



Description of the degree program

Data Science (Master)

PO 2

Date: 17.03.2026

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Ramp Up Phase

Title	Ramp up Course Mathematics		
Number	1294580	Module version	V2
Shorttext		Language	
Frequency of offer	every term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1 Semester	Institution	
Hours per Week / ECTS	6 / 10,0	Module owner	
Workload (h)			
Class attendance (h)	72	Self studying (h)	228
Compulsory requirements			
Expected performance/ Type of examination	1 ungraded examination (Prüfungsleistung): 1 written exam (120 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement			
Contents			
<ul style="list-style-type: none"> - Introduction to Data Science (2 weeks) - jointly with RampUp Computer Science - Algebra (2 weeks) - Numerics (2 weeks) - Discrete mathematics (2 weeks) - Analysis (2 weeks) - Stochastics (2 weeks) - Continuous optimization (2 weeks) 			
Objective qualification			
The students <ul style="list-style-type: none"> - know understand the underlying concepts of mathematics that are necessary for data science - understand the concepts of analysis, algebra, optimization, discrete mathematics, stochastics and numerics and are able apply them in the context of data science 			
Literature			
<ul style="list-style-type: none"> - Mathematics for machine learning, Deisenroth, Faisal, Ong, Cambridge University Press, available at https://mml-book.com/ - Networks, Crowds, and Markets: Reasoning about a Highly Connected World, Easley, Kleinberg, Cambridge University Press, available at https://www.cs.cornell.edu/home/kleinber/networks-book/networks-book.pdf 			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Ramp up Course Mathematics	6,0	Lecture/Exercise	english
Literature			
(de/en)			
<ul style="list-style-type: none"> • Mathematics for machine learning, Deisenroth, Faisal, Ong, Cambridge University Press, available at https://mml-book.com/ • Networks, Crowds, and Markets: Reasoning about a Highly Connected World, Easley, Kleinberg, Cambridge University Press, available at https://www.cs.cornell.edu/home/kleinber/networks-book/networks-book.pdf 			

Title	Ramp up Course Computer Science		
Number	4298040	Module version	V2
Shorttext		Language	english
Frequency of offer	every term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	6 / 10,0	Module owner	Prof. Dr. Wolf-Tilo Balke
Workload (h)			
Class attendance (h)	84	Self studying (h)	216
Compulsory requirements			
Expected performance/ Type of examination	Ungraded examination (Prüfungsleistung): 1 written exam (120 min.), oral exam (30 minutes) or Take-Home-Exam		
Course achievement			
Contents			
<ul style="list-style-type: none"> - Introduction to Data Science (2 weeks) - jointly with RampUp Mathematics - Software engineering (Schulze, 4 weeks) - Database management (Balke, 4 weeks) - Security and privacy (Rieck, 2 weeks) - Distributed systems (N.N., 2 weeks) 			
Objective qualification			
<p>After successful completion of this module, students have a basic understanding of the underlying concepts of computer science that are necessary for data science. They are able to</p> <ul style="list-style-type: none"> - design and develop software systems for data analysis - understand and implement distributed analysis processes - apply and operate modern database systems - evaluate and protect the security and privacy of data <p>Further, students have a general overview of the methods of data science and the application areas. They know the general principles and processes of data science projects.</p>			
Literature			
tba			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Ramp up course Computer Science	6,0	Lecture/Exercise	english
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Methods and Concepts of Computer Science

Title	Pattern Recognition		
Number	2424690	Module version	
Shorttext	ET-NT-69	Language	english german
Frequency of offer	every term	Teaching unit	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	Institution	
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Tim Fingscheidt
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination	Oral exam 30 min. or written exam 90 min.		
Course achievement			
Contents			
<ul style="list-style-type: none"> - Bayesian decision rule - Quality metrics in pattern recognition - Supervised learning with parametric distributions - Supervised learning with non-parametric distributions, classification - Linear discriminant functions, single-layer perceptron - Support vector machines (SVMs) - Multi-layer perceptron, neural networks (NNs) - Deep learning - Unsupervised learning, clustering methods <p>Note: For pattern recognition using hidden Markov models (HMMs), a separate more in-depth module, Spoken Language Processing (ET-NT-68), is offered in the summer semester.</p>			
Objective qualification			
Upon completion of this module, students gain fundamental knowledge about methods and algorithms for classification of data. They are capable to select the appropriate means for real-world problems, to design a solution and to evaluate it.			
Literature			
<ul style="list-style-type: none"> - R.O. Duda, P.E. Hart, D.G. Stork: Pattern Classification, Wiley, 2001 - C.M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006 			
Remark			
Basic knowledge of statistics, such as acquired in the module "Probability Theory and Statistics", facilitates the understanding of the lecture.			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
	2,0	Lecture	english german
Literature			
<ul style="list-style-type: none"> - R. O. Duda, P. E. Hart, D. G. Stork: Pattern Classification, Wiley, 2001 - C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006 			
	2,0	Seminar	english german
Literature			
<ul style="list-style-type: none"> - Vorlesungsfolien - R. O. Duda, P. E. Hart, D. G. Stork: Pattern Classification, Wiley, 2001 - C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006 			

Title	Deep Learning Lab		
Number	2424750	Module version	
Shorttext	ET-NT-75	Language	english german
Frequency of offer	only in the summer term	Teaching unit	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	Institution	
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Tim Fingscheidt
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement			
Contents			
Objective qualification			
Literature			
- R.O. Duda, P.E. Hart, D.G. Stork: Pattern Classification, Wiley, 2001 - C.M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006 - I. Goodfellow, Y. Bengio, A. Courville: Deep Learning, MIT Press, 2016			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
	3,0	Internship	german
Literature			
- R.O. Duda, P.E. Hart, D.G. Stork: Pattern Classification, Wiley, 2001 - C.M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006 - I. Goodfellow, Y. Bengio, A. Courville: Deep Learning, MIT Press, 2016			

	1,0	Colloquium	german
Literature			
- R.O. Duda, P.E. Hart, D.G. Stork: Pattern Classification, Wiley, 2001 - C.M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006 - I. Goodfellow, Y. Bengio, A. Courville: Deep Learning, MIT Press, 2016			

Title	Knowledge based systems and deductive database systems		
Number	4214620	Module version	V2
Shorttext	INF-IS-62	Language	english german
Frequency of offer	only in the winter term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	Institut für Informationssysteme
Hours per Week / ECTS	3 / 5,0	Module owner	Prof. Dr. Wolf-Tilo Balke
Workload (h)	150		
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	1 written exam (90 minutes) or oral exam (30 minutes) or Take-Home-Exam.		
Course achievement	50% of the exercises must be passed		
Contents			
<p>This module will give a broad overview over all methods and approaches that are necessary for reasoning over large knowledge bases using first order predicate logics. Moreover, the architecture of the Semantic Web is investigated with the a special focus on Semantic Web standards, modeling languages, ontologies and ontology languages, and advanced Semantic Web techniques. In particular,</p> <ul style="list-style-type: none"> - Logic programming, predicate logic as a data model - Top-down and bottom-up strategies for query processing - Datalog and processing recursive Datalog queries - Query optimization with Magic Sets - Knowledge representation - Object-oriented extension, path queries - Recursion in databases, Common Table Expressions - User-Defined Types and User-Defined Functions - Semantic Web standards (RDF, OWL, etc.) - Semantic Web architecture and techniques 			
Objective qualification			
<p>On completion of this module, students are aware of the challenges and problems which arise from reasoning processes over large knowledge bases. This covers technical aspects (algorithms, implementations, etc.) and also methodological aspects (e.g. uncertainty, etc.). Furthermore, the students will be able to discuss the strengths and weaknesses of different approaches to reasoning and will be able to competently propose solution strategies to practical problem scenarios.</p>			
Literature			
<ul style="list-style-type: none"> - S. Ceri, G. Gottlob, L. Tanca: Logic Programming and Databases - Surveys in Computer Science. Springer Verlag, 1990. - S.K. Das: Deductive Databases and Logic Programming. Addison-Wesley, 1992. - J. Ullman: Principles of Database and Knowledge-Base Systems, Volume II: The New Technologies. W.H. Freeman & Co., 1989. 			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
	3,0	Lecture/Exercise	english german

Title	Warehousing and Data Mining Techniques		
Number	4214680	Module version	V2
Shorttext	INF-IS-68	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	Institut für Informationssysteme
Hours per Week / ECTS	3 / 5,0	Module owner	Prof. Dr. Wolf-Tilo Balke
Workload (h)	150		
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	1 written exam (90 minutes), oral exam (30 minutes) or Take-Home-Exam		
Course achievement	50% of the exercises must be passed		
Contents			
<p>This module will give a broad overview over all methods that are necessary for building and using data warehouses in large-scale applications. Besides typical techniques for warehouse design, indexing, and online analytical processing (OLAP), also advanced data mining techniques, such as classification, clustering, frequent item set mining, and association rules are covered in the lecture. In particular,</p> <ul style="list-style-type: none"> - Statistical methods in databases - Knowledge discovery and mining of local structures - Frequent Item Set Mining and Association Rules - Hierarchical and partitioning clustering algorithms - (Linear) classification and support vector machines - Architecture of data warehouses (ROLAP, MOLAP,...) - Multi-dimensional data models (star, snowflake) - Extraction, data transformation and cleaning - Techniques for online analytical processing (OLAP) - Storage- and Index structures for data warehouses 			
Objective qualification			
<p>Data warehousing and mining the data within warehouses represent an important basis for corporate decision support. Students understand possible data warehouse architectures and their essential processes and know the details of the major data mining algorithms used, to be able to correctly and meaningfully underpin decisions with data. They are enabled to critically analyze and evaluate the respective application of various algorithms.</p>			
Literature			
<ul style="list-style-type: none"> - William H. Inmon: Building the Data Warehouse. Wiley & Sons. ISBN 10: 0-7645-9944-5 - Ralph Kimball, Margy Ross: The Data Warehouse Toolkit. Wiley & Sons. ISBN 10: 0-471-0024-7 - Andreas Bauer, Holger Günzel: Data Warehouse Systeme. dpunkt Verlag. ISBN 10: 3-89864-251-8 			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Data Warehousing and Data Mining Techniques	2,0	Lecture	english german
Literature			
<p>- William H. Inmon: Building the Data Warehouse. Wiley & Sons. ISBN 10: 0-7645-9944-5 - Ralph Kimball, Margy Ross: The Data Warehouse Toolkit. Wiley & Sons. ISBN 10: 0-471-0024-7 - Andreas Bauer, Holger Günzel: Data Warehouse Systeme. dpunkt Verlag. ISBN 10: 3-89864-251-8</p>			
	1,0	Exercise	english german

Title	Information retrieval and web search engines		
Number	4214690	Module version	V2
Shorttext	INF-IS-69	Language	english german
Frequency of offer	only in the winter term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration		Institution	
Hours per Week / ECTS	3 / 5,0	Module owner	Prof. Dr. Wolf-Tilo Balke
Workload (h)			
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	1 written exam (90 minutes) or oral exam (30 minutes) or Take-at-Home-Exam		
Course achievement	50% of the exercises must be passed		
Contents			
<p>The module gives an introduction to Web Information Retrieval with particular emphasis on the algorithms and technologies used in the modern search engines. It covers an introduction to traditional text IR, including Boolean retrieval, vector space model as well as tolerant retrieval. Afterwards, the technical basics of Web IR are discussed, starting with a Web size estimation and duplicate detection followed by link analysis and crawling. This leads on to the study of the modern search engine evaluation methods and various test collections. Finally, applications of classification and clustering in the IR domain are discussed. During the module the theoretical basis is illustrated by examples of modern search systems, such as Google, Bing, Yahoo!, etc. In particular,</p> <ul style="list-style-type: none"> - Structured vs. unstructured data - Text retrieval, probabilistic, fuzzy- and vector space models - Assessment of retrieval quality, precision-recall analysis - Architecture of Web information systems and search engines - Structure of the WWW, Web crawling and indexing - Document clustering and ontologies for search - Text and link metrics, Page-Rank, HITS, etc. 			
Objective qualification			
<p>Information retrieval techniques play a central role not only in Web search engines, but in all kinds of document-centric applications. Students need to understand different techniques, their typical application areas and limitations, as well as their advantages and disadvantages. They are enabled to choose the right techniques for the respective practical problem and to critically reflect their use in the respective application context.</p>			
Literature			
<ul style="list-style-type: none"> - Christopher D. Manning, Prabhakar Raghavan, Hinrich Schütze: Introduction to Information Retrieval. Cambridge University Press, 2008. http://www.informationretrieval.org - Ricardo Baeza-Yates, Berthier Ribeiro-Neto: Modern Information Retrieval. Addison-Wesley, 1999. - Richard K. Belew: Finding Out About: A Cognitive Perspective on Search Engine Technology and the 			

WWW. Cambridge University Press, 2000.



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Information Retrieval und Web Search Engines	3,0	Lecture/Exercise	english german
Literature			
<p>- Christopher D. Manning, Prabhakar Raghavan, Hinrich Schütze: Introduction to Information Retrieval. Cambridge University Press, 2008. http://www.informationretrieval.org</p> <p>- Ricardo Baeza-Yates, Berthier Ribeiro-Neto: Modern Information Retrieval. Addison-Wesley, 1999.</p> <p>- Richard K. Belew: Finding Out About: A Cognitive Perspective on Search Engine Technology and the WWW. Cambridge University Press, 2000.</p> <p>- Cornelis Joost van Rijsbergen: Information Retrieval. Butterworths, second edition, 1979. http://www.dcs.gla.ac.uk/Keith/Preface.html</p>			

Title	Introduction to Machine Learning		
Number	4215370	Module version	V2
Shorttext	INF-ROB-37	Language	
Frequency of offer	only in the summer term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration		Institution	
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Jochen Steil
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination	1 graded work: Written exam (90 minutes) or oral exam (30 minutes) or Take-Home-Exam.		
Course achievement			
Contents			
<p>Fundamental principles and theories of machine learning und the underlying mathematical and statistical methods are introduced and learning problems are formalized. Important fundamental terminology, concepts and methods are treated, in particular for regression, among those are</p> <ul style="list-style-type: none"> - model selection, machine learning bias vs. parameter optimization - training, test and validation - generalization, overfitting, regularization - linear regression, generalized linear models - non-linear models, neural networks - classification - estimation, unbiased minimal variance estimators - concept learning, decision trees, random forests - methods of lazy learning - unsupervised learning - Gaussian mixtures, Gaussian mixture regression - Unified Regression Model 			
Objective qualification			
<p>With successful completion of the module, the students possess the following knowledge and capabilities. They are able to</p> <ul style="list-style-type: none"> - understand and correctly apply basic concepts of machine learning - analyse and formalize a machine learning problem - distinguish between typical machine learning methods - select a suitable method for a learning problem - compare and judge machine learning methods wrt their capacity - implement machine learning methods and apply them practically apply and parametrise respective tools - judge strength and weaknesses of machine learning in applications - recognize ethical issues in the application of machine learning 			
Literature			
<p>Bishop, Pattern Recognition & Machine Learning, Springer, 2006</p> <p>Mitchell, Machine Learning, McGraw-Hill, 1997</p>			

script or slides, further references will be announced in the course



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course			
SWS		Eventtype	Language
Introduction to Machine Learning		4,0	Lecture/Exercise
english			
Literature			
Bishop, Pattern Recognition & Machine Learning, Springer, 2006			
Mitchell, Machine Learning, McGraw-Hill, 1997			
script or slides, further references will be announced in the course			
		2,0	Exercise
			english

Title	Visualization Techniques		
Number	4216340	Module version	
Shorttext	INF-CG-34	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1 Semester	Institution	
Hours per Week / ECTS	2 / 5,0	Module owner	Prof. Dr. Marcus Magnor
Workload (h)			
Class attendance (h)	28	Self studying (h)	122
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement	1 Presentation		
Contents			
<ul style="list-style-type: none"> - History of visualizaton - Visualization form an information-theoretic perspective - Aspects of visual perception theory - visualization and cognition - Information visualization techniques - Interactivity in visualization 			
Objective qualification			
This course offers an overview of computer graphics visualization. It conveys the psychological foundations of visual information perception and provides insight into their algorithmic implementation as basis for various visualization techniques. Graduates of this course will be familiar with relevant aspects of visual perception and cognition theory as well as algorithmic concepts of visualization.			
Literature			
<ul style="list-style-type: none"> - Ward, Grinstein, Keim: Interactive Data Visualization, AK Peters 2010 - Ware: Information Visualization, Elsevier 2012 - Munzner: Visualization Analysis and Design, 2014 			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Visualization Techniques	2,0	Lecture	english
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Title	Image Aspects		
Number	4216350	Module version	
Shorttext	INF-CG-35	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1 Semester	Institution	
Hours per Week / ECTS	2 / 5,0	Module owner	Prof. Dr. Marcus Magnor
Workload (h)			
Class attendance (h)	28	Self studying (h)	122
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement	1 Presentation		
Contents			
<ul style="list-style-type: none"> - Physical foundations of image formation - Statistical and other properties of natural images - Physiology of visual perception - Biological evolution of the human visual system - Optical illusions and what they are good for - Relationship between images and visual information - Visual arts as experimental neuroscience 			
Objective qualification			
This course offers insight into the formation, perception, and cognition of images. The natural phenomenon of images will be considered from the viewpoint of physics, information theory, neuroscience, and arts history. Graduates of this course will be familiar with relationships between optics, digital image processing, image statistics, visual perception, cognitive science and visual arts			
Literature			
<ul style="list-style-type: none"> - Donald Hoffman: Visual Intelligence. Norton, 1998. - Simon Ings: A Natural History of Seeing. Norton, 2007. - Patrick Cavanagh: The Artist as Neuroscientist. Nature, vol. 434, March 2005. 			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Image Aspects	2,0	Lecture	english german
Literature			
<ul style="list-style-type: none"> - Donald Hoffman: Visual Intelligence. Norton, 1998. - Simon Ings: A Natural History of Seeing. Norton, 2007. - Patrick Cavanagh: The Artist as Neuroscientist. Nature, vol. 434, March 2005. 			

Title	Python Lab		
Number	4217850	Module version	
Shorttext	INF-MI-85	Language	english
Frequency of offer	every term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1 Semester	Institution	
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Tim Kacprowski
Workload (h)			
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement	1 Team-based development and documentation of a data science software tool		
Contents			
<ul style="list-style-type: none"> - Introduction to Python - Introduction to explorative data analysis in Python - Statistical data analysis - Unsupervised machine learning - Supervised machine learning - Critical assessment of machine learning 			
Objective qualification			
<p>After successful completion of this module, students will have the competence to apply Python for designing and implementing small to medium software projects and analytic workflows with a focus on statistics and machine learning. During an interactive learning phase during which the students will be able to apply common packages such as scikit-learn, and they will be able to synthesize analysis workflows for diverse data science questions. These workflows will be presented and discussed in a mini-conference among the students. After the mini-conference, students will form small teams to develop data science software tools which will be presented during the closing event. They will gain the competence to critically evaluate machine learning workflows.</p>			
Literature			
tba			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Python Lab	4,0	Internship	english
	1,0	Colloquium	english

Title	Computational Geometry		
Number	4227250	Module version	V2
Shorttext	INF-ALG-25	Language	english german
Frequency of offer	only in the winter term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	Institut für Betriebssysteme und Rechnerverbund
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Sandor Fekete
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination	graded work: written exam (120 minutes) or oral exam (30 minutes). The form of the examination depends on the number of participants and will be announced at the beginning of the lecture.		
Course achievement	nongraded work: 50% of the exercises must be passed		
Contents			
<ul style="list-style-type: none"> * Geometric problems and data structures * Convex hulls * Nearest neighbors * Voronoi diagrams * Triangulations * Location problems * Tour problems * Case studies from research 			
Objective qualification			
Students who complete the module are familiar with basic modeling of geometric algorithms. They are able to classify the algorithmic difficulty of geometric problems and formulate appropriate objectives. They are proficient in various solution techniques and can also develop algorithmic methods for problems not previously considered. They have an overview of the practical relevance of problems and problem solutions.			
Literature			
Computational Geometry: Algorithms and Applications Mark de Berg, Marc van Kreveld, Mark Overmars, Otfried Schwarzkopf Springer Verlag, 2nd edition (2000)			
Algorithmische Geometrie Rolf Klein Springer, Heidelberg, 2005.			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Computational Geometry	3,0	Lecture/Exercise	english
Literature			
Computational Geometry: Algorithms and Applications Mark de Berg, Marc van Kreveld, Mark Overmars, Otfried Schwarzkopf Springer Verlag, 2nd edition (2000) Algorithmische Geometrie Rolf Klein Springer, Heidelberg, 2005.			
	1,0	Exercise	english
Computational Geometry	1,0	Exercise, small group	english
Literature			
Computational Geometry: Algorithms and Applications Mark de Berg, Marc van Kreveld, Mark Overmars, Otfried Schwarzkopf Springer Verlag, 2nd edition (2000) Algorithmische Geometrie Rolf Klein Springer, Heidelberg, 2005.			

Title	Approximation Algorithms		
Number	4227270	Module version	V2
Shorttext	INF-ALG-27	Language	english german
Frequency of offer	every 2 years in the summer term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	Institut für Betriebssysteme und Rechnerverbund
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Sandor Fekete
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination	graded work: written exam (120 minutes) or oral exam (30 minutes) minutes) or Take-Home-Exam. The form of the examination depends on the number of participants and will be announced at the beginning of the lecture.		
Course achievement	non-graded work: 50% of the exercises must be passed		
Contents			
<ul style="list-style-type: none"> - A basic introduction to NP-completeness and approximation - Approximation for vertex and set cover - Packing problems - Tour problems and variations - Current research problems In the context of various problems, a wide spectrum of techniques and concepts will be provided.			
Objective qualification			
Participants know the necessity and role of approximation algorithms. They can master the most important techniques for analysis and complexity of approximation algorithms for designing, including the validity of upper and lower bounds.			
Literature			
<ul style="list-style-type: none"> - Vijay V. Vazirani: Approximation Algorithms. 1st edition. Springer Verlag, 2001. - Dorit Hochbaum: Approximation Algorithms for NP-hard Problems. Course Technology Inc, 1996. 			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Approximation Algorithms	3,0	Lecture/Exercise	english german
Literature			
- Vijay V. Vazirani: Approximation Algorithms. 1st edition. Springer Verlag, 2001.			
- Dorit Hochbau: Approximation Algorithms for NP-hard Problems. Course Technology Inc, 1996.			
	1,0	Exercise, small group	english german

Title	Seminar Data Science - Section Computer Science		
Number	4299990	Module version	
Shorttext	INF-STD-99	Language	english
Frequency of offer	every term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	3 / 5,0	Module owner	
Workload (h)			
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	1 Presentation		
Course achievement			
Module grade composition	The grade is determined by the active participation in the seminar and the quality of the presentation and the accompanying paper.		
Contents			
The course content has a mandatory relation to topics of data science. The concrete course content in the seminar depends on the subject area worked on and may vary each semester.			
Objective qualification			
<ul style="list-style-type: none"> - The students are able to independently familiarize themselves with a scientific Topic. - They are able to prepare the topic and present it in an oral presentation. - The students are able to use adequate presentation technique and rhetorical skills. 			
Literature			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Seminar Theoretical Computer Science (Master)	3,0	Seminar	english
Literature			
Literature sources vary - depending on the chosen seminar topic.			

Seminar Databases and Information systems	3,0	Seminar	english german
Literature			
Literature sources vary - depending on the chosen seminar topic.			
Seminar Computer Graphics (Master)	3,0	Seminar	english german
Seminar Computer Vision (Master)	3,0	Seminar	english
Literature			
Die Literaturquellen variieren, je nach gewähltem Thema.			
Seminar Medical Informatics (Master)	3,0	Seminar	english
Seminar Data Science in Biomedicine (Master)	3,0	Seminar	english
Seminar Software Engineering and Automotive Informatics (Bachelor)	3,0	Seminar	english german
Literature			
Die Literaturquellen variieren - je nach gewähltem Seminarthema.			
Seminar Reliable System Software (Master)	3,0	Seminar	english
Seminar Algorithmics (Master)	3,0	Seminar	english german
Literature			
Literature sources vary - depending on the chosen seminar topic.			
	3,0	Seminar	german
Literature			
Die Literaturquellen variieren - je nach gewähltem Seminarthema.			
Seminar Bioinformatik (Master)	3,0	Seminar	german
Literature			
Die Literaturquellen variieren - je nach gewähltem Seminarthema.			
Seminar Software Engineering and Automotive Informatics (Master)	3,0	Seminar	english german
Literature			
Die Literaturquellen variieren - je nach gewähltem Seminarthema.			

Seminar Information Systems (Master)	3,0	Seminar	english
Literature			
Die Literaturquellen variieren, je nach gewähltem Thema.			
Seminar Artificial Intelligence (Master)	3,0	Seminar	english
Literature			
Die Literaturquellen variieren, je nach gewähltem Thema.			

Title	Graphs, Geometry, and Algorithms		
Number	4227300	Module version	V2
Shorttext		Language	english
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1 Semester	Institution	
Hours per Week / ECTS	3 / 5,0	Module owner	Prof. Dr. Sandor Fekete
Workload (h)			
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	1 written exam, 90 minutes, or 1 oral exam, 30 minutes or Take-Home-Exam		
Course achievement	50% of the homework must have been successfully completed		
Contents			
Drawings of graphs, planar graphs, spring embeddings, contact representations, morphs, visibility graphs, intersection graphs, case studies from current research.			
Objective qualification			
<p>Graduates of this module know different geometric representations of graphs. They can gauge the algorithmic complexity of computing such representations or deciding whether such a representation exists. They understand how such representations may help to solve otherwise difficult problems and are capable of developing algorithmic methods for new problems.</p> <p>In many contexts, it is useful to visualize data organized in graphs. For this purpose, approaches from algorithms, graph theory and algorithmic geometry join forces.</p> <p>This class will be held in English. Students are encouraged (but not required) to use English in exercises and exams as well.</p>			
Literature			
G. Di Battista & P. Eades & R. Tamassia & I.G. Tollis: Graph Drawing, Algorithms for the Visualization of Graphs M. Kaufmann & D. Wagner (eds): Drawing Graphs T. Nishizeki & N. Chiba: Planar Graphs, Theory and Algorithms Relevant research articles			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Graphs, Geometry, and Algorithms	3,0	Lecture/Exercise	english

Title	Fundamentals of High-Performance Computing for CFD simulations		
Number	2518000010	Module version	
Shorttext		Language	english
Frequency of offer	only in the summer term	Teaching unit	Fakultät für Maschinenbau
Module duration	1	Institution	Institut für Flugantriebe und Strömungsmaschinen
Hours per Week / ECTS	3 / 5,0	Module owner	Prof. Dr. Jens Friedrichs
Workload (h)	150		
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	1 examination element: written exam (90 min) or oral exam (30 min)		
Course achievement			
Contents			
<p>This module covers the software development process of high-performance computing (HPC) applications (CFD simulations) and its efficient automatization in Linux environments. The following aspects are included:</p> <ol style="list-style-type: none"> 1. Introduction on Unix and Linux systems in the context of HPC systems 2. Fundamental shell commands and advanced Unix tools 3. Get to know shell-based editors 4. Automatization with shell scripts 5. Introduction on the C++ programming language (compiling, testing, debugging) 6. Tools for version control and automatization of distributed software development# 7. Introduction to parallel computing 			
Objective qualification			
<p>Attending the course, the students will be able to:</p> <ul style="list-style-type: none"> • Understand and use the fundamentals of the Linux-operating system and basic Unix tools • Automate HPC workflows using Shell-scripts • Write, compile and debug programs in C++ • Automate the steps of compiling, testing and executing • To structure the development process of program code using software 			
Literature			
<ol style="list-style-type: none"> 1. "Introducing UNIX and Linux", M. Joy, S. Jarvis, M. Luck, Springer 2002, https://doi.org/10.1007/978-0-230-80245-2 2. „Keine Angst vor Linux/Unix - Ein Lehrbuch für Linux- und Unix-Anwender“, C. Wolfinger, Springer 2013, https://doi.org/10.1007/978-3-642-32079-8 			

3. "Beginning C++ Programming", R. Grimes, Packt Publishing, <https://notalentgeek.github.io/note/note/project/project-independent/pi-brp-beginning-c-programming/document/20170807-1504-cet-1-book-and-source-1.pdf>
4. "Unix Power Tools", Powers, Peek, O'Reilly, Loukides

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Fundamentals of High-Performance Computing for CFD simulations	3,0	Lecture/Exercise	english

Title	Software Product Lines		
Number	4220000020	Module version	
Shorttext		Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Thomas Thüm
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Recommended requirements	Basic knowledge of logic (in particular propositional logic) and software engineering (in particular process models, UML class diagrams, design patterns) as well as programming experience (e.g., in Java) are required.		
Expected performance/ Type of examination	1 graded work: Written exam+ (90 minutes) or oral exam+ (20 minutes)		
Course achievement	1 non-graded work: Solve exercises relevant to the lecture		
Contents			
<p>Modern software often must be available on many platforms and adapted to many different user and customer needs. This applies to system software (e.g., operating systems), application software (e.g., word processing and games) and complex cyber-physical systems (e.g., automobiles). The resulting variety of configurations poses challenges for the development, testing, and maintenance of such systems. The course teaches, among other things, how the configurability of systems can be modeled, which implementation techniques allow extensible and configurable software to be developed, and which strategies can still be used for meaningful testing despite an exponential number of variants.</p> <p>The course includes the following contents:</p> <ul style="list-style-type: none"> • Introduction to software variability and inherent challenges • Modeling and analysis of the desired variability • Implementing variability at runtime (e.g., configuration options) and at compile time (e.g., clone-and-own) • Implementation of software product lines: <ul style="list-style-type: none"> • Implementing features using conditional compilation (e.g., preprocessors and build systems). • Modular implementation of features (e.g., components, services and plug-ins) • Limitations of object orientation and extensions of object orientation (e.g. feature modules, aspects) • Design patterns for software variability • Process models for the use and development of software product lines • Problems and dealing with feature interactions • Methods for static and dynamic quality assurance of software product lines • Current topics from research and practice 			
Objective qualification			
<p>Students are able to</p> <ul style="list-style-type: none"> • identify the limitations of traditional programming techniques regarding the development of variable software. • describe modeling, analysis and configuration of variability in software product lines. • apply different implementation techniques for the development of software product lines. • evaluate the suitability of presented programming techniques for different development scenarios. 			

- explain quality assurance techniques for software product lines and the associated challenges.

Literature

- Feature-Oriented Software Product Lines - Concepts and Implementation; Sven Apel, Don Batory, Christian Kästner, Gunter Saake; Springer, 2013
- Mastering Software Variability with FeatureIDE; Jens Meinicke, Thomas Thum, Reimar Schröter, Fabian Benduhn, Thomas Leich, Gunter Saake; Springer, 2017



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Software Product Lines	4,0	Lecture/Exercise	english german

Title	Machine Learning for Data Science		
Number	4229000050	Module version	
Shorttext		Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Michel Bes-serve
Workload (h)	150		
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Recommended requirements	The lectures and exercises require a good command of the knowledge from Bachelor level "Linear Algebra" and "Analysis" courses, and a background knowledge on probability theory and the python programming language is recommended.		
Expected performance/ Type of examination	1 examination: written exam, 90 minutes or oral exam, 30 minutes or take-home exam		
Course achievement	1 academic achievement: 50% of the exercises must be passed		
Contents			
<ul style="list-style-type: none"> - Supervised Learning Algorithms - Model Selection - Unsupervised Learning Algorithms - Deep Neural network architectures for data science - Self-supervised learning and foundation models - Uses and limitations of ML in data science projects 			
Objective qualification			
After successfully completing this module, students should be able to <ul style="list-style-type: none"> - understand and correctly apply basic concepts of machine learning algorithm design, - master elementary tools for analyzing the performance of machine learning approaches, - identify the most suited ML approaches for a particular application. 			
Literature			
<ul style="list-style-type: none"> - Machine Learning, A Probabilistic Perspective, Murphy, 2012 - Deep Learning, Goodfellow et al., 2016 - Mathematics for Machine Learning, Deisenroth et al., 2020 			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Machine Learning for Data Science	3,0	Lecture/Exercise	english

Title	Constraint Solving		
Number	4220000040	Module version	
Shorttext		Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Thomas Thüm
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination	1 Examination: Exam or exam+ (90 minutes), oral exam or oral exam+ (20 minutes) or take-home exam		
Course achievement	1 study achievement: Passing practical tasks		
Contents			
<ul style="list-style-type: none"> • Deeper understanding of satisfiability (SAT) solving • Deeper understanding of propositional logic • Different logic dialects, such as constraint programming or SMT • Different logical problems, such as model counting • Application scenarios for constraint solving • Reducing problems in practice to constraint solving 			
Objective qualification			
The students learn to recognize application scenarios of learned techniques in practice. The students learn to evaluate the suitability of different approaches for a given problem setting and select promising solution. The students should acquire a basic understanding of the underlying techniques.			
Literature			
Daniel Kroening, Ofer Strichman: Decision Procedures - An Algorithmic Point of View, Springer Verlag, 10. Auflage, ISBN 978-3-662-50496-3 Armin Biere, Marijn Heule, Hans van Maaren, Toby Walsh: Handbook of Satisfiability, 2. Auflage, 2021, IOS Press, ISBN 978-1-64368-160-3			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

	4,0	Lecture/Exercise	german
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Title	AI Engineering		
Number	2424000050	Module version	
Shorttext		Language	english
Frequency of offer	only in the winter term	Teaching unit	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	Institution	Institut für Nachrichtentechnik
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Tim Fingscheidt
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements	Basic knowledge (in theory and practice) in machine learning is required, e.g. from-Mustererkennung / Pattern Recognition (2424102) und im Computerlabor Mustererkennung (2424133).		
Expected performance/ Type of examination	Written exam (120 min) or oral exam (30 min)		
Course achievement	Lab work		
Contents			
<ul style="list-style-type: none"> - Foundation Models - Prompt Engineering - Retrieval-Augmented Generation - Agents - Finetuning - Legal and Ethical Aspects - Building Applications with Foundation Models 			
Objective qualification			
<p>Students are able to explain the structure, functionality, and application of foundation models (large, generally pre-trained AI models) and describe their core components such as tokenization, embeddings, transformer architectures, and training procedures. They can apply methods such as prompt engineering, retrieval-augmented generation, finetuning, and agent systems to adapt AI models to specific tasks. Furthermore, they are able to analyze technical concepts, select appropriate tools, and design and evaluate AI applications while considering legal and ethical frameworks. In the accompanying lab sessions, students implement and experiment with the presented methods in practice, thereby deepening their understanding through hands-on experience.</p>			
Literature			
<ul style="list-style-type: none"> - Lecture slides - Publications on key technologies - C. Huyen: „AI Engineering“, O'Reilly Media, 2025 			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
AI Engineering	2,0	Lecture	english
Literature			
<ul style="list-style-type: none"> - Vorlesungsfolien - Publikationen zu Schlüsseltechnologien - C. Huyen: „AI Engineering“, O'Reilly Media, 2025 			
Computer Lab AI Engineering	2,0	Internship	english
Literature			
<ul style="list-style-type: none"> - Lecure slides - Publications on key technologies - C. Huyen: „AI Engineering“, O'Reilly Media, 2025 			

Methods and Concepts of Mathematics

Title	Algorithms and Complexity for Quantum Computing		
Number	1294480	Module version	V2
Shorttext	MAT-STD7-4	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	3 / 5,0	Module owner	Studiendekan der Mathematik
Workload (h)			
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (90 minutes) or 1 oral exam (20-30 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<ul style="list-style-type: none"> - Fundamentals from mathematics and physics for quantum computers - Computational model for quantum computers - Central algorithms for the quantum computer model - Relation to complexity 			
Objective qualification			
The students <ul style="list-style-type: none"> - understand the of the complex links between their previous mathematical knowledge and the contents of the lecture - understand the theoretical body of the lecture as a whole and master the corresponding methods - are able to analyze and apply the methods of the lecture <ul style="list-style-type: none"> - master the fundamentals to understand the model of a quantum computer - know the algorithmic applications of this model - know and understand the quantum computer model in light of the theory complexity 			
Literature			
wird in der Veranstaltung bekannt gegeben			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Algorithms and complexity for quantum computers	3,0	Lecture/Exercise	english
Literature			
(de) wird in der Veranstaltung bekannt gegeben (en) will be announced in the lecture			
Algorithms and complexity for quantum computers	1,0	Exercise	english
Literature			
(de) wird in der Veranstaltung bekannt gegeben (en) will be announced in the lecture			

Title	Computational Algebraic Geometry		
Number	1294470	Module version	V2
Shorttext	MAT-STD7-4	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	6 / 10,0	Module owner	Studiendekan der Mathematik
Workload (h)			
Class attendance (h)	84	Self studying (h)	216
Compulsory requirements			
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (120 minutes) or 1 oral exam (25-35 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<ul style="list-style-type: none"> - the Euclidean algorithm - Factoring polynomials over finite fields - Factoring polynomials over \mathbb{Z} and \mathbb{Q} - Primality tests and factoring of integers - Rings: polynomial ring and ideals Gröbner bases and S polynomials - Buchberger's algorithm for calculating Gröbner bases - Application in the algebraic solution of non-linear systems of equations - Symbolic integration and symbolic summation 			
Objective qualification			
The students <ul style="list-style-type: none"> - understand the of the complex links between their previous mathematical knowledge and the contents of the lecture - understand the theoretical body of the lecture as a whole and master the corresponding methods - are able to analyze and apply the methods of the lecture <ul style="list-style-type: none"> - understand the basic concepts of computer algebra techniques in theory and practice, such as the Euclidean algorithm and Gröbner bases, their calculation and application - understand number theoretic and algebraic techniques and are able to apply and analyze them - are able to calculate factorizations and to apply and analyze methods to solve systems of nonlinear equations and for working with algebraic objects 			
Literature			
<ul style="list-style-type: none"> - Von zur Gathen, Gerhard, Modern Computer Algebra, Cambridge University Press - Adams, Loustauanau, An Introduction to Gröbner Basis, AMS, 1991 			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Title	Discrete Optimization		
Number	1294460	Module version	V2
Shorttext	MAT-STD7-4	Language	english german
Frequency of offer	only in the winter term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	6 / 10,0	Module owner	Studiendekan der Mathematik
Workload (h)			
Class attendance (h)	84	Self studying (h)	216
Compulsory requirements			
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (120 minutes) or 1 oral exam (25-35 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<ul style="list-style-type: none"> - Efficiently solvable combinatorial and integer optimization tasks. - Integral polyhedra - Relaxation, duality und decomposition - NP-hard combinatorial optimization tasks - NP-hard integer optimization tasks - NP-hard mixed-mixed optimization tasks - Branch & Bound, Branch & Cut - Dynamic programming - Approximation algorithms - Selected applications (industry, economy, computer science, ...) 			
Objective qualification			
The students <ul style="list-style-type: none"> - understand the of the complex links between their previous mathematical knowledge and the contents of the lecture - understand the theoretical body of the lecture as a whole and master the corresponding methods - are able to analyze and apply the methods of the lecture - know and understand combinatorial and discrete optimization problems - understand the notions and results of theory of complexity - understand the important theorems, proofs and procedures of discrete and combinatorial optimization and are able to apply and analyze them - know general algorithmic principles and problem structures - are able to design, apply and analyze algorithms for applications, in particular, for NP-hard problems 			
Literature			
- W.J. Cook, W.H. Cunningham, W.R. Pulleyblank, and A. Schrijver, Combinatorial Optimization, John			

Wiley and Sons, 1998
 - Korte/Vygen, Combinatorial Optimization, Springer, 2003
 - A. Schrijver, Combinatorial Optimization, Volume A-C, Springer, 2004
 - A. Schrijver, Theory of Linear and Integer Programming, Wiley, 1986
 - G.L. Nemhauser, L.A. Wolsey, Integer and Combinatorial Optimization, Wiley, 1988
 - L.A. Wolsey, Integer Programming, Wiley, 1998



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Discrete Optimization	6,0	Lecture/Exercise	english
Literature			
<ul style="list-style-type: none"> • W.J. Cook, W.H. Cunningham, W.R. Pulleyblank, and A. Schrijver, Combinatorial Optimization, JohnWiley and Sons, 1998 • Korte/Vygen, Combinatorial Optimization, Springer, 2003 • A. Schrijver, Combinatorial Optimization, Volume A-C, Springer, 2004 • A. Schrijver, Theory of Linear and Integer Programming, Wiley, 1986 • G.L. Nemhauser, L.A. Wolsey, Integer and Combinatorial Optimization, Wiley, 1988 • L.A. Wolsey, Integer Programming, Wiley, 1998 			
Discrete Optimization	1,0	Exercise, small group	english

Title	Dynamic Optimization		
Number	1294450	Module version	V2
Shorttext	MAT-STD7-4	Language	english german
Frequency of offer	only in the summer term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	6 / 10,0	Module owner	Studiendekan der Mathematik
Workload (h)			
Class attendance (h)	84	Self studying (h)	216
Compulsory requirements			
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (120 minutes) or 1 oral exam (25-35 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<ul style="list-style-type: none"> - Modeling dynamic processes via ODE and DAE - Theory of the initial value problem for ordinary differential equations (ODE) and differential algebraic (DAE) equations - Marginal value problem, solution via single and multi shooting methods - Modeling and transformation of optimal control problems - The Bellmann principal - Direct, indirect, sequential and simultaneous approaches, including e.g. Pontryagin's Maximum Principal, Single Shot method, collocation methods, multi shooting methods, dynamic optimization, the Hamilton-Jacobi-Bellman-Equality - Structures and their use in direct multi shooting methods - Parameter estimation and dynamic problems - The generalized Gauß-Newton-method, local contraction und convergence - Statistics of the generalized Gauß-Newton-method - Optimal experimental design - Model discrimination 			
Objective qualification			
The students <ul style="list-style-type: none"> - understand the of the complex links between their previous mathematical knowledge and the contents of the lecture - understand the theoretical body of the lecture as a whole and master the corresponding methods - are able to analyze and apply the methods of the lecture <ul style="list-style-type: none"> - know and understand the problems of optimal control, parameter estimation, optimal experimental design and model discrimination - know and understand the different fundamental approaches in the field of optimal control are are able to apply and analyze them 			

- are able to analyze, interpret, refine and enhance the methods, especially to increase the efficiency of numerical algorithms exemplified for optimal control

Literature

M. Gerds: Optimal Control of ODEs and DAEs, De Gruyter, 2011.
 A. E. Bryson, Y.-C. Ho: Applied Optimal Control: Optimization Estimation and Control, Routledge, 1975.
 G. Feichtinger, R. F. Hartl: Optimale Kontrolle Ökonomischer Prozesse, De Gruyter, 1986.
 Y. Bard: Nonlinear Parameter Estimation, Academic Press, 1974.
 D. Bertsekas: Dynamic Programming & Optimal Control, Athena Scientific, 2005.

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Dynamic Optimization	6,0	Lecture/Exercise	english
Dynamic Optimization	2,0	Exercise, small group	english

Title	Introduction to Quantum Information Theory		
Number	1294540	Module version	V3
Shorttext	IntrQuantInfTH	Language	english german
Frequency of offer	every 2 years in the summer term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	4 / 6,0	Module owner	Studiendekan der Mathematik
Workload (h)	180		
Class attendance (h)	56	Self studying (h)	124
Compulsory requirements			
Recommended requirements	A basic knowledge of classical information theory is recommended		
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (90 minutes) or 1 oral exam (20-30 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<ul style="list-style-type: none"> - Vectors and Operators, - States, Observables, Statistics, - Composite Systems and Entanglement, - Classical Entropy and Information, - The Classical-Quantum Channel, - Quantum Evolutions and Channels, - Quantum Entropy and Information Quantities 			
Objective qualification			
The students <ul style="list-style-type: none"> - understand the of the complex links between their previous mathematical knowledge and the contents of the lecture - understand the theoretical body of the lecture as a whole and master the corresponding methods - are able to analyze and apply the methods of the lecture <ul style="list-style-type: none"> - acquainted with the basic objects, constructions, and mathematical theorems and their proofs of quantum information theory - obtain an understanding of the similarities of, and the fundamental differences between, classical information theory and quantum information theory - learn about applications of quantum information theory in quantum computing and communication. 			
Literature			
<ul style="list-style-type: none"> • A. Holevo: Quantum Systems, Channels, Information, De Gruyter 			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Introduction to Quantum Information Theory	3,0	Lecture/Exercise	english german
Introduction to Quantum Information Theory	1,0	Exercise, small group	german

Title	Inverse problems		
Number	1294430	Module version	V2
Shorttext	MAT-STD7-43	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	3 / 5,0	Module owner	Studiendekan der Mathematik
Workload (h)			
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Recommended requirements	Mathematical knowledge in 'Introduction to Numerical Analysis' is required. Knowledge in 'Functional Analysis' is helpful.		
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (90 minutes) or 1 oral exam (20-30 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<ul style="list-style-type: none"> • Compact operators, pseudo inverse • Regularization methods, order optimality • Tikhonov regularization, Landweber iteration, the CG method • A-priori and a-posteriori parameter choice • Nonlineare Problems, convex variational regularization methods 			
Objective qualification			
The students <ul style="list-style-type: none"> • understand the of the complex links between their previous mathematical knowledge and the contents of the lecture • understand the theoretical body of the lecture as a whole and master the corresponding methods • are able to analyze and apply the methods of the lecture • know and understand the notion of well- and ill-posedness and of regularization methods and their properties • are able to understand, analyze and apply methods to approximately solve ill-posed problems and use them with mathematical software 			
Literature			
<ul style="list-style-type: none"> • Rieder, Keine Probleme mit Inversen Problemen, Vieweg, 2003 (deutsch) • Engl, Hanke, Neubauer, Regularization of Inverse Problems, Kluwer, 2000 (english) 			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Inverse problems	3,0	Lecture/Exercise	english
Literature			
<ul style="list-style-type: none"> • Rieder, Keine Probleme mit Inversen Problemen, Vieweg, 2003 (deutsch) • Engl, Hanke, Neubauer, Regularization of Inverse Problems, Kluwer, 2000 (english) 			
Inverse problems	1,0	Exercise	english

Title	Continuous Optimization in Data Science		
Number	1294420	Module version	V2
Shorttext	MAT-STD7-4	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	3 / 5,0	Module owner	Studiendekan der Mathematik
Workload (h)			
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (90 minutes) or 1 oral exam (20-30 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<ul style="list-style-type: none"> - Linear and Nonlinear Regression - Matrix Completion - Low Rank Parameterization - Nonnegative Matrix Factorisation - Sparse Inverse Covariance - Sparse Principal Component Analysis - Nichtlineare Support Vector Machines - Logistic Regression - Deep Learning - selected applications 			
Objective qualification			
The students <ul style="list-style-type: none"> - understand the of the complex links between their previous mathematical knowledge and the contents of the lecture - understand the theoretical body of the lecture as a whole and master the corresponding methods - are able to analyze and apply the methods of the lecture <ul style="list-style-type: none"> - remember and understand exemplary problems in Data Science - master selected problem solving abilities using methods of continuous optimization and are able to apply them - understand theory and algorithms of continuous optimization in the context of statistical phenomena of the data basis 			
Literature			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Continuous Optimization in Data Science	3,0	Lecture/Exercise	english
Continuous Optimization in Data Science	1,0	Exercise	english

Title	Machine Learning with Neural Networks		
Number	1294410	Module version	V2
Shorttext	MAT-STD7-4	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	3 / 5,0	Module owner	Studiendekan der Mathematik
Workload (h)			
Class attendance (h)		Self studying (h)	
Compulsory requirements			
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (90 minutes) or 1 oral exam (20-30 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<ul style="list-style-type: none"> - Multilayer neural networks - Backpropagation-Algorithms - Regularization - Stochastic gradient methods - Second order optimization methods 			
Objective qualification			
The students <ul style="list-style-type: none"> - understand the of the complex links between their previous mathematical knowledge and the contents of the lecture - understand the theoretical body of the lecture as a whole and master the corresponding methods - are able to analyze and apply the methods of the lecture - know and understand neural networks and are able to characterize them in mathematical terms - know different use cases and applications of neural networks - know and understand optimization methods for the training of neural networks and are able to apply them 			
Literature			
<ul style="list-style-type: none"> - I. Goodfellow, Y. Bengio, A. Courville, Deep Learning, MIT Press, 2017 - C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006 			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Machine learning with neural networks	3,0	Lecture/Exercise	english
Machine Learning with Neural Networks	1,0	Exercise, small group	english

Title	Mathematical Foundations of Information Theory and Coding Theory		
Number	1294600	Module version	V3
Shorttext	MathFoundInfThCodTh	Language	english german
Frequency of offer	every 2 years in the winter term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1 Semester	Institution	
Hours per Week / ECTS	3 / 5,0	Module owner	Studiendekan der Mathematik
Workload (h)	150		
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	1 oral exam (20-30 minutes) according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework or presentation according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<ul style="list-style-type: none"> - Kraft Inequality and McMillan's Theorem - Huffman Codes - Stochastic Processes - Entropy and Entropy Rates - The Shannon-McMillan-Breiman Theorem - Universal Codes and the Lempel-Ziv Code - Rate Allocation 			
Objective qualification			
Technical/methodological skills Students understand the interconnections and complex relationships between their own mathematical knowledge and the content of the course. They understand the theory of the course as a whole and have mastered the associated methods. Students can apply and analyse the methods taught in the course and have mastered the essential fundamentals of the field. They can place individual methods in a larger context.			
Social skills Social skills are strengthened in particular through professional exchange among students, for example when working together to develop solution strategies, discussing mathematical concepts or cooperatively dealing with complex problems.			
Personal skills Students independently acquire new knowledge and perspectives and discuss mathematical content with others; they develop solutions in a focused, precise and goal-oriented manner. Students can train and improve their teamwork skills in homework assignments, compare the requirements of the module with their own prior knowledge and independently close any gaps in their knowledge, as well as reflect on their learning progress and adjust their learning behaviour if necessary.			

Literature

- Cover & Thomas „Elements of Information Theory“ (Wiley)



Related courses

Rules for the choice of courses

The module 'Mathematical Foundations of Information Theory and Coding Theory' consists of a lecture and a tutorial.

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Mathematical Foundations of Information Theory and Coding Theory	3,0	Lecture/Exercise	english german

Title	Model Order Reduction		
Number	1294500	Module version	V2
Shorttext	MAT-STD7-5	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	6 / 10,0	Module owner	Studiendekan der Mathematik
Workload (h)			
Class attendance (h)	84	Self studying (h)	216
Compulsory requirements			
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (120 minutes) or 1 oral exam (25-35 minutes) or "Portfolio" according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<ul style="list-style-type: none"> - numerical methods for model order reduction for linear (and nonlinear) systems, in particularly modal truncation (eigenvalue-based methods, singular value decomposition-based methods) - Proper orthogonal decomposition (POD)/Karhunen-Loeve decomposition - (discrete) empirical interpolation method ((D)EIM) - Reduzierte Basis Methoden für parameterabhängige Systeme - Greedy methods, certification, Applications. 			
Objective qualification			
The students <ul style="list-style-type: none"> - understand the of the complex links between their previous mathematical knowledge and the contents of the lecture - understand the theoretical body of the lecture as a whole and master the corresponding methods - are able to analyze and apply the methods of the lecture - understand the concept of model reduction - know and understand the most important methods of (non)linear model reduction - are able to analyze the method and understand of the basic limits of the applicability of the methods - are able to interpret the goodness and optimality of the achievable approximation 			
Literature			
will be announced in the lecture			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Model Order Reduction	2,0	Exercise	english
Model Order Reduction	4,0	Lecture/Exercise	english
Literature			
(de) wird in der Veranstaltung bekannt gegeben (en) will be announced in the lecture			

Title	Nonnegativity and polynomial optimization		
Number	1294380	Module version	V2
Shorttext	MAT-STD7-3	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	6 / 10,0	Module owner	Studiendekan der Mathematik
Workload (h)			
Class attendance (h)	84	Self studying (h)	216
Compulsory requirements			
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (120 minutes) or 1 oral exam (25-35 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<ul style="list-style-type: none"> - Classic nonnegativity and sums of squares (SOS) - Semidefinite optimization: reference to SOS, moments, spectrahedra - Positivstellensätze: Basics of polynomial optimization under constraints - Polynomial optimization in practice: Software and solvers; Applications; Theory vs. Practice In addition, for example: <ul style="list-style-type: none"> - Tarski-Seidenberg theorem and CAD - Stability and hyperbolic optimization - AGI forms - References to theoretical computer science 			
Objective qualification			
The students <ul style="list-style-type: none"> - understand the of the complex links between their previous mathematical knowledge and the contents of the lecture - understand the theoretical body of the lecture as a whole and master the corresponding methods - are able to analyze and apply the methods of the lecture <ul style="list-style-type: none"> - know and understand the core statements of real algebraic geometry on nonnegativity and its relation to polynomial optimization - know and understand the common methods in polynomial optimization in theory and practice 			
Literature			
<ul style="list-style-type: none"> - S. Basu, R. Pollack, M.F. Roy: "Algorithms in real algebraic geometry", Springer 2003. - G. Blekherman, P.A. Parillo, R.R. Thomas "Semidefinite Optimization and Convex Algebraic Geometry", MOS-SIAM Series on Optimization, 2013. - J.B. Lasserre: "An Introduction to Polynomial and Semi-Algebraic Optimization", Cambridge University Press, 2015. 			

- J.B. Lasserre: "Moments, Positive Polynomials and Their Applications", Imperial College Press, 2009.
 - M. Marshall: "Positive Polynomials and Sums of Squares", Mathematical Surveys and Monographs, AMS, 2008.

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Nonnegativity and polynomial optimization	6,0	Lecture/Exercise	english
Literature			
<ul style="list-style-type: none"> • S. Basu, R. Pollack, M.F. Roy: "Algorithms in real algebraic geometry", Springer 2003. • G. Blekherman, P.A. Parillo, R.R. Thomas "Semidefinite Optimization and Convex Algebraic Geometry", MOS-SIAM Series on Optimization, 2013. • J. B. Lasserre: "An Introduction to Polynomial and Semi-Algebraic Optimization", Cambridge University Press, 2015. • J. B. Lasserre: "Moments, Positive Polynomials and Their Applications", Imperial College Press, 2009. • M. Marshall: "Positive Polynomials and Sums of Squares", Mathematical Surveys and Monographs, AMS, 2008. 			
Nonnegativity and polynomial optimization	2,0	Exercise	english

Title	Numerical Linear Algebra in Data Science		
Number	1294360	Module version	V2
Shorttext	MAT-STD7-3	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	3 / 5,0	Module owner	Studiendekan der Mathematik
Workload (h)			
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (90 minutes) or 1 oral exam (20-30 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<p>Students learn basic concepts and tools from numerical linear algebra that are used in data mining. After the course, students should be able to solve problems in data mining on their own using the methods discussed in the course.</p> <p>Ideas and algorithms from numerical linear algebra are important in several areas of data mining. This course gives an introduction on the information extraction from data by means of concepts and tools from numerical linear algebra. The following topics are covered in the course: low-rank-approximation of matrices, methods for least-squares-problems, the singular value decomposition, nonnegative matrix factorizations, eigenvalue algorithms.</p>			
Objective qualification			
<p>The students</p> <ul style="list-style-type: none"> - understand the of the complex links between their previous mathematical knowledge and the contents of the lecture - understand the theoretical body of the lecture as a whole and master the corresponding methods - are able to analyze and apply the methods of the lecture <ul style="list-style-type: none"> - know and understand the methods of linear algebra in the context of data mining - are able to analyze and evaluate problems in this field and to develop methods for their solution on the basis of the content of the lecture 			
Literature			
<ul style="list-style-type: none"> - Lars Eldén, „Matrix Methods in Data Mining and Pattern Recognition“, Society for Industrial and Applied Mathematics, 2019 - James Demmel, „Applied numerical linear algebra“, Society for Industrial and Applied Mathematics, 1997 - Lloyd Trefethen, David Bau, „Numerical linear Algebra“, Society for Industrial and Applied Mathematics, 1997 - Gene Golub, Charles van Loan, „Matrix Computations“, Johns Hopkins University Press, 2013 			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Title	Numerical Methods and Learning from Data		
Number	1294350	Module version	V2
Shorttext	MAT-STD7-3	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	6 / 10,0	Module owner	Studiendekan der Mathematik
Workload (h)			
Class attendance (h)		Self studying (h)	
Compulsory requirements			
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (120 minutes) or "Portfolio" according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<ul style="list-style-type: none"> - Randomized methods, e.g., matrix multiplication, randomized decompositions (QR, SVD), rank computation - Low rank methods, basics of compressed sensing - Numerical methods for structured matrices (FFT, circulants, Toeplitz-matrices, Incidence matrices) and their applications - Basics of stochastics and optimization, particularly stochastic gradient descent method - Basics of Learning, e.g. Deep Learning - Realization of numerical methods in a programming environment such as MATLAB 			
Objective qualification			
The students <ul style="list-style-type: none"> - understand the of the complex links between their previous mathematical knowledge and the contents of the lecture - understand the theoretical body of the lecture as a whole and master the corresponding methods - are able to analyze and apply the methods of the lecture <ul style="list-style-type: none"> - know and understand numerical methods that are employed for Data Science applications such as Deep Learning or Machine Learning - know and understand basics of machine learning, e.g. deep neural networks 			
Literature			
Gilbert Strang: Linear Algebra and Learning from Data, Wellesley – Cambridge Press, 2019			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Title	Optimization in Machine Learning and Data Analysis 1		
Number	1294340	Module version	V2
Shorttext	MAT-STD7-3	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1 Semester	Institution	
Hours per Week / ECTS	3 / 5,0	Module owner	
Workload (h)			
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements	Knowledge of Linear Algebra, Analysis, Linear and combinatorial optimization and Discrete optimization is required, as well as basic knowledge of probability theory.		
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (90 minutes) or 1 oral exam (20-30 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
The lecture contains models, criteria and methods for the analysis of vector data as graphs and to analyze networks, in particular, centrality and clustering, as well as optimization methods and fundamental analyses for different forms of machine learning. This may cover deep, artificial neural networks.			
Objective qualification			
The students - understand the of the complex links between their previous mathematical knowledge and the contents of the lecture - understand the theoretical body of the lecture as a whole and master the corresponding methods - are able to analyze and apply the methods of the lecture - know and understand optimization methods for machine learning and machine learning in algorithms for optimization, in particular, discrete optimization and network optimization			
Literature			
will be announced in the lecture			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Optimization in Machine Learning and Data Analysis 1	1,0	Exercise	german
Optimization in Machine Learning and Data Analysis 1	3,0	Lecture/Exercise	german
Literature			
(de) wird in der Veranstaltung bekannt gegeben (en) will be announced in the lecture			

Title	Statistical and machine learning		
Number	1294310	Module version	V2
Shorttext	MAT-STD7-3	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	4 / 7,0	Module owner	
Workload (h)			
Class attendance (h)	56	Self studying (h)	154
Compulsory requirements	Mathematical knowledge in "Einführung in die Stochastik", "Wahrscheinlichkeitstheorie" and linear regression is required.		
Recommended requirements	Mathematical knowledge in programming with R or C++, in "Mathematical Statistics" and "Nonparametrics" is helpful.		
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (90 minutes) or 1 oral exam (20-30 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<ul style="list-style-type: none"> - Supervised learning: linear regression, logistic regression, support vector machines - Decision Trees, k-means, kernel smoothing, random forests, bagging and boosting, neural nets - Unsupervised learning: principal component analysis, clustering - Model fitting: Selection of smoothing parameter via cross validation or Bootstrap 			
Objective qualification			
The students <ul style="list-style-type: none"> - understand the of the complex links between their previous mathematical knowledge and the contents of the lecture - understand the theoretical body of the lecture as a whole and master the corresponding methods - are able to analyze and apply the methods of the lecture <ul style="list-style-type: none"> - know and understand the basic ideas and methods in machine and statistical learning - are able to analyze and evaluate these method and apply them to practical problems 			
Literature			
<ul style="list-style-type: none"> – G. James, D. Witten, T. Hastie, R. Tibshirani: „An Introduction to Statistical Learning“, Springer 2013 – T. Hastie, R. Tibshirani, J. Friedman: „The Elements of Statistical Learning“, Springer 2001 – K. Murphy: „Machine Learning – A probabilistic perspective“, The MIT Press, 2012 			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Statistical and Machine Learning	3,0	Lecture/Exercise	german
Statistical and Machine Learning	1,0	Exercise, small group	german

Title	Advanced Computerlab		
Number	1294440	Module version	
Shorttext	MAT-STD7-4	Language	english german
Frequency of offer	every term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	6 / 5,0	Module owner	Studiendekan der Mathematik
Workload (h)			
Class attendance (h)	84	Self studying (h)	66
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement	Homework according or Portfolio to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents	<p>Advanced Computerlab Numerical Analysis</p> <p>The advanced numerics computing lab deals with advanced methods of scientific computing. We will discuss high-level application problems stemming from mathematics in finance, industry or data science. For numerically solving these problems, various numerical methods will be employed most of which have already been presented in courses such as „Numerische Methoden in der Finanzmathematik“, „Numerical Linear Algebra“, „Numerik gewöhnlicher Differenzialgleichungen“ or „Numerical Methods and Learning from Data“. These methods have to be implemented efficiently, if necessary, in parallel and they should be verified for practical examples. In doing so, the possibilities of these methods as well as their limits will be seen. For some demanding numerical subtasks well-established numerical software libraries exist which have proven to be very efficient in many cases. These can be migrated with the students' own implementations and one can waive the development of hand-written codes.</p> <p>Advanced Computerlab Optimization</p> <p>The goal is to combine advanced knowledge in mathematical optimization with practical planing and realization of large-scale optimization problems. To this end algorithms to solve complex mathematical models of mathematical optimization, partly known from the lectures "discrete optimization", „continuos optimization" or various advanced courses in mathematical optimization, shall be implemented and tested. Thereby, the possibilities and limits will be explored. A sufficiently wide sub-field of optimization may serve as general theme, e.g.</p> <ul style="list-style-type: none"> - Algorithms for scheduling, knapsack, coloring or routing problems. - Algorithms for differentiable or non-smooth non-linear optimization problems with or without constraints. <p>As well-tested and highly efficient methods are available for central methods, it is important to be able to use such software (e.g. CPLEX, Gurobi, Matlab) for pertaining applications.</p> <p>Advanced Computerlab Data Science</p> <p>In the Advanced Computerlab Data Science, current machine learning models are implemented, trained, applied and interpreted in order to work on practical questions on the basis of extensive structured or unstructured data sets. Fundamentals and techniques imparted on a theoretical level (e.g. models and their evaluation, optimization algorithms, interpretation techniques) are applied and expanded in practice by means of functions provided in various frameworks (e.g. TensorFlow, Keras, Matplotlib). The independent</p>		

implementation of machine learning models in Python forms a further focus in addition to the use of specialized frameworks.

Advanced Computerlab Statistical Learning

The focus of the Advanced Computerlab Statistical Learning is on well-known machine learning methods. These are mainly considered from the perspective of mathematical statistics. For presented structured and unstructured data, students are taught how to find suitable solutions, how to implement them, e.g. in the statistical software R, and how to interpret the results. Advantages and disadvantages of the methods used as well as the underlying model assumptions are discussed from a probabilistic or statistical point of view. Students have the opportunity to apply their knowledge of probability theory and mathematical statistics acquired in previous courses. One focus of the course is the independent implementation of machine learning models using frameworks such as TensorFlow, mlr3, Keras, among others.

Objective qualification

The students

- remember and understand the basic tasks and method of mathematical algorithms and their practical application
- are able to use mathematical programming tools
- are able to apply, analyze and implement mathematical algorithms
- are able to document and present mathematical algorithms

Literature



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Advanced Computerlab Data Science	4,0	Exercise	english german
Advanced Computerlab Data Science	2,0	Lecture	english
Advanced Computerlab Statistical Learning	6,0	Lecture/Exercise	english german
Advanced Computerlab Statistical Learning	4,0	Exercise	english german
Advanced Computerlab Mathematical Optimization	2,0	Lecture	english
Advanced Computerlab Mathematical Optimization	4,0	Exercise	english

Advanced Computerlab Numerical Analysis	2,0	Lecture	english german
Advanced Computerlab Numerical Analysis	4,0	Exercise	english

Title	Seminar Data Science - Section Mathematics		
Number	1296916850	Module version	
Shorttext	MathSem	Language	english
Frequency of offer	every term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration		Institution	
Hours per Week / ECTS	2 / 5,0	Module owner	Studiendekan der Mathematik
Workload (h)	150 h		
Class attendance (h)	28	Self studying (h)	122
Compulsory requirements			
Expected performance/ Type of examination	1 "Referat" according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Course achievement			
Contents			
depending on the seminar chosen			
Objective qualification			
<ul style="list-style-type: none"> • Acquisition of social and professional skills • Competencies and skills in free speech, selected conversation techniques and selected moderation and presentation techniques • In-depth knowledge of and ability to deal with information and communication technologies • In-depth knowledge of writing mathematical-technical texts, bibliographies, excerpts and information management, as well as basics scientific reasoning • basic knowledge of the history of science of mathematics • In-depth knowledge of the societal references of mathematics (economic, political, social, ethical references) • Acquisition of action-oriented skills for communication in everyday professional life when presenting, conveying and documenting content. 			
Literature			
depending on the seminar chosen			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Master Seminar Analysis	2,0	Seminar	english german
Master Seminar Mathematical Optimization	2,0	Seminar	english
Master Seminar Mathematical Stochastics	2,0	Seminar	german
Master Seminar Nonnegativity and Polynomial Optimization	2,0	Seminar	
Master Seminar Numerical Analysis	2,0	Seminar	english
	2,0	Seminar	english
Master-Seminar Reduced order modeling for computational fluid dynamics	2,0	Seminar	english german
Seminar Dispersive partial differential equations	2,0	Seminar	english
Master Seminar Mathematical Optimization	2,0	Seminar	english

Title	Mathematical Foundations of Data Science		
Number	1296916020	Module version	
Shorttext	MathFound_DS	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	6 / 10,0	Module owner	Studiendekan der Mathematik
Workload (h)	300 h		
Class attendance (h)	84	Self studying (h)	216
Compulsory requirements			
Recommended requirements	Mathematical knowledge in 'Probability and Statistics' is required.		
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (120 minutes) or 1 oral exam (25-35 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
<p>The course provides a comprehensive overview of the mathematical foundations of statistical learning theory and its significance for machine learning. It covers fundamental concepts such as hypothesis spaces, learning algorithms, and training and test data. Participants will learn how algorithms are evaluated using loss functions, risk, and Bayes risk, and how expected risk differs from empirical risk.</p> <p>Key concepts such as risk minimization, regularization, and the bias-variance trade-off are explained to understand the balance between model complexity and overfitting. The analysis of classical learning algorithms, including Support Vector Machines, neural networks, and decision trees, involves examining trade-offs between training error and generalization ability, as well as optimization problems and regularization techniques. The course also introduces advanced topics such as Rademacher complexity and algorithm stability and discusses current research topics and application areas of statistical learning theory in machine learning.</p>			
Objective qualification			
The students are able to understand the mathematical foundations of statistical learning theory and their practical applications. They have the ability to analyze and evaluate the generalization ability of learning algorithms. The students develop a solid theoretical background for independent research and application in the fields of mathematics and data science.			
Literature			
<ol style="list-style-type: none"> 1. Steinwart/Christman, „Support Vector Machines“, Springer, 2006 2. Györfi/Kohler/Krzyzak/Walk, „A distribution free theory of nonparametric regression“, Springer, 2002 3. Wainwright, “High-dimensional statistics”, Cambridge Series in Statistical and Probabilistic Mathematics 			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Mathematical Foundations of Data Science	6,0	Lecture/Exercise	english

Title	The Mathematics of Data Science		
Number	1296105420	Module version	
Shorttext		Language	english
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	4 / 6,0	Module owner	Studiendekan der Mathematik
Workload (h)			
Class attendance (h)	56	Self studying (h)	154
Compulsory requirements			
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (90 minutes) or 1 oral exam (20-30 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
Mathematical topics in data science such as dimension reduction (PCA and nonlinear reduction), clustering and community detection, and related mathematics, such as linear algebra (singular value decomposition etc.) and probability theory (limit theorems, concentration of measures etc.).			
Objective qualification			
Students learn basic concepts arising in the mathematical theory of data science and the use of mathematics in it, such as linear algebra, probability theory. Exercise sessions aim at reviewing basic mathematics used in lectures and covering some topics in the mathematical side of data science related to the course. Students are required to have basic knowledge and familiarity in linear algebra and probability theory.			
Literature			
Ten lectures and Forty-Two Open Problems in the Mathematics of Data Science (Afonso Bandeira) [https://people.math.ethz.ch/~abandeira/TenLecturesFortyTwoProblems.pdf]			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
The Mathematics of Data Science	4,0	Lecture/Exercise	english

Title	Computational Algebraic Geometry		
Number	1296000600	Module version	
Shorttext		Language	english
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	6 / 10,0	Module owner	Studiendekan der Mathematik
Workload (h)	300 h		
Class attendance (h)	84	Self studying (h)	216
Compulsory requirements			
Recommended requirements	Knowledge of “...” is required.		
Expected performance/ Type of examination	<p>graded examination (Prüfungsleistung): 1 written exam (90 minutes) or 1 oral exam (20-30 minutes) according to examiner’s specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination.</p> <p>The exact examination specifications will be announced at the beginning of the course.</p>		
Course achievement	<p>Non-graded coursework (Studienleistung): Homework according to examiner’s specifications.</p> <p>The exact examination specifications will be announced at the beginning of the course.</p>		
Contents			
Objective qualification			
Literature			

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Related courses			
Rules for the choice of courses			
The module "Computational Algebraic Geometry" consists of a lecture and an exercise. The “small exercise (kleine Übung)” is only mandatory if it is offered instead of the “exercise (Übung)”.			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Computational Algebraic Geometry	6,0	Lecture/Exercise	german
Computational Algebraic Geometry	6,0	Lecture/Exercise	english german

Data Science in Applications - Engineering

Title	Ecological Modelling		
Number	1116130	Module version	
Shorttext	GEA-UA-13	Language	english german
Frequency of offer		Teaching unit	
Module duration	1	Institution	Abteilung für Landschaftsökologie und Umweltsystemanalyse
Hours per Week / ECTS	0 / 6,0	Module owner	Prof. Dr. Boris Schröder-Esselbach
Workload (h)			
Class attendance (h)	60	Self studying (h)	120
Compulsory requirements			
Expected performance/ Type of examination	Examination: Generation and documentation of computer programs		
Course achievement			
Contents			
[Distribution and population models(VÜ)] Approaches to and methods of ecological modelling Theoretical basics for the generation of ecological models (instructed in the exercises) Application examples of models in ecology and conservation biology Approaches to species distribution models in statistics and machine learning (parametric, semi-parametric and nonparametric techniques) Individual-based (agent-based) modelling Programming of species distribution models in R (or comparable software) Programming of individual-based population models with NetLogo (or comparable software)			
Objective qualification			
After successful completion of the module, students have knowledge of the key - statistical and machine learning - methods of species distribution modelling. They also have knowledge of the most important approaches to population dynamic modelling. The students are able to apply both modelling methods for dealing with geoeological and conservation biological questions and they know the advantages and disadvantages of these methods. They are capable to visualise and interpret data and models and to check underlying assumptions as well as to evaluate parameter sensitivities.			
Literature			
- Franklin J 2010: Mapping Species Distributions - Spatial Inference and Prediction. - Railsback SF, Grimm V 2011: Agent-based and individual-based modeling: A practical introduction. Additional literature will be provided online.			



Related courses			
Rules for the choice of courses			
In the exercises, we use R (statistical software) and NetLogo. Previous knowledge in programming (preferentially in R) is preconditioned. NetLogo will be newly introduced (no previous knowledge required).			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
	4,0	Lecture/Exercise	german

Title	Fundamentals of Turbulence Modeling		
Number	2512380	Module version	
Shorttext	MB-ISM-38	Language	english
Frequency of offer	only in the summer term	Teaching unit	Fakultät für Maschinenbau
Module duration	1	Institution	Institut für Strömungsmechanik
Hours per Week / ECTS	3 / 5,0	Module owner	Prof. Dr. David Rival
Workload (h)	150		
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Recommended requirements	This is an advanced course on fluid mechanics, it is strongly suggested that the participants have attended a previous fluid mechanics or CFD course.		
Expected performance/ Type of examination	1 Examination element: written exam (90 min) or oral exam (30 min to 45 min)		
Course achievement			
Contents			
<ul style="list-style-type: none"> • Numerical simulation of fluid flow • Overview of computational approaches to turbulent flow (RANS, ... , LES, DNS) • RANS: turbulence modeling • LES: partly resolved turbulence (filtering, modeling of unresolved scales, boundary and initial conditions requirements on numerical scheme and resolution) • Hybrid RANS-LES • Applications of scale-resolving simulations 			
Objective qualification			
Students acquire the concepts and fundamentals of engineering turbulence modeling. Students learn the underlying physics, assumptions and application of various turbulence models. They know the assumptions, governing equations, and the numerical algorithms of each methodology. Students are able to explain and evaluate the results of scale-resolution simulations in a critical way. At the end of the course, students will be able to use concepts from turbulence modeling for the solution of problems within the engineering field.			
Literature			
<ol style="list-style-type: none"> 1. Turbulence Modeling for CFD, Third edition, by David C. Wilcox 2. Large Eddy Simulation for Incompressible Flows: An Introduction, P. Sagaut, 2005 3. Computational Techniques for Fluid Dynamics, Volume I, Springer, 1997, C.A.J. Fletcher 			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
	3,0	Lecture/Exercise	english

Title	Basic Coastal Engineering		
Number	4398090	Module version	V1
Shorttext		Language	german
Frequency of offer	only in the winter term	Teaching unit	
Module duration	1	Institution	Abteilung Hydromechanik, Küsteningenieurwesen und Seebau
Hours per Week / ECTS	0 / 6,0	Module owner	Prof. Dr. Nils Goseberg
Workload (h)	180		
Class attendance (h)	70	Self studying (h)	110
Compulsory requirements			
Expected performance/ Type of examination	Written exam (90 min.)		
Course achievement	Term paper		
Contents			
<ul style="list-style-type: none"> - Introduction to coastal engineering (sociological and ecological significance of the coastal zone, tasks and future of the coastal engineer) - Linear and nonlinear wave theories, including areas of validity and application - Wave transformation in shallow water (shoaling, refraction, breaking) and in interaction with obstacles (reflection, diffraction) - Formation mechanisms of the sea state, including procedures for its parameterization and prediction - Formation and prediction of tides in coastal areas and estuaries, including their special forms, significance and benefits - Formation and prediction of storm surges and design water levels Insight into the current state of research in various fields of coastal engineering			
Objective qualification			
<p>After successful completion of the module, students will have a broad and solid basic knowledge of the mechanics of water waves and hydrodynamic processes in the coastal area, which enables them to determine the load, erosion and transport parameters for the required constructive and functional planning of engineering measures.</p> <p>The students are able to use the linear and nonlinear theory of water waves to calculate the total wave induced current parameters and the associated effects on sediments, structures and other obstacles. By the mediated calculation basics for wave transformation the students can calculate the effects of the bottom in shallow water (shoaling, refraction, wave breaking) as well as of buildings and other obstacles (reflection, diffraction) on the parameters (height, length, direction) of the waves and their stability (refraction criterion) at the given planning location.</p> <p>On the basis of the acquired basics of the origin, parameterization, mathematical/statistical description and prediction of the sea state, the students are able to determine the design waves for the functional and constructive planning. They can determine the design water levels on the basis of the acquired knowledge on the formation and prediction of tides on open coasts and in estuaries as well as of storm surges on the German North Sea and Baltic Sea coasts. In the seminar, students are enabled to conduct scientific research and to present research results from current publications in an appropriate manner.</p>			

Literature

unter anderem / amongst others:

- Detailed Presentation Slides of the Lecture, Exercises, Solutions (PDF)
- Teaching Platform with educational videos, interactive diagrams, screencasts and lab videos (coastal.i-wi.tu-bs.de)
- Task Library of the Institute
- EAK (2003): Empfehlungen für Küstenschutzwerke. Die Küste, Heft 65, Heide i. Holstein.
- Oumeraci, H. (2001): Küsteningenieurwesen. Kapitel 12 in: Lecher, K. et al.: Taschenbuch der Wasserwirtschaft, Berlin.
- CEM (2008): Coastal Engineering Manual. Washington, D.C: U.S. Army Corps of Engineers, Online-Resource.
- Dean, Robert G.; Dalrymple, Robert A. (1991): Water wave mechanics for engineers and scientists. Advanced Series on Ocean Engineering, Singapore: World Scientific.
- Goda, Yoshimi (2010): Reanalysis of regular and random breaking wave statistics. Coastal Engineering Journal, vol. 52, no.1, JSCE.

Remark

In the Seminar in Coastal Engineering on the topic Data Science & Coastal Engineering, an introduction is given to the use of Python as a universal tool for the evaluation and presentation of data; students will implement and evaluate data and methods from the lecture. The successful completion and submission of code implementations will be credited as study achievement (Studienleistung).



Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
	1,0	Seminar	english
	4,0	Lecture/Exercise	english german

Title	Introduction to Finite Element Methods		
Number	4398470	Module version	
Shorttext	BAU-STD5-4	Language	german
Frequency of offer		Teaching unit	Fakultät Architektur, Bauingenieurwesen und Umweltwissenschaften
Module duration	1	Institution	
Hours per Week / ECTS	0 / 5,0	Module owner	
Workload (h)	150 h		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination	written exam (90 min) or oral exam (30 min)		
Course achievement	Homework		
Module grade composition	Exam 70%, homework 30%		
Contents			
Displacement-based finite elements for 1D and 2D elasticity problems as well as for stationary heat conduction problems; FEM algorithm including postprocessing; numerical integration, isoparametric elements, computer-lab			
Objective qualification			
The students know mathematical models for solid bodies and structures in engineering, especially formulations for beam, plane and volume structures. They are able to create finite element models and apply adequate solution methods.			
Literature			
- Bathe,K.J.: Finite-Elemente-Methoden, 2. Auflage, Springer, ISBN: 3540668063, Berlin, 2002 - Zienkiewicz,O.C.; Taylor,R.L.: The Finite Element Method, 6. Auflage, Butterworth Heinemann, ISBN: 0750663200, 2005 - Hughes,T.J.R.: The Finite Element Method - Linear Static and Dynamic Finite Element Analysis, Prentice-Hall Inc., ISBN: 0133170179, 1987 Introduction to Finite Element Methods: manuscript and extended textbook			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
	2,0	Exercise	english
	2,0	Lecture	english

Title	Deep Learning in Remote Sensing		
Number	4398860	Module version	
Shorttext		Language	english
Frequency of offer	only in the summer term	Teaching unit	
Module duration	1	Institution	Institut für Geodäsie und Photogrammetrie
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Markus Gerke
Workload (h)	150 h		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Recommended requirements	As it is planned, the students should first take "Machine learning" or any similar course like "Pattern Recognition" in Winter semester and then "Deep learning in Remote Sensing" in Summer semester.		
Expected performance/ Type of examination			
Course achievement			
Contents			
<p>In this module students are introduced to the concepts of deep learning in order to process Remote sensing data. Remote sensing is the science that provides geometric and semantic information about objects at or near the surface of the Earth using the sensors which are installed on satellites or other airborne platforms. Along with fundamentals of remote sensing, some applications like object detection and classification especially on images and also regression algorithms on remote sensing observations will be covered. In the context of image understanding, an introduction to digital image processing will be given, which deals with the application of filters on the images to extract the information which could be used in machine learning and deep learning algorithms. Each of the lectures in this module is supplemented by practical parts to enable the students to process real-world remote sensing datasets, efficiently. After completing the module, students know and understand the most important concepts of deep learning for image analysis. Furthermore, a student is able to implement a selection of algorithms and evaluate the respective result.</p>			
Objective qualification			
Upon completion of this module, the students will be able to understand basic principles and applications of deep learning and to apply them on Remote Sensing as well as similar problems.			
Literature			
<ul style="list-style-type: none"> • Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems, Aurélien Géron, 2019. • Pattern Recognition and Machine Learning, Bishop, C. M. 2006 • Machine Learning with PyTorch and Scikit-Learn, Sebastian Raschka, Yuxi (Hayden) Liu, Vahid Mirjalili, 2022 • Deep Learning, Goodfellow, Y. Bengio, and A. Courville, MIT Press, 2016 • Deep Learning for Remote Sensing Images with Open Source Software, Rémi Cresson, CRC Press, 2020. 			



Related courses			
Rules for the choice of courses			
As it is planned, the students should first take “Machine learning” or any similar course like “Pattern Recognition” in Winter semester and then “Deep learning in Remote Sensing” in Summer semester.			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
	2,0	Lecture	english
	2,0	Exercise	english

Title	Machine Learning		
Number	4398870	Module version	
Shorttext		Language	english
Frequency of offer	only in the winter term	Teaching unit	Fakultät Architektur, Bauingenieurwesen und Umweltwissenschaften
Module duration		Institution	Institut für Geodäsie und Photogrammetrie
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Markus Gerke
Workload (h)	150 h		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement			
Contents			
<p>This Module will introduce the fundamental methods at the core of machine learning, including -but not limited to- classification, regression analysis, clustering, and dimensionality reduction. This course is designed for BSc. and MSc. students in different disciplines who employ machine learning algorithms in their fields. Students will learn about the basic concepts of machine learning and will apply the learned concepts on the practical problems using open source libraries from the Python programming ecosystem. The course will also briefly cover neural networks and will be closed by a short introduction to deep learning. Classes on theoretical aspects will be complemented by practical lab sessions. In this course we do not concentrate on a specific type of data and various datasets will be used in the practical example.</p>			
Objective qualification			
<p>Upon completion of this module, the students will be able to understand basic principles and applications of machine learning and to apply them on practical examples.</p>			
Literature			
<ul style="list-style-type: none"> • Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems, Aurélien Géron, 2019. • Pattern Recognition and Machine Learning, Bishop, C. M. 2006 • Machine Learning with PyTorch and Scikit-Learn, Sebastian Raschka, Yuxi (Hayden) Liu, Vahid Mirjalili, 2022 <p>Further information and material will be provided during the course.</p>			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
		Lecture	english
Literature			
<ul style="list-style-type: none"> • Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems, Aurélien Géron, 2019. • Pattern Recognition and Machine Learning, Bishop, C. M. 2006 • Machine Learning with PyTorch and Scikit-Learn, Sebastian Raschka, Yuxi (Hayden) Liu, Vahid Mirjalili, 2022 <p>Further information and material will be provided during the course.</p>			
	2,0	Exercise	english

Title	Data-Driven Material Modeling		
Number	4398690	Module version	
Shorttext	BAU-STD5-69	Language	english
Frequency of offer		Teaching unit	
Module duration	1	Institution	Institut für Angewandte Mechanik
Hours per Week / ECTS	4 / 6,0	Module owner	Prof. Dr. Henning Wes-sels
Workload (h)			
Class attendance (h)	56	Self studying (h)	124
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement			
Contents			
Objective qualification			
Literature			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
	4,0	Lecture/Exercise	english

Title	Experimental Fluid Dynamics		
Number	2512000030	Module version	
Shorttext		Language	english
Frequency of offer	only in the summer term	Teaching unit	Fakultät für Maschinenbau
Module duration	1	Institution	Institut für Strömungsmechanik
Hours per Week / ECTS	3 / 5,0	Module owner	Prof. Dr. David Rival
Workload (h)	150		
Class attendance (h)	60	Self studying (h)	90
Compulsory requirements			
Recommended requirements	<ul style="list-style-type: none"> • Knowledge from the bachelor's degree in fluid mechanics, physics and electrical engineering • In-depth knowledge of fluid mechanics and aerodynamics of aircraft 		
Expected performance/ Type of examination	1 examination element: written exam (90 min) or oral exam (30 min)		
Course achievement			
Contents			
Theory and Experiment, Measurement Uncertainties, Flow visualization methods (smoke, oil flow pictures, laser sheet visualization), pressure measurement, force measurement, hot-wire anemometry, basics of optics, Particle Image Velocimetry (PIV) and its extensions, Schlieren techniques, thermography, pressure sensitive paint, particle measurement techniques			
Objective qualification			
The students are able to explain mechanical, electrical and optical measurement techniques to determine fluid mechanical quantities like pressure, density, velocity, temperature and shear stress. Beyond the basic principle and the accuracy of the different measurement techniques, the students can evaluate the limitations of the techniques and use methods to improve and expand them. The students are able to apply selected measurement techniques in the laboratory course.			
Literature			
<ol style="list-style-type: none"> 1. H. Eckelmann: Einführung in die Strömungsmesstechnik, Teubner, 1997 2. W. Nitsche: Strömungsmesstechnik, Springer, 2005 3. C. Tropea, A. L. Yarin, J. F. Foss: Springer Handbook of Experimental Fluid Mechanics, Springer Verlag, 2007 4. H. Oertel sen., H. Oertel jun.: Optische Strömungsmesstechnik, G. Braun Verlag, Karlsruhe 1989 5. M. Raffel, C. Willert, J. Kompenhans: Particle Image Velocimetry, Springer Verlag, 1997 6. W. Merzkirch: Flow Visualization, Acad. Press Inc., 1987 7. Folienskript #Measurement methods in fluid mechanics# 			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Experimental Fluid Dynamics	2,0	Lecture	english
Laboratory Experimental Fluid Dynamics	1,0	Laboratory	english

Data Science in Applications - Image and Signal Processing

Title	Mathematical Image Processing		
Number	1294300	Module version	V2
Shorttext	MAT-STD7-3	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	6 / 10,0	Module owner	Studiendekan der Mathematik
Workload (h)			
Class attendance (h)	84	Self studying (h)	216
Compulsory requirements			
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (120 minutes) or 1 oral exam (25-35 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Contents			
- Interpolation and sampling, histograms - Linear and Morphological filters A selection from the following topics: frequency methods, sampling theorem, applications of partial differential equations or variational methods.			
Objective qualification			
The students - understand the of the complex links between their previous mathematical knowledge and the contents of the lecture - understand the theoretical body of the lecture as a whole and master the corresponding methods - are able to analyze and apply the methods of the lecture - know and understand the characterization of the quality of an image through mathematical quantities - know and understand the most important basic tasks in image processing and various methods of solving them			
Literature			
- Aubert, Kornprobst, Mathematical Problems in Image Processing, Springer, 2006 - Bredies, Lorenz, Mathematische Bildverarbeitung, Vieweg, 2011 - Bernd Jähne, Digitale Bildverarbeitung, Springer 2005 - Gilles Aubert und Pierre Kornprobst, Mathematical Problems in Image Processing, Springer 2006			

- Tony F. Chan und Jianghong Shen, Image Processing and Analysis: Variational, PDE, Wavelet and Stochastic Methods, SIAM, 2005

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Mathematical Image Processing	4,0	Lecture/Exercise	english
Literature			
<ul style="list-style-type: none"> • Aubert, Kornprobst, Mathematical Problems in Image Processing, Springer, 2006 • Bredies, Lorenz, Mathematische Bildverarbeitung, Vieweg, 2011 • Bernd Jähne, Digitale Bildverarbeitung, Springer 2005 • Gilles Aubert und Pierre Kornprobst, Mathematical Problems in Image Processing, Springer 2006 • Tony F. Chan und Jianghong Shen, Image Processing and Analysis: Variational, PDE, Wavelet and Stochastic Methods, SIAM, 2005 			
Mathematical Image Processing	2,0	Exercise	english

Title	Deep Learning for imaging in nano and quantum science		
Number	1520500	Module version	
Shorttext	PHY-AP-50	Language	german
Frequency of offer	only in the winter term	Teaching unit	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	Institution	
Hours per Week / ECTS	3 / 5,0	Module owner	Uwe Rossow
Workload (h)	0		
Class attendance (h)	35	Self studying (h)	115
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement			
Contents			
Objective qualification			
Literature			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Deep Learning for imaging in nano and quantum science	3,0	Lecture	english
Deep Learning for imaging in nano and quantum science	1,0	Exercise	english

Title	Network Information Theory		
Number	2424650	Module version	
Shorttext	ET-NT-65	Language	english
Frequency of offer	only in the summer term	Teaching unit	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	Institution	
Hours per Week / ECTS	4 / 6,0	Module owner	Prof. Dr. Eduard Jorswieck
Workload (h)	180		
Class attendance (h)	56	Self studying (h)	124
Compulsory requirements			
Expected performance/ Type of examination	Written exam (90 min) or oral exam (30 min)		
Course achievement			
Contents			
<ul style="list-style-type: none"> • Review point-to-point channel capacity and coding theorem • Strong typical sequences and their properties • Multiple-Access Channel: Capacity region compared to TDMA/FDMA/SDMA/NOMA • #Broadcast Channel: degraded BC capacity region, non-degraded BC achievable rate region and converse • Interference Channel: very strong, strong, weak interference capacity region, medium interference achievable rate region and converse • #Relay Channel: achievable schemes amplify-and-forward, decode-and-forward, compress-and-forward, estimate-and-forward #Generalization and application of elements to complex networks 			
Objective qualification			
After completing the lecture, the students will know the building blocks of complex communications networks, i.e., the multiple-access channel, the broadcast channel, the relay channel and the interference channel, their achievable rates and capacity regions including coding and decoding schemes. In addition, the students obtain knowledge to design future wireless and multi-hop as well as ad-hoc networks. They master information-theoretic and mathematical tools to prove coding theorems. They know the state of the art as well as open problems in network information theory.			
Literature			
#A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011. D. Tse and P. Viswanath: Fundamentals of Wireless Communications, Cambridge University Press, 2007. T. M. Cover and J. A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006. S. Boyd and L. Vandenberghe: Convex Optimization, Cambridge University Press, 2004. R. W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008.			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course			
SWS		Eventtype	Language
Network Information Theory		2,0	Lecture
Literature			
<p>A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011 D. Tse and P. Viswanath: Fundamentals of Wireless Communications, Cambridge University Press, 2007 T. M. Cover and J. A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006 S. Boyd and L. Vandenberghe: Convex Optimization, Cambridge University Press, 2004 R. W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008</p>			
Network Information Theory		2,0	Exercise
Literature			
<p>- A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011. - D. Tse and P. Viswanath: Fundamentals of Wireless Communications, Cambridge University Press, 2007. - T. M. Cover and J. A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006. - S. Boyd and L. Vandenberghe: Convex Optimization, Cambridge University Press, 2004. - R. W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008.</p>			

Title	Spoken Language Processing		
Number	2424680	Module version	
Shorttext	ET-NT-68	Language	german
Frequency of offer	only in the winter term	Teaching unit	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	Institution	
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Tim Fingscheidt
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination	Oral exam 30 minutes or written exam 90 minutes (depending on number of participants)		
Course achievement			
Contents			
<ul style="list-style-type: none"> - Basics of speech production and perception - Feature extraction - Hidden Markov models - Acoustic models and language models - Automatic speech recognition - Spoken language systems 			
Objective qualification			
After successful completion of the module, students will be able to classify time series (e.g., speech signals) using hidden Markov modeling. The students acquire all the necessary knowledge to suitably select, design, and evaluate methods and algorithms for automatic speech recognition to solve problems in practice.			
Literature			
<ul style="list-style-type: none"> - Lecture slides - X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001 - B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008 - A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004 - E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995 - G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003 - L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993 - K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990 			
Remark			
This module from the master's program is also suitable for bachelor students. Basic knowledge of digital signal processing, as e.g. acquired in the module #digital signal processing#, facilitates the understanding of this lecture.			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
	2,0	Lecture	english
Literature			
<ul style="list-style-type: none"> - X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001 - B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008 - A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004 - E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995 - G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003 - L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993 - K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990 			
	2,0	Seminar	english
Literature			
<ul style="list-style-type: none"> - X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001 - B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008 - A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004 - E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995 - G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003 - L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993 - K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990 			

Title	Fundamentals of Digital Signal Processing		
Number	2424760	Module version	
Shorttext	ET-NT-76	Language	german
Frequency of offer	every term	Teaching unit	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	Institution	
Hours per Week / ECTS	3 / 5,0	Module owner	Prof. Dr. Tim Fingscheidt
Workload (h)	150		
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement			
Contents			
Objective qualification			
Literature			
- Vorlesungsfolien - A.V. Oppenheim, R.W. Schafer, J.R. Buck: "Zeitdiskrete Signalverarbeitung" , Pearson Verlag, 2004 - K.D. Kammeyer, K. Kroschel: "Digitale Signalverarbeitung" , Teubner Verlag, 2002 - A.V. Oppenheim, R.W. Schafer, J.R. Buck: "Discrete Time Signal Processing" , Prentice-Hall, 2004 - H.-W. Schüßler: "Digitale Signalverarbeitung 1" , Springer Verlag, 1994			
Remark			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

	2,0	Lecture	german
Literature			
<ul style="list-style-type: none"> • A. V. Oppenheim, R. W. Schafer, J. R. Buck: Zeitdiskrete Signalverarbeitung, Pearson Studium, 2004 • K. D. Kammeyer, K. Kroschel: Digitale Signalverarbeitung, Teubner Verlag, 2002 • A. V. Oppenheim, R. W. Schafer, J. R. Buck: Discrete Time Signal Processing, Prentice Hall, 2004 • H.-W. Schüßler: Digitale Signalverarbeitung, Springer Verlag, 1994 			
	1,0	Exercise	german
Literature			
siehe Vorlesung			

Title	Digital Signal Processing		
Number	2424770	Module version	
Shorttext	ET-NT-77	Language	german
Frequency of offer	only in the summer term	Teaching unit	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	Institution	
Hours per Week / ECTS	5 / 8,0	Module owner	Prof. Dr. Tim Fingscheidt
Workload (h)	240		
Class attendance (h)	70	Self studying (h)	170
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement			
Contents			
Objective qualification			
Literature			
- Vorlesungsfolien - A.V. Oppenheim, R.W. Schafer, J.R. Buck: "Zeitdiskrete Signalverarbeitung" , Pearson Verlag, 2004 - K.D. Kammeyer, K. Kroschel: "Digitale Signalverarbeitung" , Teubner Verlag, 2002 - A.V. Oppenheim, R.W. Schafer, J.R. Buck: "Discrete Time Signal Processing" , Prentice-Hall, 2004 - H.-W. Schüßler: "Digitale Signalverarbeitung 1" , Springer Verlag, 1994			
Remark			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

	2,0	Lecture	german
Literature			
<ul style="list-style-type: none"> • A. V. Oppenheim, R. W. Schafer, J. R. Buck: Zeitdiskrete Signalverarbeitung, Pearson Studium, 2004 • K. D. Kammeyer, K. Kroschel: Digitale Signalverarbeitung, Teubner Verlag, 2002 • A. V. Oppenheim, R. W. Schafer, J. R. Buck: Discrete Time Signal Processing, Prentice Hall, 2004 • H.-W. Schüßler: Digitale Signalverarbeitung, Springer Verlag, 1994 			
	2,0	Laboratory	german
Literature			
siehe Vorlesung			
	1,0	Exercise	german
Literature			
siehe Vorlesung			

Title	Computer Vision and Machine Learning		
Number	4216330	Module version	V2
Shorttext	INF-CG-33	Language	
Frequency of offer	only in the summer term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	0 / 5,0	Module owner	Prof. Dr. Martin Eise- mann
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination	1 exam: written exam, 90 minutes or oral exam, 30 minutes or Take-Home-Exam.		
Course achievement	1 study achievement: 50% of the exercises must be passed		
Contents			
<ul style="list-style-type: none"> - Feature Detectors and Descriptors - Object Detectio - Matting - Image Compositing and Editing - Dense Correspondences - Motion Capture - Cameracalibration - Epipolar Geometry - Stereo and Multi-View Reconstruction - Cameras and Scanner - Machine Learning for Computer Vision Problems 			
Objective qualification			
Upon successful completion of this module, students will have a basic understanding of how to develop complex computer vision applications. They are able to analyze computer vision problems and to design and implement appropriate solutions.			
Literature			
<ul style="list-style-type: none"> - Radke: Computer Vision for Multimedia, Cambridge University Press - Szeliski: Computer Vision - Algorithms and Applications, Springer Verlag - Goodfellow et al.: Deep Learning - Das umfassende Handbuch, mitp 			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Computer Vision und Machine Learning	4,0	Lecture/Exercise	english german
Literature			
<ul style="list-style-type: none"> - Radke: Computer Vision for Multimedia, Cambridge University Press - Szeliski: Computer Vision - Algorithms and Applications, Springer Verlag - Goodfellow et al.: Deep Learning - Das umfassende Handbuch, mitp 			
	2,0	Exercise	english german

Title	Biomedical Image and Signal Analysis		
Number	4217760	Module version	V2
Shorttext	INF-MI-76	Language	english
Frequency of offer	only in the winter term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	Peter L. Reichertz Institut für Medizinische Informatik
Hours per Week / ECTS	0 / 5,0	Module owner	Prof. Dr. Thomas Deserno
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Recommended requirements	Knowledge of the bachelor's module 'Image and Signal Production in Biomedicine' is recommended.		
Expected performance/ Type of examination	graded work: written exam (90 minutes) or oral exam (30 minutes) or experimental work or Portfolio or Take-Home-Exam.		
Course achievement			
Contents			
<p>Using examples from ECG, X-ray imaging, magnetic resonance imaging and optical imaging systems we explain the general methods in medical signal and image processing. The methods are categorized according to their general properties, and the pros and cons of the manifold of methods is discussed using these categories. Systematic evaluation of signal and image analytics with and without ground truth is also addressed in this module.</p>			
Objective qualification			
<p>Passing this module, the students can classify and compare different methodologies for medical signal and image acquisition. They can differ and compare linear with non-linear filtering and analyze electrocardiography (ECG) data into their components. They can segment medical images in two and three dimensions and are able to apply model-based approaches for image and signal analytics.</p>			
Literature			
<p>- Lehmann, T.M., Oberschelp, W., Pelikan, E., Regges, R.(1997): Bildverarbeitung für die Medizin: Grundlagen, Modelle, Methoden, Anwendungen. Springer-Verlag, Berlin. ISBN-13: 978-3540614586.</p> <p>- Deserno, T.M.(Ed). (2011): Biomedical Image Processing. Springer-Verlag Berlin Heidelberg. ISBN-13: 978-3642267307.</p> <p>- Handels, H.(2009):Medizinische Bildverarbeitung: Bildanalyse, Mustererkennung und Visualisierung für die computergestützte ärztliche Diagnostik und Therapie. 2. Auflage. Vieweg & Teubner Verlag. ISBN-13: 978-3835100770.</p> <p>- Süße, H., Rodner, E.(2014): Bildverarbeitung und Objekterkennung: Computer Vision in Industrie und Medizin. Springer Vieweg. ISBN-13: 978-3834826053.</p> <p>- Dougherty, G.(2009): Digital Image Processing for Medical Applications. Cambridge University Press. ISBN-13: 978-0521181938.</p>			

- Burger, W., Burge, M.J. (2015): Digitale Bildverarbeitung: Eine algorithmische Einführung mit Java.3. Auflage. Springer-Vieweg. ISBN-13: 978-3-642-04604-9.

- Jähne, B.(2012): Digitale Bildverarbeitung und Bildgewinnung. 7. Auflage. Springer-Verlag Berlin. ISBN-13: 978-3642049514.

- Broeke, J., Mateos Perez, J.M., Pascau, J.(2015): Image Processing with ImageJ. 2. Edition. Packt Publishing. ISBN-13: 978-1785889837.



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Biomedical Image and Signal Analysis	4,0	Lecture/Exercise	english
Literature			
<p>- Lehmann, T.M., Oberschelp, W., Pelikan, E., Reppes, R.(1997): Bildverarbeitung für die Medizin: Grundlagen, Modelle, Methoden, Anwendungen. Springer-Verlag, Berlin. ISBN-13: 978-3540614586. - Deserno, T.M.(Ed). (2011): Biomedical Image Processing. Springer-Verlag Berlin Heidelberg. ISBN-13: 978-3642267307. - Handels, H.(2009): Medizinische Bildverarbeitung: Bildanalyse, Mustererkennung und Visualisierung für die computergestützte ärztliche Diagnostik und Therapie. 2. Auflage. Vieweg & Teubner Verlag. ISBN-13: 978-3835100770. - Süße, H., Rodner, E.(2014): Bildverarbeitung und Objekterkennung: Computer Vision in Industrie und Medizin. Springer Vieweg. ISBN-13: 978-3834826053. - Dougherty, G.(2009): Digital Image Processing for Medical Applications. Cambridge University Press. ISBN-13: 978-0521181938. - Burger, W., Burge, M.J. (2015): Digitale Bildverarbeitung: Eine algorithmische Einführung mit Java.3. Auflage. Springer-Vieweg. ISBN-13: 978-3-642-04604-9. - Jähne, B.(2012): Digitale Bildverarbeitung und Bildgewinnung. 7. Auflage. Springer-Verlag Berlin. ISBN-13: 978-3642049514. - Broeke, J., Mateos Perez, J.M., Pascau, J.(2015): Image Processing with ImageJ. 2. Edition. Packt Publishing. ISBN-13: 978-1785889837.</p>			
	2,0	Exercise	english

Title	Deep Learning in Remote Sensing		
Number	4398860	Module version	
Shorttext		Language	english
Frequency of offer	only in the summer term	Teaching unit	
Module duration	1	Institution	Institut für Geodäsie und Photogrammetrie
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Markus Gerke
Workload (h)	150 h		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Recommended requirements	As it is planned, the students should first take "Machine learning" or any similar course like "Pattern Recognition" in Winter semester and then "Deep learning in Remote Sensing" in Summer semester.		
Expected performance/ Type of examination			
Course achievement			
Contents			
<p>In this module students are introduced to the concepts of deep learning in order to process Remote sensing data. Remote sensing is the science that provides geometric and semantic information about objects at or near the surface of the Earth using the sensors which are installed on satellites or other airborne platforms. Along with fundamentals of remote sensing, some applications like object detection and classification especially on images and also regression algorithms on remote sensing observations will be covered. In the context of image understanding, an introduction to digital image processing will be given, which deals with the application of filters on the images to extract the information which could be used in machine learning and deep learning algorithms. Each of the lectures in this module is supplemented by practical parts to enable the students to process real-world remote sensing datasets, efficiently. After completing the module, students know and understand the most important concepts of deep learning for image analysis. Furthermore, a student is able to implement a selection of algorithms and evaluate the respective result.</p>			
Objective qualification			
Upon completion of this module, the students will be able to understand basic principles and applications of deep learning and to apply them on Remote Sensing as well as similar problems.			
Literature			
<ul style="list-style-type: none"> • Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems, Aurélien Géron, 2019. • Pattern Recognition and Machine Learning, Bishop, C. M. 2006 • Machine Learning with PyTorch and Scikit-Learn, Sebastian Raschka, Yuxi (Hayden) Liu, Vahid Mirjalili, 2022 • Deep Learning, Goodfellow, Y. Bengio, and A. Courville, MIT Press, 2016 • Deep Learning for Remote Sensing Images with Open Source Software, Rémi Cresson, CRC Press, 2020. 			



Related courses			
Rules for the choice of courses			
As it is planned, the students should first take “Machine learning” or any similar course like “Pattern Recognition” in Winter semester and then “Deep learning in Remote Sensing” in Summer semester.			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
	2,0	Lecture	english
	2,0	Exercise	english

Title	Machine Learning		
Number	4398870	Module version	
Shorttext		Language	english
Frequency of offer	only in the winter term	Teaching unit	Fakultät Architektur, Bauingenieurwesen und Umweltwissenschaften
Module duration		Institution	Institut für Geodäsie und Photogrammetrie
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Markus Gerke
Workload (h)	150 h		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement			
Contents			
<p>This Module will introduce the fundamental methods at the core of machine learning, including -but not limited to- classification, regression analysis, clustering, and dimensionality reduction. This course is designed for BSc. and MSc. students in different disciplines who employ machine learning algorithms in their fields. Students will learn about the basic concepts of machine learning and will apply the learned concepts on the practical problems using open source libraries from the Python programming ecosystem. The course will also briefly cover neural networks and will be closed by a short introduction to deep learning. Classes on theoretical aspects will be complemented by practical lab sessions. In this course we do not concentrate on a specific type of data and various datasets will be used in the practical example.</p>			
Objective qualification			
<p>Upon completion of this module, the students will be able to understand basic principles and applications of machine learning and to apply them on practical examples.</p>			
Literature			
<ul style="list-style-type: none"> • Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems, Aurélien Géron, 2019. • Pattern Recognition and Machine Learning, Bishop, C. M. 2006 • Machine Learning with PyTorch and Scikit-Learn, Sebastian Raschka, Yuxi (Hayden) Liu, Vahid Mirjalili, 2022 <p>Further information and material will be provided during the course.</p>			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
		Lecture	english
Literature			
<ul style="list-style-type: none"> • Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems, Aurélien Géron, 2019. • Pattern Recognition and Machine Learning, Bishop, C. M. 2006 • Machine Learning with PyTorch and Scikit-Learn, Sebastian Raschka, Yuxi (Hayden) Liu, Vahid Mirjalili, 2022 <p>Further information and material will be provided during the course.</p>			
	2,0	Exercise	english

Title	Computer Lab Pattern Recognition		
Number	2424000020	Module version	
Shorttext		Language	english german
Frequency of offer	every term	Teaching unit	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	Institution	Institut für Nachrichtentechnik
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Tim Fingscheidt
Workload (h)			
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement	Development and documentation of a computer / software program		
Contents			
<p>The course consists of hands-on programming tasks that are solved by the participants and subsequently evaluated in a semi-automated way. In total, seven units from the sub-fields (i) basics of hands-on application of machine learning methods, (ii) image processing (computer vision) and (iii) time series analysis have to be completed. The seven units are:</p> <ul style="list-style-type: none"> • Interactive introduction to Python fundamentals using Jupyter notebooks, fundamentals of data processing, preparation and visualization. • Use of single-layer machine learning models to solve a two-class problem: Support vector machines (based on libsvm) and neural networks. Splitting and use of datasets, application of appropriate metrics for evaluation, use of high-level machine learning libraries such as SciKit-Learn • Use of deep neural networks to solve a multi-class classification problem, introduction to recognized academic datasets such as MNIST and CIFAR-10, introduction to the use of deep learning libraries PyTorch and Tensorflow, usage and adaptation of pre-trained models • Use of convolutional neural networks to solve more challenging image processing problems such as semantic segmentation and depth estimation, use of regularization methods in training • Use of diverse cost functions to optimize neural networks, implementation of generative models such as Generative Adversarial Networks (GANs) • Use of recurrent neural networks to solve problems based on time series data, application of concepts for anomaly detection • Use of recurrent neural networks for speech processing, e.g., for noise reduction, analysis of neural networks with respect to their complexity (FLOPs, number of parameters) <p>Six out of the seven units have to be successfully passed for the entire computer lab module to be passed, among these unit 4 (convolutional neural networks) and unit 7 (recurrent neural networks in speech processing).</p>			
Objective qualification			
In this course, students acquire the competencies to independently select and apply appropriate machine learning and deep learning methods for complex problems. The students ...			

- ... master the programming language Python as well as the basics of the deep learning libraries PyTorch and Tensorflow.
- ... evaluate the effectiveness of simple machine learning models and neuronal networks for classification and regression problems.
- ... evaluate the quality of deep learning models on appropriate data (sub)sets with meaningful metrics
- ... know and use different types of neural networks for problems in the areas of image processing, time series processing and generative problems
- ... know and use different strategies for data preprocessing and data augmentation
- ... know and use different training and regularization methods for the optimization of neural networks
- ... evaluate the complexity of a neural network on the basis of various parameters

Literature

- Christopher M. Bishop, Nasser M. Nasrabadi, "Pattern Recognition and Machine Learning", Springer 2006
- Ian Goodfellow, Yoshua Bengio, Aaron Courville, "Deep Learning", MIT Press 2016



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Computer Lab Pattern Recognition	3,0	Internship	english german
Literature			
<ul style="list-style-type: none"> • Christopher M. Bishop, Nasser M. Nasrabadi, "Pattern Recognition and Machine Learning", Springer 2006 • Ian Goodfellow, Yoshua Bengio, Aaron Courville, "Deep Learning", MIT Press 2016 			
Computer Lab Pattern Recognition	1,0	Colloquium	english german
Literature			
<ul style="list-style-type: none"> • Christopher M. Bishop, Nasser M. Nasrabadi, "Pattern Recognition and Machine Learning", Springer 2006 • Ian Goodfellow, Yoshua Bengio, Aaron Courville, "Deep Learning", MIT Press 2016 			

Data Science in Applications - Biology, Chemistry and Pharma

Title	Immunmetabolism		
Number	1398590 Bio-BB 31 / Bio-SB 31	Module version	
Shorttext	BB 31 / SB 31	Language	english german
Frequency of offer	only in the summer term	Teaching unit	Fakultät für Lebenswissenschaften
Module duration	1	Institution	
Hours per Week / ECTS	8 / 10,0	Module owner	Prof. Dr. Karsten Hiller
Workload (h)	300		
Class attendance (h)	112	Self studying (h)	188
Compulsory requirements	none		
Recommended requirements	none		
Expected performance/ Type of examination	- term paper - oral presentation		
Course achievement	Successful participation in the practical course and seminar		
Module grade composition	The module grade corresponds to the grade for the examination performance.		
Contents			
<p>The seminar gives an introduction into the metabolism of macrophages and how to analyze it by using isotope-labeling experiments and modeling. Especially the role of itaconic acid, ROS, NO and glutathione is discussed. Afterwards, different analytical methods for studying the Immunometabolism of different cell lines will be presented by the students. The students will plan themselves the workflow for the practical course to answer different biological questions. The students will present their work by using different presentation concepts (talk, poster, etc). Practical course: Students will apply their theoretical knowledge to answer different biological questions by using the methods discussed in the seminar. The students will apply several methods, covering cell cultivation, metabolite extraction, seahorse measurements, GC-MS measurements and data analysis, metabolic flux analysis with stable isotopes, etc.</p>			
Objective qualification			
<p>After completing the module, students are able to</p> <ul style="list-style-type: none"> - explain the importance of the metabolism of immune cells during infection/inflammation. - apply modern analytical techniques, such as isotope labelling, mass spectrometry and metabolic flux analysis - evaluate and interpret GC-MS data. - interpret the energy metabolism by means of respiration measurements. - develop concepts for solving systems biology problems with the help of different methods. - present and discuss scientific work. - discuss controversial scientific topics and questions. <p>- search, present and discuss relevant scientific content. - contribute to controversial discussions of scientific topics. - work successfully and independently in a team, organize a team and communicate efficiently with different target groups.</p>			

- carry out advanced practical and scientific work independently and analyze experimental data.
- apply in-depth foreign language skills (usually English).

Literature



Related courses

Rules for the choice of courses

Compulsory attendance

Attendance is compulsory for practicals, exercises, seminars, and excursions.

Name of the course	SWS	Eventtype	Language
Immunmetabolism (Bio-BB 31, Bio-SB 31, AM-C-2)		Seminar	english german
Immunmetabolism (Bio-BB 31, Bio-SB 31, AM-C-2)		Practical exercise	english german

Title	CM-B-3 Elucidation and Modelling of Biological Structures		
Number	1498680	Module version	
Shorttext	CHE-STD2-6	Language	german
Frequency of offer		Teaching unit	Fakultät für Lebenswissenschaften
Module duration		Institution	
Hours per Week / ECTS	0 / 8,0	Module owner	
Workload (h)	240		
Class attendance (h)		Self studying (h)	
Compulsory requirements			
Expected performance/ Type of examination	oral or written exam+ (30% of the practical work mark are taken into account in the overall module mark)		
Course achievement	Practical work (marked)		
Module grade composition	Practical work (marked) oral or written exam+ (30% of the practical work mark are taken into account in the overall module mark)		
Contents			
<p>Lecture Biomolecular Modelling: Introduction to the basics of simulations of biomacromolecules - Born-Oppenheimer approximation, potential energy surface, basics of statistical thermodynamics, empirical force fields and their efficient implementation - geometry optimization, molecular dynamics methods, thermodynamic and static description of (bio)chemical processes, analysis of molecular dynamics simulations, calculation of free energies, multiscale simulation methods - implicit solvent models, coarse-grained models, hybrid QM/MM methods, quantum-chemical embedding methods.</p> <p>Computer Lab: Use of force field programs, visualization of crystal structures, geometry optimization, molecular dynamics and normal mode analysis of polypeptides, simulation of (bio)molecules) with different computational methods and their analysis, analysis of dynamical and entropic effects.</p> <p>Project Lab: Molecular Dynamics Simulations of Biomolecules.</p>			
Objective qualification			
The students are familiar with modern methods for modelling the structure of biomacromolecules and for simulating their thermodynamic properties. They know empirical force field methods, methods for performing molecular dynamics simulations, as well as modern multiscale simulation methods. The students are able to judge the applicability and the limitations of such methods, to choose suitable simulation methods for their own research projects and to perform, analyze, and evaluate molecular dynamics simulations.			
Literature			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Biomolecular Modelling	2,0	Lecture	english
Computer Lab Biomolecular Modelling	2,0	Exercise	english
Project Lab Biomolecular Modelling	2,0	Internship	english

Title	Network Biology		
Number	4217840	Module version	V2
Shorttext	INF-MI-84	Language	english
Frequency of offer	only in the summer term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	Peter L. Reichertz Institut für Medizinische Informatik
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Tim Kacprowski
Workload (h)			
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination	written exam, 90 minutes, or oral exam, 30 minutes or Take-Home-Exam		
Course achievement	50% of exercises must be passed		
Contents			
<ul style="list-style-type: none"> - Introduction graph theory - Biological networks - Biological network databases - Statistical network analysis - Graph algorithms - Graph-based machine learning 			
Objective qualification			
<p>After successful completion of this module, students will have a basic understanding of graph theory and its applications for the analysis of biomedical data. They will be able to use network biology tools and critically assess network analyses. They will be capable to devise new graph-based strategies for the analysis of biomedical data.</p>			
Literature			
tba			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Network Biology	4,0	Lecture/Exercise	english
Literature			
to be announced			
	2,0	Exercise	english

Title	Biophysical Chemistry		
Number	1498670 CM-B-2	Module version	
Shorttext		Language	english
Frequency of offer	only in the winter term	Teaching unit	Fakultät für Lebenswissenschaften
Module duration		Institution	
Hours per Week / ECTS	4 / 8,0	Module owner	Prof. Dr. Peter Jomo Walla
Workload (h)	240		
Class attendance (h)	66	Self studying (h)	174
Compulsory requirements			
Expected performance/ Type of examination	oral exam or written exam (PL) nach BPO §5 (3)		
Course achievement	completing exercises (SL)		
Contents			
<p>Lecture Biophysical Chemistry: Brief review of biochemical and microbiological basics, traditional methods such as fluorescence and absorption spectroscopy, light scattering, Raman spectroscopy, NMR, ESR and mass spectrometry on biomolecules. Modern methods such as fluorescence microscopy, single molecule detection, nonlinear and ultrafast spectroscopy or nanotechnology to study biomolecules. Prospects for industrial applications and drug discovery.</p> <p>Exercise: Independent calculation and answering of questions with corrections by instructors and assistants, discussion of solution methods in the exercise.</p> <p>Applied Biophysical Chemistry: In this course, the knowledge gained will be deepened through guest lectures on concrete examples of industrial research, e.g. in combination with an excursion to a pharmaceutical company, or from basic research, e.g. at Max Planck Institutes.</p>			
Objective qualification			
<p>The students know the basics of the most important physicochemical methods for the elucidation of biomolecular interactions and structures and are able to decide which modern or traditional method is most efficient to answer such biochemical questions. They know the limitations and dynamic range of these methods and the importance of structure and dynamics of biomolecules for their function. Students will be able to classify which methods are suitable for studying biomolecules and answering biomolecular questions in the different environments of industrial or basic research.</p>			
Literature			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Biophysical Chemistry	3,0	Lecture	english german
Biophysical Chemistry	1,0	Exercise	english german
Applied Biophysical Chemistry	0,7	Seminar	english german

Title	Biomolecular Modelling		
Number	1499680 CM-B-3	Module version	
Shorttext		Language	english
Frequency of offer	only in the summer term	Teaching unit	Fakultät für Lebenswissenschaften
Module duration	1 Semester	Institution	
Hours per Week / ECTS	6 / 8,0	Module owner	Prof. Dr. Christoph Jacob
Workload (h)	240		
Class attendance (h)	84	Self studying (h)	156
Compulsory requirements	none		
Recommended requirements	none		
Expected performance/ Type of examination	Oral or written exam+ (30% of the practical work mark are taken into account in the overall module mark)		
Course achievement	Practical work (marked)		
Module grade composition	see expected performance		
Contents			
<p>Lecture: Introduction to the basics of simulations of biomacromolecules - BornOppenheimer approximation, potential energy surface, basics of statistical thermodynamics, empirical force fields and their efficient implementation - geometry optimization, molecular dynamics methods, thermodynamic and static description of (bio)chemical processes, analysis of molecular dynamics simulations, calculation of free energies, multiscale simulation methods - implicit solvent models, coarsegrained models, hybrid QM/MM methods, quantum-chemical embedding methods.</p> <p>Computer Lab: Use of force field programs, visualization of crystal structures, geometry optimization, molecular dynamics and normal mode analysis of polypeptides, simulation of (bio)molecules) with different computational methods and their analysis, analysis of dynamical and entropic effects.</p> <p>Project Lab: Molecular Dynamics Simulations of Biomolecules.</p>			
Objective qualification			
The students are familiar with modern methods for modelling the structure of biomacromolecules and for simulating their thermodynamic properties. They know empirical force field methods, methods for performing molecular dynamics simulations, as well as modern multiscale simulation methods. The students are able to judge the applicability and the limitations of such methods, to choose suitable simulation methods for their own research projects and to perform, analyze, and evaluate molecular dynamics simulations.			
Literature			
information in the courses			

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Related courses			
Rules for the choice of courses			
none			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Biomolecular Modelling	2,0	Lecture	english
Computer Lab Biomolecular Modelling	2,0	Exercise	english
Project Lab Biomolecular Modelling	2,0	Internship	english

Title	Advanced Theoretical Chemistry		
Number	1499170 AM-A-9	Module version	
Shorttext		Language	english
Frequency of offer	irregular	Teaching unit	Fakultät für Lebenswissenschaften
Module duration		Institution	
Hours per Week / ECTS	6 / 8,0	Module owner	Prof. Dr. Christoph Jacob
Workload (h)	240		
Class attendance (h)	84	Self studying (h)	156
Compulsory requirements			
Expected performance/ Type of examination	Oral or Written Exam+ (20% of the coursework and 20% of the practical work mark are taken into account in the overall module mark)		
Course achievement	Solve coursework problems (unmarked) Practical work (marked)		
Contents			
<p>Lecture and Computer Lab Advanced Quantum Chemistry: Mathematical Foundations of quantum-chemical methods, Hartree-Fock theory, perturbation theory and configuration interaction, coupled-cluster theory, density-functional theory.</p> <p>Lecture and Computer Lab Theoretical Spectroscopy: Time-dependent quantum mechanics, interaction of electromagnetic radiation with molecules, basics of Hartree-Fock and density-functional theory, quantum-chemical calculation of spectroscopic data (Infrared and Raman spectroscopy, UV/Vis spectroscopy, ESR and NMR, simulation of spectra.</p> <p>Lecture and Computer Lab Artificial Molecular Intelligence: Molecular quantum mechanics in a nutshell: Hartree-Fock (HF) theory, post-HF methods, density functional theory; Molecular machine learning in a nutshell: molecular representations, deep learning and kernel methods, generative models, uncertainty quantification, active learning; Applications: structure-property relationships, chemical space exploration, molecular design.</p> <p>Project Lab Theoretical Biophysical Chemistry: Introduction to scientific programming and in-depth study of selected quantum-chemical methods. Application of quantum-chemical methods that usually cannot be used as "black-box" methods in own independent projects.</p>			
Objective qualification			
<p>The students have acquired knowledge on modern methods of quantum chemistry. They are familiar with the foundations of important methods and possess an overview of commonly used quantum-chemical methods, their implementation in scientific software, and their use in chemistry. They are able to judge the applicability and the limits of different quantum-chemical methods and to use choose suitable methods for their own research projects, to perform quantum-chemical calculations and to analyse, evaluate, and assess their results.</p>			
Literature			



Related courses			
Rules for the choice of courses			
To complete the module one out of the three lectures and the associated exercise must be completed as well as the project lab.			
One of the three lectures and the associated exercise is offered every winter term. The project lab is offered every winter term.			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Advanced Quantum Chemistry	3,0	Lecture	english german
Computer Lab Advanced Quantum Chemistry	1,0	Exercise	english
Project Lab Advanced Quantum Chemistry	2,0	Internship	english

Title	Machine Learning in Computational Chemistry		
Number	1499180 AM-A-10	Module version	
Shorttext		Language	
Frequency of offer	only in the winter term	Teaching unit	Fakultät für Lebenswissenschaften
Module duration		Institution	
Hours per Week / ECTS	6 / 8,0	Module owner	Prof. Dr. Jonny Proppe
Workload (h)	240 h		
Class attendance (h)	84	Self studying (h)	156
Compulsory requirements			
Expected performance/ Type of examination	oral or written exam+ (PL, 20% of the coursework and 20% of the practical work mark are taken into account in the overall module grade)		
Course achievement	solve coursework problems (ÜbA, SL unmarked) practical work (expA, SL marked)		
Contents			
<p>Lecture and Computer Lab Artificial Molecular Intelligence: Molecular quantum mechanics in a nutshell: Hartree–Fock (HF) theory, post-HF methods, density functional theory; molecular machine learning in a nutshell: molecular representations, deep learning and kernel methods, generative models, uncertainty quantification, active learning; Applications: structure–property relationships, chemical space exploration, molecular design.</p> <p>Project Lab: In-depth study of molecular machine learning methods, application of methods of artificial molecular intelligence in own independent projects.</p>			
Objective qualification			
The students have acquired knowledge on modern methods of molecular machine learning and molecular artificial intelligence. They are familiar with the foundations of important methods and possess an overview of commonly used methods, their implementation, and their use in chemistry. They are able to judge the applicability and the limits of different methods and to use choose and apply suitable methods for their own research projects and to analyse, evaluate, and assess their results.			
Literature			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Machine Learning in Computational Chemistry	3,0	Lecture	english
Computer Lab Machine Learning in Computational Chemistry	1,0	Exercise	english
Project Lab Machine Learning in Computational Chemistry	2,0	Internship	english

Title	Theoretical Spectroscopy		
Number	1498120 AM-B-8	Module version	
Shorttext		Language	english
Frequency of offer	irregular	Teaching unit	Fakultät für Lebenswissenschaften
Module duration		Institution	Institut für Physikal. und Theoretische Chemie
Hours per Week / ECTS	/ 8,0	Module owner	Prof. Dr. Christoph Jacob
Workload (h)			
Class attendance (h)		Self studying (h)	
Compulsory requirements			
Expected performance/ Type of examination	oral or written exam+ (PL, 20% of the coursework and 20% of the practical work mark are taken into account in the overall module grade)		
Course achievement	solve coursework problems (ÜbA, SL unmarked) practical work (expA, SL marked)		
Contents			
<p>Lecture and Computer Lab Theoretical Spectroscopy: Time-dependent quantum mechanics, interaction of electromagnetic radiation with molecules, basics of Hartree-Fock and density-functional theory, quantum-chemical calculation of spectroscopic data (Infrared and Raman spectroscopy, UV/Vis spectroscopy, ESR and NMR), simulation of spectra.</p> <p>Project Lab: Introduction to scientific programming and in-depth study of selected quantum-chemical methods. Application of quantum-chemical methods that usually cannot be used as "black-box" methods in own independent projects.</p>			
Objective qualification			
The students have acquired knowledge in time-dependent quantum mechanics and on modern methods of theoretical spectroscopy. They are familiar with the foundations of important methods and possess an overview of commonly used quantum-chemical methods in theoretical spectroscopy, their implementation in scientific software, and their use in chemistry. They are able to judge the applicability and the limits of different methods and to use choose suitable methods for their own research projects, to perform calculations and to analyse, evaluate, and assess their results.			
Literature			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Theoretical Spectroscopy	3,0	Lecture	english german
Computer Lab Theoretical Spectroscopy	1,0	Exercise	english
Project Lab Theoretical Spectroscopy	2,0	Internship	english

Data Science in Applications - Medicine

Title	Medical-methodological specialization module 1		
Number	4217720	Module version	V2
Shorttext	INF-MI-72	Language	english german
Frequency of offer	only in the winter term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	Peter L. Reichertz Institut für Medizinische Informatik
Hours per Week / ECTS	0 / 5,0	Module owner	Prof. Dr. Thomas Deserno
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination	graded work: oral exam (30 minutes) or development and documentation of computer programs or Portfolio or Take-Home-Exam		
Course achievement			
Contents			
The module focus on several examples, all taken from IT-supported clinical research and medical trials.			
Objective qualification			
Passing this module, the students develop a fundamental understanding for methodological aspects of medical informatics. They can plan and conduct scientific studies and can develop novel research projects in the field of electronic health. The students can use, compare, and evaluate specific IT tools in medical informatics. They know about data privacy and security issues for medical data in Europe.			
Literature			
- Roos-Pfeuffer, B.: Klinische Prüfung von Medizinprodukten: Ein Kommentar zu DIN EN ISO 14155. Beuth Verlag, 2015. ISBN-13: 978-3410241539 - Schumacher, M.: Methodik Klinischer Studien: Methodische Grundlagen der Planung, Durchführung und Auswertung (Statistik und ihre Anwendungen). Springer Verlag, 2008. ISBN-13: 978-3540851356. - Gaus, W., Chase, D.: Klinische Studien: Regelwerke, Strukturen, Dokumente, Daten. DVMD Verlag, 2008. ISBN-13: 978-3833472220 - Johner, C., Hölzer-Klüpfel, M., Wittorf, S.: Basiswissen Medizinische Software. Aus- und Weiterbildung zum Certified Professional for Medical Software. Dpunkt Verlag Heidelberg. 2. Auflage, 2015. ISBN-13: 978-3864902307. - Schneider, UK: Sekundärnutzung klinischer Daten: Rechtliche Rahmenbedingungen. Medizinisch Wissenschaftliche Verlagsgesellschaft, 2015. ISBN-13: 978-3954661428. - Jäschke, T. (Hrsg.): Datenschutz im Gesundheitswesen: Grundlagen, Konzepte, Umsetzung. Medizinisch Wissenschaftliche Verlagsgesellschaft, 2016. ISBN-13: 978-3954662210.			

- IT-Reviewing Board der TMF (Hrsg.): IT-Infrastrukturen in der patientenorientierten Forschung. Aktueller Stand und Handlungsbedarf 2015. TMF, 2016. ISBN-13: 978-389838-7101.



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
	4,0	Lecture/Exercise	english german
Literature			
<ul style="list-style-type: none"> • Roos-Pfeuffer B. Klinische Prüfung von Medizinprodukten: Ein Kommentar zu DIN EN ISO 14155. Beuth Verlag, 2015, ISBN-10: 3410241531, ISBN-13: 978-3410241539 • Schumacher M. Methodik Klinischer Studien: Methodische Grundlagen der Planung, Durchführung und Auswertung (Statistik und ihre Anwendungen). Springer Verlag 2008, ISBN-10: 3540851356, ISBN-13: 978-3540851356 • Gaus W, Chase D. Klinische Studien: Regelwerke, Strukturen, Dokumente, Daten. DVMD Verlag 2008, ISBN-10: 3833472227, ISBN-13: 978-3833472220 • Johner C, Hölzer-Klüpfel M, Wittorf S. Basiswissen Medizinische Software. Aus- und Weiterbildung zum Certified Professional for Medical Software. Dpunkt Verlag Heidelberg, 2. Auflage 2015; ISBN-13: 978-3864902307 • Schneider UK. Sekundärnutzung klinischer Daten: Rechtliche Rahmenbedingungen. Medizinisch Wissenschaftliche Verlagsgesellschaft 2015; ISBN-13: 978-3954661428 • Jäschke T. (Hrsg). Datenschutz im Gesundheitswesen: Grundlagen, Konzepte, Umsetzung. Medizinisch Wissenschaftliche Verlagsgesellschaft 2016; ISBN-13: 978-3954662210 • IT-Reviewing Board der TMF (Hrsg). IT-Infrastrukturen in der patientenorientierten Forschung. Aktueller Stand und Handlungsbedarf 2015. TMF 2016; ISBN-13: 978-389838-7101 			
	2,0	Online-exercise	english german

Title	Medical Methodology Course 2		
Number	4217730	Module version	V2
Shorttext	INF-MI-73	Language	english german
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	Peter L. Reichertz Institut für Medizinische Informatik
Hours per Week / ECTS	3 / 5,0	Module owner	Prof. Dr. Thomas Deserno
Workload (h)	150		
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	written exam (90 minutes) or oral exam (30 minutes) or Portfolio or Take-Home-Exam.		
Course achievement			
Contents			
The courses in this module vary from semester to semester. They are announced timely on the web page of PLRI.			
Objective qualification			
Passing this module, the students have earned a fundamental understanding of the methodological aspects of medical informatics. They can plan and conduct clinical trials and apply appropriate statistics to evaluate the recorded data. They can assess the systematics of scientific research in the broad biomedical field of applied computer science. They can compare IT tools for medical statistics and significance tests.			
Literature			
will be announced in the course			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Smart Living	2,0	Lecture	german
Literature			
will be announced in the course			

	1,0	Exercise	german
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Title	Accident Informatics		
Number	4217740	Module version	V2
Shorttext	INF-MI-74	Language	english
Frequency of offer	only in the summer term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	Peter L. Reichertz Institut für Medizinische Informatik
Hours per Week / ECTS	0 / 5,0	Module owner	Prof. Dr. Thomas Deserno
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination	graded work: written exam (90 minutes) or Portfolio or Take-Home-Exam.		
Course achievement			
Contents			
<ul style="list-style-type: none"> - Selected aspects of eHealth and mHealth - Relevant data formats, standards, and terminologies - Existing systems in accident and emergency informatics - Fundamentals to combine medical informatics and technical accident research 			
Objective qualification			
Passing this module, the students can define the goals and perform a technical analysis of traffic accidents. They understand accident and emergency informatics on a more general level, and know the components of this novel field of research. They can use IT systems for accident research and build systems using appropriate data formats, standards, and protocols. Furthermore, they can construct scientific experiments in the field of accident and emergency informatics.			
Literature			
<ul style="list-style-type: none"> - World Health Organization (WHO)(2016): Global diffusion of eHealth: Making universal health coverage achievable. WHO. ISBN-13: 978-92-4-151178-0; URL: http://www.who.int/goe/publications/global_diffusion/en/ - World Health Organization (WHO): Global Status Report on Road Safety 2015. WHO. ISBN-13: 978-9241565066, URL: http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/ - World Health Organization (WHO). Data Systems: A road safety manual for decision-makers and practitioners. WHO ISBN-13: 978-9241598965, URL: http://www.who.int/roadsafety/projects/manuals/data/en/ - OECD (Ed)(2017): New Health Technologies: Managing Access, Value and Sustainability. OECD. ISBN-13: 978-9264266421. - Johannsen, H.(2013): Unfallmechanik und Unfallrekonstruktion. Grundlagen der Unfallaufklärung. 3.Auflage. Springer-Vieweg. ISBN-13: 978-3658015930. 			

- Taschenmacher, R., Eifinger, W.(2014): Verkehrsunfallaufnahme. Unfallort – Tatort, Recht, Maßnahmen. 4. Auflage: Verlag Deutsche Polizeiliteratur. ISBN-13:978-3801106713.
- Ortlepp, J., Butterwegge. P.(2016): Unfalltypen-Katalog. Leitfaden zur Bestimmung des Unfalltyps. Neuauflage. Gesamtverband der deutschen Versicherungswirtschaft. URL: <https://udv.de/download/file/fid/9308>.

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
	2,0	Lecture	english
	2,0	Exercise	english

Title	Biomedical Image and Signal Analysis		
Number	4217760	Module version	V2
Shorttext	INF-MI-76	Language	english
Frequency of offer	only in the winter term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	Peter L. Reichertz Institut für Medizinische Informatik
Hours per Week / ECTS	0 / 5,0	Module owner	Prof. Dr. Thomas Deserno
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Recommended requirements	Knowledge of the bachelor's module 'Image and Signal Production in Biomedicine' is recommended.		
Expected performance/ Type of examination	graded work: written exam (90 minutes) or oral exam (30 minutes) or experimental work or Portfolio or Take-Home-Exam.		
Course achievement			
Contents			
<p>Using examples from ECG, X-ray imaging, magnetic resonance imaging and optical imaging systems we explain the general methods in medical signal and image processing. The methods are categorized according to their general properties, and the pros and cons of the manifold of methods is discussed using these categories. Systematic evaluation of signal and image analytics with and without ground truth is also addressed in this module.</p>			
Objective qualification			
<p>Passing this module, the students can classify and compare different methodologies for medical signal and image acquisition. They can differ and compare linear with non-linear filtering and analyze electrocardiography (ECG) data into their components. They can segment medical images in two and three dimensions and are able to apply model-based approaches for image and signal analytics.</p>			
Literature			
<p>- Lehmann, T.M., Oberschelp, W., Pelikan, E., Regges, R.(1997): Bildverarbeitung für die Medizin: Grundlagen, Modelle, Methoden, Anwendungen. Springer-Verlag, Berlin. ISBN-13: 978-3540614586.</p> <p>- Deserno, T.M.(Ed). (2011): Biomedical Image Processing. Springer-Verlag Berlin Heidelberg. ISBN-13: 978-3642267307.</p> <p>- Handels, H.(2009):Medizinische Bildverarbeitung: Bildanalyse, Mustererkennung und Visualisierung für die computergestützte ärztliche Diagnostik und Therapie. 2. Auflage. Vieweg & Teubner Verlag. ISBN-13: 978-3835100770.</p> <p>- Süße, H., Rodner, E.(2014): Bildverarbeitung und Objekterkennung: Computer Vision in Industrie und Medizin. Springer Vieweg. ISBN-13: 978-3834826053.</p> <p>- Dougherty, G.(2009): Digital Image Processing for Medical Applications. Cambridge University Press. ISBN-13: 978-0521181938.</p>			

- Burger, W., Burge, M.J. (2015): Digitale Bildverarbeitung: Eine algorithmische Einführung mit Java.3. Auflage. Springer-Vieweg. ISBN-13: 978-3-642-04604-9.

- Jähne, B.(2012): Digitale Bildverarbeitung und Bildgewinnung. 7. Auflage. Springer-Verlag Berlin. ISBN-13: 978-3642049514.

- Broeke, J., Mateos Perez, J.M., Pascau, J.(2015): Image Processing with ImageJ. 2. Edition. Packt Publishing. ISBN-13: 978-1785889837.



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Biomedical Image and Signal Analysis	4,0	Lecture/Exercise	english
Literature			
<p>- Lehmann, T.M., Oberschelp, W., Pelikan, E., Reppes, R.(1997): Bildverarbeitung für die Medizin: Grundlagen, Modelle, Methoden, Anwendungen. Springer-Verlag, Berlin. ISBN-13: 978-3540614586. - Deserno, T.M.(Ed). (2011): Biomedical Image Processing. Springer-Verlag Berlin Heidelberg. ISBN-13: 978-3642267307. - Handels, H.(2009): Medizinische Bildverarbeitung: Bildanalyse, Mustererkennung und Visualisierung für die computergestützte ärztliche Diagnostik und Therapie. 2. Auflage. Vieweg & Teubner Verlag. ISBN-13: 978-3835100770. - Süße, H., Rodner, E.(2014): Bildverarbeitung und Objekterkennung: Computer Vision in Industrie und Medizin. Springer Vieweg. ISBN-13: 978-3834826053. - Dougherty, G.(2009): Digital Image Processing for Medical Applications. Cambridge University Press. ISBN-13: 978-0521181938. - Burger, W., Burge, M.J. (2015): Digitale Bildverarbeitung: Eine algorithmische Einführung mit Java.3. Auflage. Springer-Vieweg. ISBN-13: 978-3-642-04604-9. - Jähne, B.(2012): Digitale Bildverarbeitung und Bildgewinnung. 7. Auflage. Springer-Verlag Berlin. ISBN-13: 978-3642049514. - Broeke, J., Mateos Perez, J.M., Pascau, J.(2015): Image Processing with ImageJ. 2. Edition. Packt Publishing. ISBN-13: 978-1785889837.</p>			
	2,0	Exercise	english

Title	Health-Enabling Technologies A		
Number	4217800	Module version	V2
Shorttext	INF-MI-80	Language	english
Frequency of offer	only in the winter term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	Peter L. Reichertz Institut für Medizinische Informatik
Hours per Week / ECTS	0 / 6,0	Module owner	Prof. Dr. Thomas Deserno
Workload (h)	180		
Class attendance (h)	56	Self studying (h)	124
Compulsory requirements			
Expected performance/ Type of examination	graded work: written exam, 90 minutes, or oral exam, 30 minutes, or Portfolio or Take-Home-Exam.		
Course achievement			
Contents			
<ul style="list-style-type: none"> - Healthcare delivery with respect to specific diseases. - Sensors and data analytics - Architecture of appropriate information systems - Evaluation and future perspectives of HET-based healthcare - Ethical, regulatory and social aspects of HET 			
Objective qualification			
Passing this module, the students are able to name different health enabling technologies (HET) and explain their ethical, regulatory and social aspects. The students can use methods and tools to build HET systems.			
Literature			
<ul style="list-style-type: none"> - Bardram JE, Mihailidis A, Wan D (Hrsg.). Pervasive Computing in Healthcare. Boca Raton, FL: CRC Press; 2006. - Haux R, Koch S, Lovell NH, Marschollek M, Nakashima N, Wolf KH. Health-Enabling and Ambient Assistive Technologies: Past, Present, Future. Yearb Med Inform. 2016: S76-91. - Öberg A, Togawa T, Francis A, Spelman FA (Hrsg.). Sensors in Medicine and Health Care (eBook). Weinheim: Wiley-VCH; 2006. - van Hoof, J, Demiris, G, Wouters, EJM (Hrsg.). Handbook of Smart Homes, Health Care and Well-Being. Heidelberg: Springer: 2017. - Ligges U. Programmieren mit R. Statistik und ihre Anwendungen. Springer-Verlag Berlin, 3. Auflage 2008; ISBN-10: 3540799974, ISBN-13: 978-3540799979 - Wollschläger D. Grundlagen der Datenanalyse mit R: Eine anwendungsorientierte Einführung. Springer-Verlag, Berlin, 3. Auflage 2015; ISBN-10: 3662455064, ISBN-13: 978-3662455067 			

- Beckerman AP, Childs DZ, Petchey OL. Getting Started with R: An Introduction for Biologists. Oxford University Press, 2. Edition 2017; ISBN-10: 0198787847, ISBN-13: 978-0198787846



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Health-enabling technologies A	2,0	Lecture	english
Literature			
<p>- Bardram JE, Mihailidis A, Wan D (Hrsg.). Pervasive Computing in Healthcare. Boca Raton, FL: CRC Press; 2006. - Haux R, Koch S, Lovell NH, Marschollek M, Nakashima N, Wolf KH. Health-Enabling and Ambient Assistive Technologies: Past, Present, Future. Yearb Med Inform. 2016: S76-91. - Öberg A, Togawa T, Francis A, Spelman FA (Hrsg.). Sensors in Medicine and Health Care (eBook). Weinheim: Wiley-VCH; 2006. - van Hoof, J, Demiris, G, Wouters, EJM (Hrsg.). Handbook of Smart Homes, Health Care and Well-Being. Heidelberg: Springer: 2017. - Ligges U. Programmieren mit R. Statistik und ihre Anwendungen. Springer-Verlag Berlin, 3. Auflage 2008; ISBN-10: 3540799974, ISBN-13: 978-3540799979 - Wollschläger D. Grundlagen der Datenanalyse mit R: Eine anwendungsorientierte Einführung. Springer-Verlag, Berlin, 3. Auflage 2015; ISBN-10: 3662455064, ISBN-13: 978-3662455067 - Beckerman AP, Childs DZ, Petchey OL. Getting Started with R: An Introduction for Biologists. Oxford University Press, 2. Edition 2017; ISBN-10: 0198787847, ISBN-13: 978-0198787846</p>			
	2,0	Exercise	english

Title	Health-Enabling Technologies B		
Number	4217810	Module version	V2
Shorttext	INF-MI-81	Language	english
Frequency of offer	only in the summer term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	Peter L. Reichertz Institut für Medizinische Informatik
Hours per Week / ECTS	0 / 5,0	Module owner	Prof. Dr. Thomas Deserno
Workload (h)	150		
Class attendance (h)	56	Self studying (h)	94
Compulsory requirements			
Expected performance/ Type of examination	graded work: written exam (90 minutes) or oral exam (30 minutes) or Portfolio or Take-Home-Exam.		
Course achievement			
Contents			
Plan and conduct appropriate experiments including the data analytics using different sensors for unobtrusive assessment of health-determining parameters.			
Objective qualification			
Passing this module, the students can explain and compare health enabling technologies (HET). This includes knowledge and practical use of HET applications, and its underlying scientific foundation. The students are able to build HET systems using recent technologies and can plan, conduct, and analyze experiments to evaluate HET technologies.			
Literature			
- Bardram, J.E., Mihailidis, A., Wan, D. (Hrsg.)(2006): Pervasive Computing in Healthcare. Boca Raton, FL: CRC Press.			
- Haux, R., Koch, S., Lovell, N.H., Marschollek, M., Nakashima, N., Wolf, K.H.(2016): Health-Enabling and Ambient Assistive Technologies: Past, Present, Future. Yearb Med Inform. S.76-91.			
- Öberg, A., Togawa, T., Francis, A., Spelman, F.A. (Hrsg.)(2006): Sensors in Medicine and Health Care (eBook). Weinheim: Wiley-VCH.			
- van Hoof, J., Demiris, G., Wouters, E.J.M. (Hrsg.)(2007): Handbook of Smart Homes, Health Care and Well-Being. Heidelberg, Springer.			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
	1,0	Lecture	english
	3,0	Exercise	english

Title	Selected Topics of Representation and Analysis of Medical Data		
Number	4217880	Module version	V2
Shorttext	INF-MI-88	Language	english german
Frequency of offer	only in the winter term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	Peter L. Reichertz Institut für Medizinische Informatik
Hours per Week / ECTS	0 / 5,0	Module owner	Prof. Dr. Reinhold Haux
Workload (h)	150		
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	written exam (90 minutes) or oral exam (30 minutes) or Portfolio or Take-Home-Exam		
Course achievement			
Contents			
There is a rapid change in methodology and assessment of current techniques for medical data analytics, in particular using deep learning. Therefore, the content of this module reflects the actual technologies and will be announced shortly before the module starts.			
Objective qualification			
The students can recall recent trends and technologies to represent and analyze medical data. They are able to compare approaches and report their key characteristics resp. differences. They can construct tools and scientific methodologies for data modelling and analytics. The students recognize quality criteria and can recommend specific approaches.			
Literature			
IMIA Yearbook of Medical Informatics [erscheint jährlich]			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
	3,0	Lecture/Exercise	english german

Data Science in Applications - Project Work

Title	Project Work Data Science		
Number	4299980	Module version	
Shorttext	INF-STD-98	Language	english
Frequency of offer	every term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration		Institution	
Hours per Week / ECTS	1 / 15,0	Module owner	
Workload (h)			
Class attendance (h)	14	Self studying (h)	436
Compulsory requirements			
Expected performance/ Type of examination	Software/program development and report on a data science project.		
Course achievement			
Contents			
The teaching contents depend on the specific task and are partly taken from the project environment of the lecturer offering the course. They may vary on an annual basis.			
Objective qualification			
The project thesis can serve as preparation for the master's thesis. The students are able to use scientific methods systematically to solve a complex task in the area of data science. They are able to plan the work independently and estimate the work time required. They are able to carry out the project controlling and quality assurance e.g. using milestones which they have set for themselves.			
Literature			
Please ask your supervisor for current literature for your project thesis.			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Key Qualifications and Ethics

Title	Ethics and Epistemology		
Number	4411440	Module version	
Shorttext	GE-Phil-44	Language	english
Frequency of offer	only in the winter term	Teaching unit	Fakultät für Geistes- und Erziehungswissenschaften
Module duration	1	Institution	
Hours per Week / ECTS	2 / 5,0	Module owner	Prof. Dr. Hans-Christoph Schmidt am Busch
Workload (h)	Präsenzzeit: 30 h Selbststudium: 120 h Gesamtworkload: 150 h		
Class attendance (h)	30	Self studying (h)	120
Compulsory requirements			
Expected performance/ Type of examination	1 graded examination (Prüfungsleistung): written exam, 120 minutes		
Course achievement	1 non graded examination (Studienleistung): Protokoll, 2 pages		
Contents			
<p>This course provides students with philosophical knowledge in order to reason thoughtfully, judge effectively and act morally in the field of data science. Students learn to differentiate between concepts, phenomena and actions, which is relevant for understanding the presuppositions and implications of machine ethics. This new field is, on the one hand, concerned with established ethical approaches (Kant, Utilitarianism); on the other hand, with giving machines ethical principles, i.e. programs and operations for discovering a way to resolve ethical dilemmas they might encounter. Whereas enabling machines to function in an ethically responsible manner through their own ethical decision making is a long wished-for in AI and robotics, philosophers and society highlight basic questions still in need for an answer; for example: can machines be moral agents? When adopting norms and values, who should they take as paradigmatic role model? Who has the right to judge about that, and why? Students will learn the preconditions and limits of modeling the world according to machines. Not last, which kind of world machines face by means of artificial sensory perception matters for understanding the difficult questions of embodiment, and really being in the world instead of only having one.</p>			
Objective qualification			
<p>The course:</p> <ul style="list-style-type: none"> • provides a philosophical framework and moral compass for guiding the judgement of students regarding data science and its applications (artificial intelligence, robotics, etc.). • aims to develop communication skills, social and civic competences, • reassures students on the limits of machines, machinery settings, and machine ethics, • strengthens personal development in the light of digit(al)ization and related claims of social change. <p>The students will be able to recognize and interpret social and technical problems in technology and information processing based in classical and recent position in theoretical and practical philosophy. They will be able to interpret these problems ethically and support their position with arguments from machine ethics.</p>			
Literature			
Anderson, Michael/Anderson, Susan Leigh (eds.): Machine Ethics, 2011			

Misselhorn, Catrin: Grundfragen der Maschinenethik, 3rd ed. 2018
 Nagel, Thomas: What is it like to be a Bat? Englisch/Deutsch, Reclam 2016



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Ethics and Epistemology	2,0		english german
Literature			
Literatur: <ul style="list-style-type: none"> • Misselhorn, Catrin: Grundfragen der Maschinenethik, 3rd ed. 2018 • Anderson, Michael/Anderson, Susan Leigh (eds.): Machine Ethics, 2011 • Nagel, Thomas: What is it like to be a Bat? Englisch/Deutsch, Reclam 2016 			

Title	Data Privacy & Data Governance		
Number	2216010	Module version	
Shorttext		Language	english
Frequency of offer	irregular	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration		Institution	
Hours per Week / ECTS	0 / 5,0	Module owner	Prof. Dr. Anne Paschke
Workload (h)			
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	written exam, 60 minutes, or oral exam, 20 minutes, or term paper or Portfolio or Take-Home-Exam		
Course achievement			
Contents			
<p>Target is to develop a sensitivity when dealing with data especially if it is person related data. Henceforth the lecture progresses to Data Governance beyond personal data ownership. The students will learn how an organisation can control the use of data by internal regulations and provisions and how intra-organisational data exchange is shaped by standards. The students should develop a broad understanding of the importance of standards and interoperability. Furthermore the students will learn what it takes and what to consider before such a provision/standard is established whether inside an organisation or on intra-organisational level.</p>			
Objective qualification			
<p>The students understand the differences between the two main legal systems (case law vs. common law) in the EU. They know different sources of legal knowledge. The students are able to assess company privacy regulations and business models in relation to the legal provisions.</p>			
Literature			
<p>A list of papers and videos will be provided in the first lecture. Please see the LMS for further details.</p>			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Master-Seminar Law (Civil Law)	2,0	Lecture	german
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Title	Key Qualifications		
Number	4298010	Module version	
Shorttext	INF-STD2-0	Language	german
Frequency of offer	every term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration		Institution	
Hours per Week / ECTS	0 / 5,0	Module owner	
Workload (h)			
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement	An active performance record is required for the selected courses/modules (e.g. written examination, term paper, presentation, minutes). A certificate of attendance is not sufficient. The type of academic achievement depends on the module or course.		
Contents			
Various in the elective courses of the overall program			
Objective qualification			
Superordinate reference/ embedding of the field of study Students will be able to classify their field of study in societal, historical, legal or professionally oriented references (depending on the focus of the course). They are able to recognize, analyze and evaluate higher-level, subject-related connections and their significance. The students acquire an insight into the networking possibilities of the field of study and application references of their field of study in professional life.			
Literature			
To be announced by the respective lecturers			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

Title	Scientific and Method-Oriented Working		
Number	4217000000	Module version	
Shorttext		Language	english
Frequency of offer	only in the summer term	Teaching unit	
Module duration	1	Institution	Department Informatik
Hours per Week / ECTS	4 / 5,0	Module owner	Prof. Dr. Tim Kacprowski
Workload (h)			
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	Homework (Term Paper)		
Course achievement	active participation in group work		
Contents			
<ul style="list-style-type: none"> - Philosophy of Science - Literature Research - Scientific Citation - Project Planning - Project Documentation - Scientific Writing 			
Objective qualification			
Upon successful completion of the module, students will be able to independently familiarize themselves with a scientific topic, plan and document a project, and write a scientific report.			
Literature			
tba			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
		Internship	english

Title	Better Scientific Presentations and Writing		
Number	4217000020	Module version	
Shorttext		Language	english
Frequency of offer	only in the winter term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration	1	Institution	
Hours per Week / ECTS	4 / 5,0	Module owner	
Workload (h)	150		
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ Type of examination	Portfolioexam		
Course achievement			
Contents			
<p>In the first part of the course, topics include structuring the text, appropriate wording, comprehensibility of text, efficient production, review process and ethical aspects.</p> <p>The second part addresses the creation of "good" visualizations. Students will learn about fundamentals of perception, a proper mapping of data to visual variables, design principles, and visualization techniques and tools for specific types of data.</p> <p>The third part covers oral presentations and scientific talks. Using their own research projects as well as other topics in exercises, students will practice and improve the delivery of their oral presentations.</p>			
Objective qualification			
<p>Students will learn the principles of scientific writing and gain insights into how to improve their writing. They will be enabled to properly criticize existing visualizations and create new visualizations that are effective, efficient, and appropriate. They will also learn how to properly structure a talk, how to prepare adequate visual aids ("presentations"), and how oral presentations are different from written text.</p>			
Literature			
tba			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

		Seminar	english
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Master's Thesis

Title	Master's Thesis Data Science		
Number	4299970	Module version	
Shorttext	INF-STD-97	Language	german
Frequency of offer	every term	Teaching unit	Carl-Friedrich-Gauß-Fakultät
Module duration		Institution	
Hours per Week / ECTS	0 / 30,0	Module owner	
Workload (h)			
Class attendance (h)	1	Self studying (h)	899
Compulsory requirements			
Expected performance/ Type of examination	Written thesis (final thesis) The presentation can be included in the evaluation with up to 3 of 30 credit points according to § 5 paragraph 7 (BPO)		
Course achievement			
Contents			
The contents depend on the specific assignment.			
Objective qualification			
The students are able to work on a problem in the field of data science independently using scientific methods within a given time period.			
The following points are particularly important:			
<ul style="list-style-type: none"> - The student can familiarize themselves with the topic of the work independently. - They can systematically work on a research problem relevant to data science using scientific methods. - They are able to present the methods and the results in the form of a report. - They present the main results in an understandable form in a presentation. - They able to research literature and put their work into context. 			
Literature			



Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language

