (2009). Causality. Cambridge University Press • Morgan, S. L., & Winship, C. (2015). Counterfactuals and causal inference. Methods and Principles for Social Research. Cambridge University Press. • Angrist, J. D., & Pischke, J. S. (2014). Mastering'metrics: The path from cause to effect. Princeton university press. • Gerber, A. S., & Green, D. P. (2012). Field experiments: Design, analysis, and interpretation. WW Norton. A few additional shorter articles or chapters might be provided during the course of the module.
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• 3 written partial examinations, 30 min each (each weighted 1/3)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	Tutorials are open to questions in English and German.
Module Components	• Lecture Causal Data Science – 2 Hours per Week per Semester • Exercice Causal Data Science – 2 Hours per Week per Semester
Components to be offered in the Current Semester	No assignment

Module 14731 Combining Operations Research and Data Science

assign to: Fundamentals of Data Science

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	14731	Compulsory elective

Modul Title	**Combining Operations Research and Data Science** Kombination von Operations Research und Data Science
Department	Faculty 5 - Business, Law and Social Sciences
Responsible Staff Member	Prof. Dr. rer. pol. Xie, Lin
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	By the end of the course, students will be able to analyze and solve complex decision-making and optimization problems under uncertainty. They will be capable of selecting, combining, and adapting appropriate methods from Operations Research, Data Science, and Machine Learning. Additionally, they will be able to identify, evaluate, and apply suitable optimization algorithms to real-world problem settings.
Contents	• Introductory Case Study, Representing and Computing with Uncertain Quantities • Obtaining Probability Distributions and Probabilistic Machine Learning • Decision Making Under Uncertainty, the Value of Information • Optimization Under Uncertainty I: Two-Stage Stochastic Programming • Optimization Under Uncertainty II: Chance-Constrained Programming • Machine Learning for Algorithm Selection • Algorithm Configuration Home Assignments: • A new set of tasks (including formulating and implementing mathematical optimization models, writing and executing python code for simple machine learning tasks, etc) will be assigned **each week** for students to work on **independently at home**. • These homework tasks are **not mandatory**, but students are **strongly encouraged** to attempt them. • During the **exercise sessions**, selected homework problems will be discussed and solved collaboratively. • Students who **present solutions** (oral presentation) to homework problems during these sessions will earn **bonus points**.

	In the Exam students will be required to: • Provide the **mathematical formulation** of given problems. • Write the **pseudocode** for the solution of some tasks. • Answer **conceptual questions** related to the course content.
Recommended Prerequisites	• Basics of Python programming, • basics of linear programming, • basics of probability distributions
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• Santos, H.G., Toffolo, T.A.M., Silva, R.M., & Resende, M.G.C. *Mixed Integer Linear Programming with Python*. Retrieved from https://app.readthedocs.org/projects/python-mip/downloads/pdf/latest/ • Birge, J.R., & Louveaux, F. (1999). An introductory tutorial on stochastic linear programming models. *Interfaces*, 29(2), 33–44. https://doi.org/10.1287/inte.29.2.33 • Hutter, F., Kotthoff, L., & Vanschoren, J. (2018). Model evaluation, model selection, and algorithm selection in machine learning. *arXiv preprint arXiv:1811.12808*. Retrieved from https://arxiv.org/pdf/1811.12808
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• written exam, 90 min. 100% exam + bonus points (maximum 10% of the final grade and only valid after passing the exam)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	20
Remarks	Home Assignments: • A new set of tasks (including formulating and implementing mathematical optimization models, writing and executing python code for simple machine learning tasks, etc) will be assigned **each week** for students to work on **independently at home**. • These homework tasks are **not mandatory**, but students are **strongly encouraged** to attempt them. • During the **exercise sessions**, selected homework problems will be discussed and solved collaboratively. • Students who **present solutions** (oral presentation) to homework problems during these sessions will earn **bonus points**. These **bonus points** will be **added to the final grade**, but **only if the student passes the final exam**
Module Components	• Lecture • Exercise

Components to be offered in the Current Semester	**531001** Lecture Combining Operations Research and Data Science - 2 Hours per Term **531002** Exercise Combining Operations Research and Data Science - 2 Hours per Term **531005** Examination Combining Operations Research and Data Science

Module 11494 Control Engineering 1

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	11494	Compulsory elective

Modul Title	**Control Engineering 1** Regelungstechnik 1
Department	Faculty 3 - Mechanical Engineering, Electrical and Energy Systems
Responsible Staff Member	Prof. Dr.-Ing. Schiffer, Johannes
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	On completion of this module, students should be able to: • Analyze the behavior of linear dynamical systems in the frequency domain; • Design single-input-single-output controllers in the frequency domain; • Control linear systems with time delays; • Have developed an understanding for the application of control engineering methods to real-world applications based on examples and laboratory exercises.
Contents	Feedforward and feedback control; Fundamentals on signals and systems (repetition); Description of dynamical systems in the time and frequency domains; Frequency response; Control system properties and specifications; Stability; Hurwitz criterion; Nyquist criterion; Bode diagrams; Controller synthesis in the frequency domain; PID control; Cascaded control; Control of systems with time delays.
Recommended Prerequisites	none
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Laboratory training - 1 hours per week per semester Self organised studies - 105 hours
Teaching Materials and Literature	• K. J. Åström and R. M. Murray, "Feedback Systems", Princeton University Press, 2009

- G. F. Franklin, J. D. Powell, A. Emami-Naeini, "Feedback Control of Dynamic Systems", Vol. 3. Reading, MA: Addison-Wesley, 1994
- J. Lunze, "Regelungstechnik 1", Springer-Verlag, 2013
- Unbehauen, Heinz, "Regelungstechnik I – Klassische Verfahren zur Analyse und Synthese linearer kontinuierlicher Systeme", Vieweg Verlag Braunschweig/Wiesbaden

Module Examination

Prerequisite + Final Module Examination (MAP)

Assessment Mode for Module Examination

Prerequisite:
- Submission of at least 65% of the online homework
- Successful participation in all lab sessions including short tests (ungraded)

Final Module Examination:
- Written exam, 90 minutes

Permitted aids are **two** DIN A4 sheets, **handwritten** on both sides. For calculations, non-programmable calculators are allowed. Any other type of electronic device is **not** allowed. For successfully completed online homework, a maximum of 10% bonus points can be earned for the final examination.

Evaluation of Module Examination

Performance Verification – graded

Limited Number of Participants

none

Remarks

none

Module Components

- Control Engineering 1 (lecture)
- Control Engineering 1 (exercise/practical training)
- Control Engineering 1 (exam)

Components to be offered in the Current Semester

320630 Lecture
Control Engineering 1 - 2 Hours per Term
320631 Exercise/Practical training
Control Engineering 1 - 3 Hours per Term
320673 Examination
Control Engineering 1

Module 11747 Control Engineering 2

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	11747	Compulsory elective

Modul Title	**Control Engineering 2** Regelungstechnik 2
Department	Faculty 3 - Mechanical Engineering, Electrical and Energy Systems
Responsible Staff Member	Prof. Dr.-Ing. Schiffer, Johannes
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	On completion of this module, students should be able to: • Model dynamical multiple-input-multiple-output (MIMO) systems from diverse domains in state-space form; • Analyze the behavior of linear state-space systems; • Understand the concepts of controllability and observability for linear time-invariant (LTI) systems; • Design static and observer-based dynamic state-feedback controllers for LTI MIMO systems.
Contents	State space modeling of dynamical systems; Dynamic behavior of linear systems; Solution of linear time-invariant systems; Lyapunov stability; Controllability and observability; State feedback; Pole placement; PI state feedback control; Control design via linear matrix inequalities; Duality principle; Luenberger-observer and observer-based control; Separation principle; Optimal control (Linear quadratic regulator, H-infinity control)
Recommended Prerequisites	Knowledge in: • Mathematics • Physics • Control Engineering 1 (or equivalent)
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Laboratory training - 1 hours per week per semester Self organised studies - 105 hours

Teaching Materials and Literature	• K. J. Åström and R. M. Murray, "Feedback Systems", Princeton University Press, 2009 • G. F. Franklin, J. D. Powell, A. Emami-Naeini, "Feedback Control of Dynamic Systems", Vol. 3. Reading, MA: Addison-Wesley, 1994 • H. Khalil, "Nonlinear Systems", Prentice-Hall, New Jersey, 1996 • J. Lunze, "Regelungstechnik 2: Mehrgrößensysteme Digitale Regelung", Springer-Verlag, 2013
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	Prerequisite: • Submission of at least 65% of the online homework • Successful participation in all lab sessions including short tests (ungraded) Final Module Examination: • Written exam, 90 minutes Permitted aids are **two** DIN A4 sheets, **handwritten** on both sides. For calculations, non-programmable calculators are allowed. Any other type of electronic device is **not** allowed. For successfully completed online homework, a maximum of 10% bonus points can be earned for the final examination.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	none
Module Components	• Control Engineering 2 (lecture) • Control Engineering 2 (exercise/laboratory) • Control Engineering 2 (exam)
Components to be offered in the Current Semester	**320671** Examination Control Engineering 2

Module 12790 Seminar Advanced Topics in Network and System Security

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	12790	Compulsory elective

Modul Title	**Seminar Advanced Topics in Network and System Security** Seminar Fortgeschrittene Themen in Netzwerk- und Systemsicherheit
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. Panchenko, Andriy
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	Students have a deeper understanding of distributed vs. centralized communication, security and privacy paradigms and their application in collaborative environments. They are capable to establish links between the basic concepts and applied scenarios, with reference to ongoing research activities within the research group IT Security. Students are prepared for the Master's thesis.
Contents	Concrete topics and application scenarios are adapted to the focus of the discussed methods. Typical topics are network and system security, anonymity, privacy enhancing technologies, digital forensics, computer networks, distributed systems, mobile security, web security, applied cryptography, etc. Master students will get assigned a topic that is based on recent publications in one of the top conferences in the field (e.g., IEEE S&P, ACM CCS, NDSS, USENIX Security, PETS) and have to prepare a paper on the state of the art on their topic. In this time, we will have presentations on ongoing research of our group members as well as streaming of presentations from top conferences in the field with the follow-up internal discussion. Depending on the format, it is also possible that in the second phase, students will be asked to write a conference-style review for a few papers of the others. These reviews will be presented and publicly discussed. Next, based on the reviews, students will have the possibility to improve their paper and have to prepare a presentation on their topic. Before publicly presenting it to the class, they have to make a test presentation by their supervisor. Finally, there will be a presentation and discussion within the class.

Recommended Prerequisites	Solid knowledge in the field of the seminar
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Seminar - 2 hours per week per semester Research paper/essay - 60 hours Self organised studies - 60 hours
Teaching Materials and Literature	Literature references for individual retrieval will be provided at the beginning of the seminar.
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• Successful oral presentation, 30-45 minutes depending on topic (50% of total marks) • Written report, 10-15 pages depending on topic (30% of total marks) • Active participation in courses (20% of total marks) 75% of the total marks are needed to pass the module.
Evaluation of Module Examination	Study Performance – ungraded
Limited Number of Participants	15
Remarks	• Study programme Cyber Security M.Sc.: Compulsory elective module in complex „Cyber Security Methods“ • Study programme Informatik M.Sc.: Compulsory elective module in complex „Seminare oder Praktika“ (level 400) • Study programme eBusiness M.Sc.: Compulsory elective module in main focus: „Development and Deployment of eBusiness Systems“ • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Seminare oder Praktika“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“
Module Components	Seminar Advanced Topics in Network and System Security
Components to be offered in the Current Semester	**120530** Seminar Research Seminar "Advanced Topics in Network and System Security" - 2 Hours per Term

Module 12973 Network and System Security

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	12973	Compulsory elective

Modul Title	**Network and System Security** Netzwerk- und Systemsicherheit
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. Panchenko, Andriy
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	Students will get familiar with challenges in securing computer systems and networks. They will get acquainted with fundamental security and privacy concepts that will be used as building blocks for later specialization.
Contents	In the scope of this module, we explore, among others, the following topics: • Anonymity and Privacy (mixes, onion routing, Tor • Firewalls • Malware, Botnets, and Intrusion Detection • Exploits • Wireless Security • Physical Security • Biometrics • Access Control • Electronic Payments • E-voting • Digital Rights Management
Recommended Prerequisites	Knowledge of the contents of modules • 11859 *Kryptographie* • 11889 *Einführung in die IT-Sicherheit*
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester

	Self organised studies - 120 hours
Teaching Materials and Literature	Provided on the homepage of the chair.
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful treatment of all assigned project tasks including successful presentation of the results **Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30-45 min. (with small number of participants) In the first lecture it will be anounced, if the examination will be offered in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Cyber Security M.Sc.: Compulsory elective module in complex „Cyber Security Methods“ • Study programme Informatik M.Sc.: Compulsory elective module in complex „Angewandte und technische Informatik“ (level 400) • Study programme eBusiness M.Sc.: Compulsory elective module in complex „Entwicklung und Aufbau von eBusiness-Systemen“ • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Hardware-basierte Systeme: Elektrotechnik, Informationstechnik und Sensorik“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“
Module Components	• Lecture: Network and System Security • Accompanying exercises • Related examination
Components to be offered in the Current Semester	**120580** Examination Network and System Security (Wiederholung)

Module 13294 Control Technology for Processes and Networks

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13294	Compulsory elective

Modul Title	**Control Technology for Processes and Networks** Leittechnik für Prozesse und Netze
Department	Faculty 3 - Mechanical Engineering, Electrical and Energy Systems
Responsible Staff Member	Prof. Dr.-Ing. Schiffer, Johannes
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	The students get some advanced knowledge about applications, tasks and technical equipment of Process Control Systems (PCS) and Network Control Systems (NCS) with the focus on power grids. The students are able to describe concentrated and distributed systems of process and network control technology and to project and configure them for an application. Tasks from the process and automation level up to the operating and visualization level are included. This requires the application of interdisciplinary knowledge. In theoretical and practical exercises, the students are enabled to solve detailed tasks of signal and information processing and visualization. The exercises promote both, independent work in preparation and jointly exchange in technical discussions.
Contents	Terms and definitions for modern control systems and the primary processes (with the focus on power grids). A short view to the history. Structure and parts of modern control systems: Real time units, stations for operation and visualisation, communication buses, analog and digital signal processing and informations, sensors and actors, computeraided design and programming, project management and documentation. Basic and advanced tasks of modern control systems: control, stabilisation, safety, visualisation and operation, reporting and optimization (important for power grids: generation and distribution management). View to the future: Smartgrids
Recommended Prerequisites	none
Mandatory Prerequisites	No successful participation in Modul 35416 Prozessleitsysteme.

Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	Actual informations in the lectures. Scripts and working materials are available.
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	Prerequisite: • short tests during the semester Final Module Examination: • written examination at the end of the semester (90 minutes) Printed and written materials like scripts or books are allowed. For possible calculations a non-programmable calculator is allowed.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	none
Module Components	Lectures - 2 hours per week per semester Exercises - 2 hours per week per semester Self organised studies -120 hours
Components to be offered in the Current Semester	**320645** Lecture Control Technology for Processes and Networks - 2 Hours per Term **320646** Exercise Control Technology for Processes and Networks - 2 Hours per Term **320679** Examination Control Technology for Processes and Networks

Module 13335 Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13335	Compulsory elective

Modul Title	**Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology** Brain-Computer-Interfaces für Neuroadaptive Technologien
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Zander, Thorsten O.
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every semester
Credits	6
Learning Outcome	After successfully completing the module, students possess a basic understanding of the methodology of Brain-Computer Interfaces (BCIs), including measurement of brain activity, signal processing, machine learning and the principle of automated interpretation of brain activity to assess information of changes in cognitive states. Furthermore, they are familiar with the use of BCIs in current and to-be-created human-computer interactions which includes the current development of beneficial Artificial Intelligence.
Contents	The module will consist of lectures describing the methodology and use of Brain-Computer Interfaces from the scratch. This includes knowledge from machine learning and signal processing, as well as psychophysiology and psychology, and human-computer interaction. In the seminar, students will be introduced to AI safety and the ethics of neurotechnology, and will prepare group presentations on various related topics and issues. Ethical issues and social consequences are discussed and guidelines for research and development are derived.
Recommended Prerequisites	none
Mandatory Prerequisites	Passing the exam of module • 13942: Foundations of Psychophysiology
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Seminar - 2 hours per week per semester Self organised studies - 120 hours

Teaching Materials and Literature	• Zander, T. O. (2011). Utilizing Brain-Computer Interfaces for Human-Machine Systems (Doctoral dissertation, Universitätsbibliothek der Technischen Universität Berlin).
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• active participation by asking questions during or after the classes (20%) • moderated discussion of selected topics related to the lecture, 45 minutes (30%) • written exam, 60 minutes (50%)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	72
Remarks	• Study programme Medizininformatik: B.Sc.: Compulsory elective module in complex „Medizininformatik" • Study programme Informatik M.Sc.: Compulsory elective module in complex „Praktischer Informatik" (level 400) • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Learning and Reasoning“ • Study programme Künstliche Intelligenz Technologie B.Sc.: Compulsory elective module in complex „Kognitions- und Neurowissenschaft“ • Study programme Micro- and Nanoelectronics M.Sc.: Compulsory elective module in complex „Applications“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Computer Science & Artificial Intelligence“
Module Components	• Lecture: Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology • Accompanying seminar
Components to be offered in the Current Semester	**142110** Lecture Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology - 2 Hours per Term **142112** Seminar Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology - 2 Hours per Term **142114** Examination Brain-Computer Interfaces (BCIs) for Neuroadaptive Technology

Module 13569 Biological Neuronal Networks

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13569	Compulsory elective

Modul Title	**Biological Neuronal Networks** Biologische Neuronale Netzwerke
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. habil. Glasauer, Stefan
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	After successfully completing the module, students will be familiar with major topics of the current state of knowledge on biological neuronal networks from the neuroanatomical and neurophysiological point of view and to leading theoretical concepts about how biological neuronal networks operate and fulfill their diverse functions.
Contents	• Neurons as constituents of biological neuronal networks • Synapses: the connection between neurons, more than just a summation point • The role of dendritic trees and neuron morphology • Examples of biological neuronal networks: the cerebellum, the head direction cell system, the hippocampus, cortical columns, etc. • Experimental approaches to understanding biological neuronal networks • Theoretical and computational approaches
Recommended Prerequisites	Knowledge of the topics of the modules • 11112 *:* Mathematics IT-1 (Discrete Mathematics) • 11113 : Mathematics IT-2 (Linear Algebra) • 11213 : Mathematics IT-3 (Analysis) • 11756 : Algorithms and Data Structures, or 12101 : Algorithmieren und Programmieren
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester

	Self organised studies - 120 hours
Teaching Materials and Literature	• Gerstner W, Kistler WM, Naud R, Paninski L.: Neuronal Dynamics – From single neurons to networks and models of cognition, Cambridge University Press (2014), https://neuronaldynamics.epfl.ch
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• written exam, 120 min. **OR** • oral examination, 30-45 min. In the first class meeting it will be announced whether the examination is to be taken in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	100
Remarks	• Study programme Informatik B. Sc.: Compulsory elective module in "Praktische Informatik" (level 300) • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Learning and Reasoning“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Natural Sciences and Engineering“
Module Components	• Lecture: Biological Neuronal Networks • Accompanying exercise • Related examination
Components to be offered in the Current Semester	**140324** Examination Biological Neuronal Networks

Module 13839 Advanced Database Models

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13839	Compulsory elective

Modul Title	**Advanced Database Models** Erweiterte Datenbankmodelle
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. habil. Schmitt, Ingo
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	Students understand • SQL:2003, • object-relational and object-oriented database model, • XML-queries, • spatial data and queries.
Contents	For special applications from the areas of manufacturing and science classical relational database modelling basing on table structures is not adequate. Alternatively, several new database models and technologies were developed. The course covers SQL:2003, ODMG and XML. Focus is on data modelling and query techniques as well as implementation of behaviour in form of methods. Further focus is on spatial data and queries for geographical information systems. Acquired knowledge will be applied within a project.
Recommended Prerequisites	The module cannot be successfully completed without knowledge of the content of • 12330: Datenbanken
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 1 hours per week per semester Laboratory training - 1 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• "SQL:1999 & SQL:2003" von Can Türker, dpunkt.verlag, 2003

	• "Objektrelationale Datenbanken: Ein Lehrbuch" von Can Türker und Gunter Saake, Punkt.verlag 2006
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • successful completion in practical training tasks and in exercises tasks **Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30-45 min. (with small number of participants) In the first lecture it will announced, whether the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	80
Remarks	• Study programme Informatik B.Sc.: Compulsory elective module in complex "Praktische Informatik" (level 300). • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“ • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex “Software-basierte Systeme“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“
Module Components	• Lecture: Advanced Data Models • Accompanying exercises (with integrated laboratory) • Related examination
Components to be offered in the Current Semester	No assignment

Module 13840 Data Warehouses

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13840	Compulsory elective

Modul Title	**Data Warehouses** Data-Warehouse-Technologien
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. habil. Schmitt, Ingo
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	After successfully completing the module, students will have acquired knowledge and capability to design, model, and to optimize a data warehouse.
Contents	Data is frequently stored redundantly and is distributed over several data sources in an enterprise. Data quality is usually low. Analyzing data should be made possible. The course gives an introduction into the architecture and processes of data warehouse systems. Focus is on database aspects including design, modelling, ETL-processes, querying and optimization. Acquired knowledge will be applied within a project. This module builds on existing database knowledge. In particular, expertise in SQL, normalization theory and database design is needed.
Recommended Prerequisites	The module cannot be successfully completed without knowledge of the content of • 12330 *Datenbanken*
Mandatory Prerequisites	No successful participation in module 14459 Data-Warehouse-Technologien.
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 1 hours per week per semester Laboratory training - 1 hours per week per semester Self organised studies - 120 hours

Teaching Materials and Literature	• A. Bauer, H. Günzel: "Data Warehouse Systeme -- Architektur, Entwicklung, Anwendung": 3. Auflage, dpunkt.verlag, Heidelberg, 2009 • W. Lehner: "Datenbanktechnologie für Data-Warehouse-Systeme": dpunkt.verlag, Heidelberg, 2003 • W.H. Inmon: "Building the Data Warehouse": Wiley & Sons, New York, 1996 • G. Saake, A. Heuer, K. Sattler: "Datenbanken: Implementierungstechniken": 2. Auflage, mitp-Verlag, Bonn, 2005 • R. Kimball, L. Reeves, M. Ross, W. Thornthwaite: The Data Warehouse Lifecycle Toolkit": Wiley & Sons, New York, 1998
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • successful completion in practical training tasks and in exercises tasks **Final module examination:** • Written examination, 120 min. **OR** • Oral examination, 30-45 min. (with small number of participants) In the first lecture it will introduced, if the examination will organized in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	80
Remarks	• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Knowledge Acquisition, Representation, and Processing“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“
Module Components	• Lecture: Data Warehouses • Accompanying exercises (with integrated laboratory) • Related examination
Components to be offered in the Current Semester	**120281** Examination Data Warehouses (Wiederholung)

Module 13847 Cognitive Systems: Behavior Control

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13847	Compulsory elective

Modul Title	**Cognitive Systems: Behavior Control** Kognitive Systeme: Verhaltenssteuerung
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. habil. Wolff, Matthias
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	After successfully completing the module, students can understand and develop techniques for semantics processing, methods for automatic planning and decision making under uncertainties, and the behavior control of cognitive technical systems.
Contents	• Unsupervised learning, strategy learning (Q-learning) • Markov decision processes (MDP) • Partially observable Markov decision processes (POMDP) • Bidirectional signal processing • Semantic modeling with feature-value relations • Petri-net transducers as semantic carriers • Modeling of higher cognitive processes (e.g. coping) • Applications in communications and dialog systems
Recommended Prerequisites	Knowledge of the content of module • 11744 *Kognitive Systeme: Perzeption und Aktion*
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 1 hours per week per semester Seminar - 1 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• Haykin, S.; Cognitive Dynamic Systems, Cambridge University Press, 2012

- Ertel, W.: Grundkurs Künstliche Intelligenz, 2. Überarbeitete Auflage 2009, Vieweg+Teubner Verlag ISBN: 978-3-8348-0783-0.
- R. Hoffmann, M. Wolff: Intelligente Signalverarbeitung 2: Signalerkennung, 2. Auflage. Springer Vieweg, 2015. ISBN 978-3-662-46725-1.

Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• Processing of a seminar task in groups and presentation, approx. 10 minutes with subsequent technical discussion (25 %) (Solution of a programming task on the topic of the lecture and preparation of a presentation in self-study; presentation scheduled in the course of the lecture, usually on the last exercise date) • written examination, 60 minutes (75 %)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	120
Remarks	• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Learning and Reasoning“ • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Kognitions- und Neurowissenschaft“ • Study programme Informatik M.Sc.: Compulsory elective module in field of application „Maschinenbau/Elektrotechnik“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Computer Science & Artificial Intelligence“
Module Components	• Lecture: Cognitive Systems: Behavior Control • Accompanying exercise • Related examination
Components to be offered in the Current Semester	No assignment

Module 13849 Introduction to Computational Neuroscience

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13849	Compulsory elective

Modul Title	**Introduction to Computational Neuroscience** Einführung in Computational Neuroscience
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. habil. Glasauer, Stefan
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	Upon completion of the module, students are able to understandof neuronal systems and behavioral performance, to evaluate the analysis and modeling of neurons, as well as to implement and to analyse neurons and neural networks.
Contents	Based on examples the module presents the methodical procedure for the analysis and modeling of neurons and neural systems. Ethical aspects are discussed in connection with animal and human experiments. **Presented Topics:** Spiking neurons, resting membrane potential, ion channels, action potential, Hodgkin-Huxley model, phase plane analysis, leaky integrate-and-fire model, synaptic transmission, synaptic plasticity, firing rate neurons, neural networks, perceptron, Hebb's learning rule, attractor networks.
Recommended Prerequisites	Knowledge of the topics of the modules • 11112 *Mathematik IT-1 (Diskrete Mathematik)* • 11113 *Mathematik IT-2 (Lineare Algebra)* • 11213 *Mathematik IT-3 (Analysis)* • 11756 *Algorithmen und Datenstrukturen*, or 12101 *Algorithmieren und Programmieren*
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester

	Self organised studies - 120 hours
Teaching Materials and Literature	• P. Dayan, L. Abbott, Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems (2005), MIT Press, ISBN 978-0262541855 • Gerstner W, Kistler WM, Naud R, Paninski L: Neuronal Dynamics: From single neurons to networks and models of cognition, Cambridge University Press (2014), https://neuronaldynamics.epfl.ch
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite:** • Successful completion of exercises **Final Module Examinatio:** • Written exam, 120 minutes **OR** • Oral examination, 30-45 minutes In the first lecture it will be announced, if the examination will be offered in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	100
Remarks	• Study programme Medizininformatik B.Sc.: Compulsory elective module in complex „Informatik" • Study programme Informatik B.Sc.: Compulsory elective module in complex „Praktische Informatik" (level 300) • Study programme Informations- und Medientechnik B.Sc.: Complex „Computer Science", compulsory elective module module in the field of study „Kognitive Systeme" • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanded Methods“ • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Kognitions- und Neurowissenschaft“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Natural Sciences and Engineering“
Module Components	• Lecture: Introduction to Computational Neuroscience • Accompanying exercise • Related examination
Components to be offered in the Current Semester	**140300** Lecture Introduction to Computational Neuroscience - 2 Hours per Term **140301** Exercise Introduction to Computational Neuroscience - 2 Hours per Term **140304** Examination Introduction to Computational Neuroscience

Module 13942 Foundations of Psychophysiology

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13942	Compulsory elective

Modul Title	**Foundations of Psychophysiology** Grundlagen der Psychophysiologie
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr. rer. nat. Zander, Thorsten O.
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every semester
Credits	6
Learning Outcome	After successfully completing the module, students possess an understanding of the physiological processes in the human body that lead to biomarkers of different mental states. They furthermore understand the principles of experimental design in the context of psychophysiology, and have experience reading, critiquing, and writing psychophysiological research literature.
Contents	The module consists of lectures and a seminar. The lectures cover relevant aspects of general human physiology as well as more specific processes that can be measured using electrocardiography (ECG, heart activity), electromyography (EMG, muscle activity), electrodermal activity (EDA, skin conductance), eye tracking, as well as brain activity through functional near-infrared spectroscopy (fNIRS) and electroencephalography (EEG). The techniques behind each of these methods are discussed as well, along with properties of the recorded signal and some known correlates of that signal to mental processes or psychological states. Ethical, social and legal issues arising from research into the use of psychophysiological data will be discussed. This includes the recording of data, data security, transparency and ethical issues relating to experiments. In the seminar, students will read, present and discuss relevant papers published in scientific journals, reflecting different experiments involving physiological data. Additionally, students will write an essay on a related topic.
Recommended Prerequisites	none

Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Seminar - 2 hours per week per semester Self organised studies - 120 hours
Teaching Materials and Literature	• Andreassi, J. (2007). Psychophysiology: Human Behavior and Physiological Response (5th Edition). New York, NY, USA: Psychology Press • Gramann, K. & Schandry, R. (2009). Psychophysiologie (4. Auflage). Basel, Switzerland: Beltz • Selected scientific papers
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• written test, 60 minutes (60%) • discussion of selected topics related to the lecture as preparation for the term paper, 90 minutes (5%) • term paper, 6 pages (35%)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	72
Remarks	• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Learning and Reasoning“ • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Kognitions- und Neurowissenschaft“ • Study programme Medizininformatik B.Sc.: Compulsory elective module in complex „Medizininformatik“ • Study programme Micro- and Nanoelectronics M.Sc.: Compulsory elective module in complex „Applications“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“
Module Components	• Lecture: Foundations of Psychophysiology • Accompanying seminar
Components to be offered in the Current Semester	**142120** Lecture Foundations of Psychophysiology - 2 Hours per Term **142121** Seminar Foundations of Psychophysiology - 2 Hours per Term **142124** Examination Foundations of Psychophysiology **142125** Examination Foundations of Psychophysiology

Module 13951 Project Laboratory Control and Network Control Technology

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13951	Compulsory elective

Modul Title	**Project Laboratory Control and Network Control Technology** Projektpraktikum Regelungs- und Netzleittechnik
Department	Faculty 3 - Mechanical Engineering, Electrical and Energy Systems
Responsible Staff Member	Prof. Dr.-Ing. Schiffer, Johannes
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	After completion of this module, students should be able to: • Apply modern methods of control systems and network control technology to emerging research and development challenges in a core engineering domain, such as power system operation, microgrids, grid integration of renewable generation, robotics or multi-agent systems; • Define an overall R&D project design objective including technical specifications; • Develop a work plan suitable to achieve the overall project task and which distributes the workload amongst all team members; • Demonstrate project management skills including time planning, team work, working to deadlines and producing deliverables; • Demonstrate creativity, innovation, independence and technical competence by implementing the project proposal, delivering the design and development work as specified in the project plan; • Demonstrate improved proficiency in written and oral communications; • Understand how to make use of technical literature and other information sources.
Contents	In the project laboratory groups of two to four students are involved in the joint organization and delivery of a R&D engineering project in the areas of control systems and network control technology. The project topics are suggested by the module leader (and possible further project supervisors) based on current research and development activities in the abovementioned areas. Hence students are provided with a unique hands-on experience in the application of modern control systems and

	network control technology methods to meet emerging technological challenges. In contrast to conventional laboratory modules, students will only be provided with the project task and will have to develop independently their own plan of work and distribute the work load amongst the different team members. Therefore each team member is responsible for the success of the whole group. The supervision of the project laboratory mainly consists of consultation and feedback on the project design, organization and implementation through regular meetings at fixed times. Necessary technical devices and reading material as well as data sheets will be provided.
Recommended Prerequisites	Scientific curiosity and interest in application-oriented research. Depending on the specific project topic good knowledge of some of the following topics is helpful: control systems fundamentals, Matlab/ Simulink, C/C++, hardware-oriented programming of microcontrollers, communication systems and network control technology.
Mandatory Prerequisites	No successful participation on module *12893 - Project Laboratory Control and Network Control Technology*
Forms of Teaching and Proportion	Seminar - 2 hours per week per semester Study project - 120 hours Self organised studies - 30 hours
Teaching Materials and Literature	None
Module Examination	Continuous Assessment (MCA)
Assessment Mode for Module Examination	• Project report, 15-25 pages (70%) • Oral presentation ~15 min. (20%) • Brief oral question and answer session, 15 min. (10%)
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	None
Module Components	Seminar and Project "Project Laboratory Control and Network Control Technology"
Components to be offered in the Current Semester	No assignment

Module 13952 Lab Control Engineering

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13952	Compulsory elective

Modul Title	**Lab Control Engineering** Labor Regelungstechnik
Department	Faculty 3 - Mechanical Engineering, Electrical and Energy Systems
Responsible Staff Member	Dr.-Ing. Rau, Uwe
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every summer semester
Credits	6
Learning Outcome	The students deepen the basic and advanced knowledge of control engineering by applying it to real laboratory experiments and simulated processes. The students are able to reflect on the relationships between modelling, design and practical implementation and to assess the real results in a well-founded manner. With the help of preparatory tasks and experimental instructions, they can develop their own questions and propose justified adjustments to the standard methods of control engineering. The students are able to work together in a group and solve tasks together. On the other hand, independence in the development and application of subject-specific knowledge is encouraged.
Contents	Laboratory experiments with tasks from mechanical engineering, electrical engineering and process engineering: Analysis and controller design in the time and frequency domain, state models, digital control, use of the Matlab/Simulink software package.
Recommended Prerequisites	Ready-to-use knowlegde of the Module 11494 Control Engineering 1 (or similar courses).
Mandatory Prerequisites	No successfull completion of module *35463 - Labor Regelungstechnik*
Forms of Teaching and Proportion	Laboratory training - 4 hours per week per semester Self organised studies - 120 hours per week per semester
Teaching Materials and Literature	Lecture and exercise scripts, instructions of the experiments
Module Examination	Continuous Assessment (MCA)

Assessment Mode for Module Examination	There will be 5-7 experiments (the number will be announced at the beginning of the course). Each laboratory experiment includes: • the preparation (5-10 sheets of paper in the self-study time), • a written test (15 min in attendance time), • the execution (approx. 165 min in attendance time) and • the evaluation (10-15 sheets of paper in the self-study time). Points are awarded for the individual performances. They are distributed as follows: • Preparatory tasks 30%, • Written test 10%, • Execution and protocol 60%. The module grade is calculated on the basis of the total points achieved in the semester. The module is passed (grade 4.0) if 50% of the total points have been achieved.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	None
Module Components	320619 "Laborpraktikum Regelungstechnik".
Components to be offered in the Current Semester	No assignment

Module 13969 Introduction to Cyber Security

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13969	Compulsory elective

Modul Title	**Introduction to Cyber Security** Einführung in die IT-Sicherheit
Department	Faculty 1 - Mathematics, Computer Science, Physics, Electrical Engineering and Information Technology
Responsible Staff Member	Prof. Dr.-Ing. Panchenko, Andriy
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	After successfully completing the module, students will • have Basic knowledge of IT security, • now the technical terms to understand current publications and relevant system solutions, • be able to independently familiarise themselves with advanced IT security concepts and to acquire futher skills.
Contents	Introductory definition of technical terms; protection objectives; security risks and threats; Malware; Attack techniques; security functions and services; Access control; basic cryptographic functions: symmetric crypto systems (stream and block ciphers, DES, AES)h public key cryptography (RSA, El-Gamal, ECC), Subject and object authentication (cryptographic hash values, message authentication codes), digital signatures, key management; cryptographic protocols (Diffie-Hellmann, Kerberos, Needham-Schröder, and others); protection of IT infrastructures, firewalls, intrusion detection; honeypots;
Recommended Prerequisites	none
Mandatory Prerequisites	No successful participation in module *11889 - Introduction to Cyber Security*.
Forms of Teaching and Proportion	Lecture - 4 hours per week per semester Exercise - 2 hours per week per semester Self organised studies - 90 hours

Teaching Materials and Literature	• Stallings: Cryptography and Network Security: Principles and Practice, Pearson • Paar, Pelzl: Understanding Cryptography: A Textbook for Students and Practitioners, Springer
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	**Final module examination:** • Written examination, 90 min. **OR** • Oral examination, 30-45 min. (with small number of participants) In the first lecture it will be anounced, if the examination will be offered in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Advanded Methods“ • Study programme Künstliche Intelligenz Technologie M.Sc.: Compulsory elective module in complex „Software-basierte Systeme“ • Study programme Mathematical Data Science M.Sc.: Compulsory elective module in complex „Data Science Applications“ • Study programme Mathematics M.Sc.: Compulsory elective module in complex „Applications: Computer Science & Artificial Intelligence“ The module is not approved for the study programmes Cyber Security M.Sc. and Computer Science M.Sc.
Module Components	• Lecture: Introduction into Cyber Security • Accompanying exercise • Related examination
Components to be offered in the Current Semester	**120510** Lecture Introduction to Cyber Security - 4 Hours per Term **120511** Exercise Introduction to Cyber Security - 2 Hours per Term **120514** Examination Introduction to Cyber Security

Module 13978 Bioinformatics: Artificial Intelligence and Algorithmic Approaches

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13978	Compulsory elective

Modul Title	**Bioinformatics: Artificial Intelligence and Algorithmic Approaches** Bioinformatik: Methoden aus Künstlicher Intelligenz und Algorithmik
Department	Faculty GW - Faculty of Health Sciences Brandenburg
Responsible Staff Member	Prof. Dr. rer. nat. Schliep, Alexander
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	6
Learning Outcome	After successfully completing the module, students will have acquired an introduction to modern bioinformatics and to selected applications from biology and medicine. They understand the methodology through presentation of the central computational problems and an introduction of solutions based on classical algorithms and statistical machine learning, as well as modern deep learning approaches.
Contents	The focus will be on four fundamental problem areas: • Comparing sequences: Sequence alignment algorithms, Genome-scale approaches using index data structures, Alignment-free methods • Analyzing gene expression: alignment-based and alignment-free methods to analyzing RNASeq, single-cell analysis • Signals in sequences: identification of motifs, accessibility, and modification of DNA • Sequence variations and relation to phenotypes: structural variants in disease, pan-genome approaches
Recommended Prerequisites	• Basic knowledge of probability and statistics, algorithms and data structures at the undergraduate level • Introduction to machine learning at Master's level • Working knowledge of Python • Knowledge of the contents of module 14336 *Introduction to Bioinformatics*
Mandatory Prerequisites	none

Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Study project - 30 hours Self organised studies - 90 hours
Teaching Materials and Literature	• Biological Sequence Analysis. Cambridge University Press (Exerpts) • Genome-Scale Algorithm Design. Cambridge University Press (Exerpts) • Review and Original Research Articles for the ML aspects
Module Examination	Prerequisite + Final Module Examination (MAP)
Assessment Mode for Module Examination	**Prerequisite for Final Module Examination:** • Successful completion of homework **Final Module Examination:** • Written examination, 120 min. **OR** • Oral examination, 30-45 min. (with small number of participants) In the first lecture it will be announced, the examination will be offered in written or oral form.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	none
Module Components	• Lecture „Bioinformatics: AI and Algorithmic Approaches“ • Accompanying exercise • Related examination
Components to be offered in the Current Semester	**100041** Examination Bioinformatics: Artifical Intelligence and Algorithmic Approaches (Wiederholung)

Module 13979 Artificial Intelligence for Drug Design

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	13979	Compulsory elective

Modul Title	**Artificial Intelligence for Drug Design** Künstliche Intelligenz in der Medikamentenentwicklung
Department	Faculty GW - Faculty of Health Sciences Brandenburg
Responsible Staff Member	Prof. Dr. rer. nat. Schliep, Alexander
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	On special announcement
Credits	4
Learning Outcome	After successfully completing the module, students have insight into this exciting field of application for Artificial Intelligence (AI). They are able to acquire research literature and to present the topic orally as well as in a written report.
Contents	AI is revolutionizing drug design both for small molecule drugs - the prevalent drug modality - and novel modalities such as oligonucleotide therapeutics. Some of the progress has been achieved by transferring methods from established AI areas such as NLP. For other areas novel methodological developments were instrumental, with very exciting developments on the intersection between molecular dynamics and AI. The focus of the seminar will be on state-of-the-art methods and applications of AI in drug design for small molecule drugs and oligonucleotide therapeutics.
Recommended Prerequisites	Working knowledge of probability/statistics and modern machine learning methods.
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Seminar - 2 hours per week per semester Self organised studies - 90 hours
Teaching Materials and Literature	A list of original literature will be made available at the beginning of the semester.
Module Examination	Continuous Assessment (MCA)

Assessment Mode for Module Examination	• Seminar presentation, 30-45 min depending on the subject (40%) • Report on the topic of the seminar presentation, 10-15 pages (40%) • Active participation (20% of the total points) A student passes the module, if he/she achieves 75% of the total.
Evaluation of Module Examination	Study Performance – ungraded
Limited Number of Participants	25
Remarks	• Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Seminars or Laboratories“
Module Components	• Seminar: AI for Drug Design
Components to be offered in the Current Semester	No assignment

Module 14038 Computing at Scale in Machine Learning: Distributed Computing and Algorithmic Approaches

assign to: Data Science Applications

Study programme Mathematical Data Science

Degree	Module Number	Module Form
Master of Science	14038	Compulsory elective

Modul Title	**Computing at Scale in Machine Learning: Distributed Computing and Algorithmic Approaches** Computing-at-Scale im Maschinellen Lernen: Verteiltes Rechnen und Algorithmische Ansätze
Department	Faculty GW - Faculty of Health Sciences Brandenburg
Responsible Staff Member	Prof. Dr. rer. nat. Schliep, Alexander
Language of Teaching / Examination	English
Duration	1 semester
Frequency of Offer	Every winter semester
Credits	6
Learning Outcome	After successfully completing the module, students have an overview on how to solve large-scale computational problems in data science and machine learning. They know parallel approaches from multi-threaded computation on individual machines to implicit parallelism frameworks on compute clusters. They are familiar with algorithms and data structures supporting efficient exact or approximate (e.g. sketching) computation with massive data sets in and out of core. They are able to implement the algorithms. They can assess which methods can be used in a given situation.
Contents	The focus will be on the following areas: • A review of memory-compute co-location and its impact on big data computations. • Solving Machine Learning (ML) work loads using explicit parallelism, specifically multi-threaded computation on an individual machine. • Introduction of implicit parallelism programming models as implemented for example in MapReduce, Spark and Ray and their application in ML. • Probabilistic algorithms such as sketching algorithms (incl. CountMinSketch, Hy-perLogLog) or Bloom filters. • Implementing ML methods using index data structures such as suffix or kd-trees.suffix or kd-trees.
Recommended Prerequisites	• Good working knowledge of discrete probability, algorithms and data structures at the undergraduate level is absolutely necessary

	• Introduction to machine learning at Master's level • Advanced knowledge of programming in Python and the Linux command line
Mandatory Prerequisites	none
Forms of Teaching and Proportion	Lecture - 2 hours per week per semester Exercise - 2 hours per week per semester Study project - 30 hours Self organised studies - 90 hours
Teaching Materials and Literature	• Data Science Design Manual. S. Skiena. Springer (Exerpts) • Parallel Programming for Multicore and Cluster Systems. T. Rauber and G. Rünger. Springer (Exerpts) • Review and Original Research Articles
Module Examination	Final Module Examination (MAP)
Assessment Mode for Module Examination	• Written examination, 120 min. OR • Oral examination, 30-45 min. The nature of the examination will be announced in the first lecture.
Evaluation of Module Examination	Performance Verification – graded
Limited Number of Participants	none
Remarks	• Study programme Informatik M.Sc.: Compulsory elective module in complex „Praktische Informatik"(level 400) • Study programme Artificial Intelligence M.Sc.: Compulsory elective module in complex „Learning and Reasoning"
Module Components	• Lecture: Computing at Scale in Machine Learning: Distributed computing and algorithmic approaches • Accompanying exercise • Related examination
Components to be offered in the Current Semester	**100060** Lecture Computing at Scale in Machine Learning: Distributed computing and algorithmic approaches - 2 Hours per Term **100061** Exercise Computing at Scale in Machine Learning: Distributed computing and algorithmic approaches - 2 Hours per Term **100062** Examination Computing at Scale in Machine Learning: Distributed computing and algorithmic approaches

Erläuterungen

Das Modulhandbuch bildet als Teil der Prüfungsordnung die Rechtsgrundlage für ein ordnungsgemäßes Studium. Darüber hinaus soll es jedoch auch Orientierung bei der Gestaltung des Studiums geben.

Dieses Modulhandbuch wurde am 19. September 2025 automatisch für den Master (universitär)-Studiengang Mathematical Data Science (universitäres Profil), PO-Version 2025, aus dem Prüfungsverwaltungssystem auf Basis der Prüfungsordnung generiert. Es enthält alle zugeordneten Module einschließlich der ausführlichen Modulbeschreibungen mit Stand vom 19. September 2025. Neben der Zusammensetzung aller Veranstaltungen zu einem Modul wird zusätzlich das Veranstaltungsangebot für das jeweils aktuelle Semester gemäß dem Veranstaltungsverzeichnis der BTU ausgegeben.

The module catalogue is part of the examination regulation and as such establishes the legal basis for studies according to the rules. Furthermore, it should also give orientation for the organisation of the studies.

This module catalogue was generated automatically by the examination administration system on the base of the examination regulation on the 19 September 2025, for the Master (universitär) of Mathematical Data Science (research-oriented profile). The examination version is the 2025, Catalogue contains all allocated modules including the detailed module descriptions from 19 September 2025. Apart from the composition of all components of a module, the list of lectures, seminars and events for the current semester according to the catalogue of lectures of the BTU is displayed.