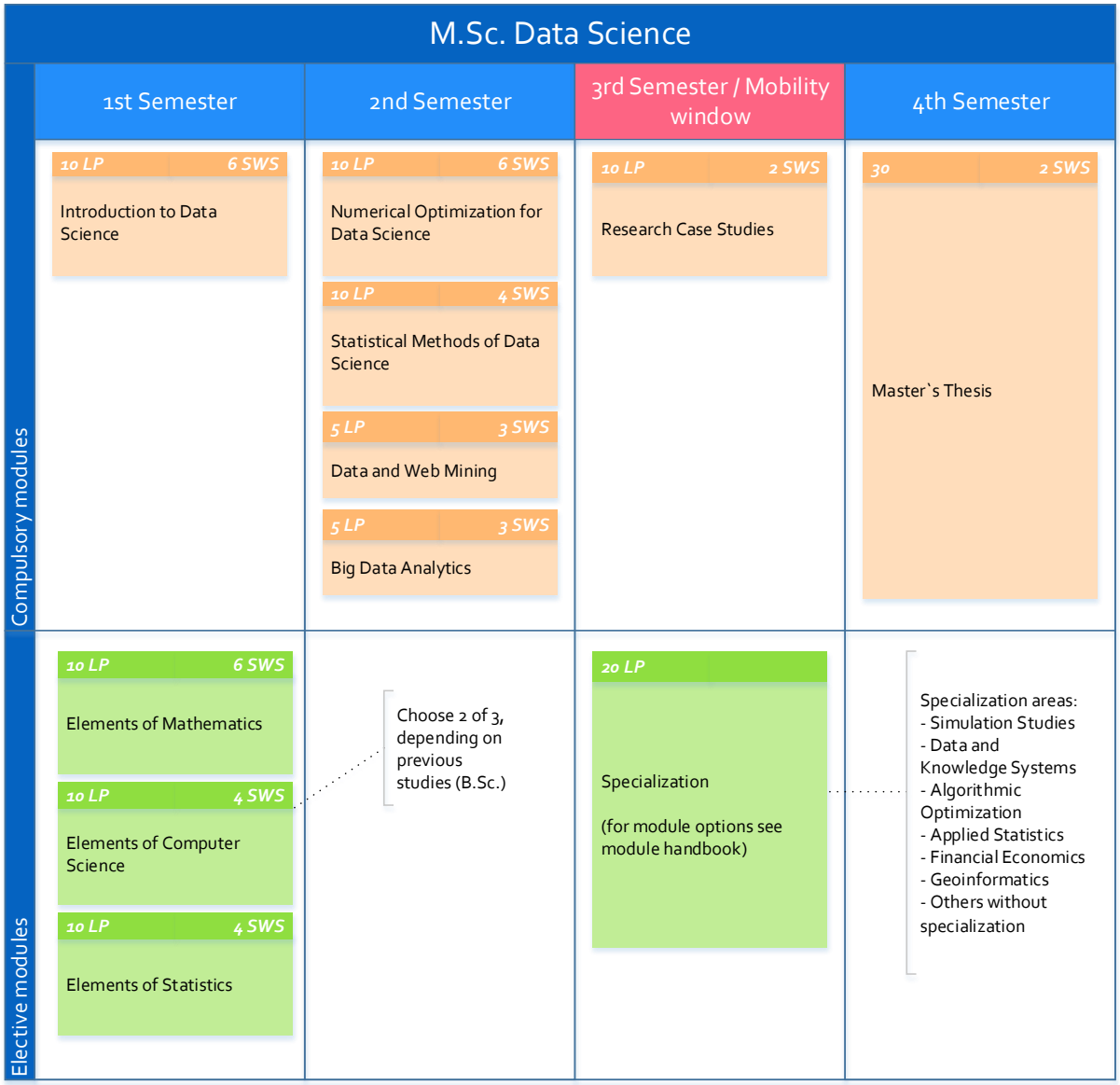
Module Handbook

Master Degree Programme
M.Sc. Data Science

28/11/2017

Curriculum


M.Sc. Data Science
1st Semester
2nd Semester
3rd Semester / Mobility window
4th Semester
Compulsory modules
10 LP 6 SWS
Introduction to Data Science
10 LP 6 SWS
Numerical Optimization for Data Science
10 LP 4 SWS
Statistical Methods of Data Science
5 LP 3 SWS
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Elective modules
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Elements of Mathematics
10 LP 4 SWS
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10 LP 4 SWS
Elements of Statistics
Choose 2 of 3, depending on previous studies (B.Sc.)
20 LP
Specialization
(for module options see module handbook)
Specialization areas:
- Simulation Studies
- Data and Knowledge Systems
- Algorithmic Optimization
- Applied Statistics
- Financial Economics
- Geoinformatics
- Others without specialization

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1 Compulsory Modules

Module Title	Module Code
Introduction to Data Science	DS.GENE.01

Semester	1st semester
Duration	One semester
Taught semesters	Every year (winter semester)
Language	English

Credits / ECTS	10 CP
Semester periods per week	4 weekly hours (lecture)
Contact hours	60 hours
Self-study	240 hours
Workload	60 + 240 hours

Type of assessment	exam
Non-graded assessment tasks	
Prerequisites	None
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes	After completing the module, students will have a thorough understanding of what data science and big data are, which methods are used in these fields and which ethical/legal considerations have to be taken into account when working in these fields. **Competences** Students are able to define data science and big data. Students understand the interrelation of ethics and, particularly, big data. Students can apply basic methods of data science to chosen problems.
Content	The module introduces data science as a field and, in doing so, gives a broad overview of the contents taught throughout the degree programme. Highlights are presented using small applications of concepts.

	The topics covered include: - Overview of data science methods in computer science, mathematics, and statistics - Definition of data science - Definition of big data - Ethics/disclosure control and data science
Reading	As the field is still rather young, there are no comprehensive textbooks on data science yet. Nevertheless, many books cover major topics in data science. More focussed references will be given in the course syllabus.
Types of courses	Lecture (Vorlesung) (4 weekly hours)
Recommended prerequisites	None
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Compulsory module in degree programme „Data Science" (M.Sc.)

Module Convenor	Prof. Dr. Ralf Schenkel / Prof. Dr. Volker Schulz / Prof. Dr. Ralf Münnich
Additional information	

Module Title	Module Code
Numerical Optimization for Data Science	DS.MATH.02

Semester	2nd semester
Duration	one semester
Taught semesters	every year (summer semester)
Language	English
Credits / ECTS	10 CP
Semester periods per week	6 weekly hours
Contact hours	90 hours
Self-study	210 hours
Workload	300 hours
Type of assessment	Oral exam or written exam
Non-graded assessment tasks	exercises
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	The students know the mathematical foundations in the area of numerical optimization and their relation to data science. They know, how to implement basic optimization methods and how to control advanced optimization methods and to interpret their results. As part of the course, deepen knowledge in the programming language Python. - Optimization problems in data science - Theoretical foundations of nonlinear optimization - Algorithms for nonlinear optimization: steepest descent, (Quasi-) Newton method, conjugate gradient method, quadratic programming, SQP methods - Convergence and complexity analysis
Reading	- J. Nocedal and S. Wright: Numerical Optimization, 2nd Edition, Springer 2006
Types of courses	Lecture (4 weekly hours) and practical course (2 weekly hours) including exercises
Recommended prerequisites	none

Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Compulsory module in degree programme „Data Science" (M.Sc.)

Module Convenor	Prof. Dr. Volker Schulz
Additional information	

Module Title	Module Code
Statistical Methods of Data Science	DS.STAT.02

Semester	2nd semester
Duration	One semester
Taught semesters	Every year (summer semester)
Language	English

Credits / ECTS	10 CP
Semester periods per week	4 weekly hours (2 + 2, lecture and presentations)
Contact hours	60 hours
Self-study	240 hours
Workload	60 + 240 hours

Type of assessment	Presentation (40%) and written exam (90 minutes; 60%)
Non-graded assessment tasks	
Prerequisites	
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes	After completing the module, students will have a solid knowledge of tools and statistical methods needed to deal with big data and data collected using non-probability samples. **Competences** Students are able to extract data from the internet and analyse such data, taking their collection into account. Students are able to finish a small practical project in the context of big data/data collected using non-probability sampling and to present the results in a concise manner.
Content	The module covers statistical methods that can be used to solve practical problems in data science. Furthermore, awareness for the specifics of the collection of big data etc. and related implications for the analysis of big data is raised. Big data is an essential part of data science. The analysis of vast amounts of, potentially unstructured, data, i.e. data streams, requires the use of special methods which are introduced in this module. Furthermore, some programming tools needed to extract such data are introduced as well.

	A key assumption behind traditional statistical methods is that data has been sampled using some form of probability sampling. In the context of data science, this assumption often does not hold (e.g. people using a social network have explicitly chosen to do so, leading to self-selection problems for a sample taken from the population of users of the social network). Proper analysis has to take this non-probability into account.
Reading	Some suggestions: Hastie, T.; Tibshirani, R.; Friedman, J. (2009): The Elements of Statistical Learning. Data Mining, Inference, and Prediction. Springer. Prajapati, V. (2013): Big Data Analytics with R and Hadoop. Packt Publishing. More focussed references will be given in the course syllabus.
Types of courses	Lecture (Vorlesung) and presentations (2 + 2 weekly hours)
Recommended prerequisites	Elements of Statistics
Requirements for awarding CPs	Regular attendance at courses, successful completion of (non-graded) assessment-tasks, passing of module exam.
Module applicability	Compulsory module in degree programme „Data Science" (M.Sc.)

Module Convenor	Prof. Dr. Ralf Münnich
Additional information	

Module Title	**Module Code**
Data and Web Mining	DS.INFO.03

Semester	2nd semester
Duration	one semester
Taught semesters	every summer semester
Language	English
Credits / ECTS	5 CP
Semester periods per week	3 weekly hours
Contact hours	45 hours
Self-study	105 hours
Workload	150 hours
Type of assessment	written exam (90 minutes)
Non-graded assessment tasks	excercises
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes

- students are able to explain the various data mining algorithms in detail and to evaluate them with respect to their advantages and shortcomings
- students are able to apply the various data mining methods for the analysis of given data using a data mining tool and to interpret the results
- students are aware of the standard data mining process model
- students are aware of the criteria for the selection of data mining tools

Competences

- ability to structure and aggregate new information and knowledge in the field of data and web mining
- self-directed and self-organised learning
- professional use of advanced information technology
- presentation skills

Content

- clarification of terms: knowledge discovery, data mining, web mining, data warehouses
- learning conjunctive concepts

- learning of decision trees
- analogy-based learning
- probabilistic learning
- neural nets
- cluster analysis
- web mining & recommender systems
- data pre-processing
- data mining tools
- practical exercises with Rapid Miner

Reading	• Tom Mitchell (1997). *Machine Learning. McGraw-Hill.* • Ian H. Witten & Eibe Frank (2011). *Data Mining: Practical Machine Learning Tools and Techniques. Morgan Kaufmann* • Bing Liu (2011). Web Data Mining: Exploring Hyperlinks, Contents, and Usage Data (Data-Centric Systems and Applications). Springer
Types of courses	(a) lecture (2 weekly hours) and practical course (1 weekly hours) including exercises
Recommended prerequisites	foundational knowledge in computer science and algorithms
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam
Module applicability	Compulsory module in degree programme "Data Science" (M. Sc.) Elective module in degree programme "Informatik" (M.Sc.) Elective module in degree programme "Wirtschaftsinformatik" (M.Sc.) Elective module in degree programme "Digital Humanities" (M.Sc.) Elective module in degree programme "Wirtschaftsinformatik" (B.Sc.)

Module Convenor	Prof. Bergmann
Additional information	Last edited, Oct 19,2017.

Module Title	Module Code
Big Data Analytics	DS.INFO.02

Semester	2nd semester
Duration	one semester
Taught semesters	every year (summer semester)
Language	English
Credits / ECTS	5 CP
Semester periods per week	3 weekly hours
Contact hours	45 hours
Self-study	105 hours
Workload	150 hours
Type of assessment	written exam (90 minutes) or oral (individual) exam
Non-graded assessment tasks	exercises
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	The course provides in-depth methodological knowledge on solving typical analytical problems on big data with standard software packages. Students acquire profound methodological knowledge and are, therewith, prepared to solve analytical tasks with standard approaches on large data collections. They are able to choose the best tool for a given application scenario. Students also know the underlying theoretical foundations of these systems. Furthermore, students develop an in-depth understanding of the core approaches and algorithms for data organization and data processing.
Content	• distributed file systems with HDFS as an example • the map-reduce programming paradigm with Apache Hadoop as an example • implementation of simple analysis tasks with Hadoop • systems for processing big data, including Apache Spark and Apache Flink • typical analysis on big data collections and their implementation, e.g., recommender systems, graph analysis, text analysis, machine learning, geometric and temporal analysis • NoSQL databases, including Apache HBase, Apache HIVE, and MongoDB
Reading	• Guy Harrison: Next Generation Databases: NoSQL, NewSQL, and Big Data. Apress, 2015. ISBN 978-1484213308 • Tom White: Hadoop: The Definitive Guide. O'Reilly UK Ltd.,

	2015. ISBN 978-1491901632 • Martin Kleppmann: Designing Data-Intensive Applications: The Big Ideas Behind Reliable, Scalable, and Maintainable Systems. O'Reilly UK Ltd., 2017. ISBN 978-1449373320 • Sandy Ryza, Uri Laserson, Josh Wills, Sean Owen: Advanced Analytics with Spark (2nd edition). O'Reilly UK Ltd., 2017. ISBN 978-1491972953
Types of courses	(a) lecture (2 weekly hours) (b) practical course (1 weekly hour) including exercises
Recommended prerequisites	None
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Compulsory module in degree programme „Data Science" (M.Sc.) Elective module in degree programme „Informatik" (M.Sc.)

Module Convenor	Prof. Schenkel
Additional information	none

Module Title	Module Code
Research Case Studies	DS.GENE.02

Semester	3rd semester
Duration	One semester
Taught semesters	Every year (winter semester)
Language	English

Credits / ECTS	10 CP
Semester periods per week	2 weekly hours (colloquium/seminar)
Contact hours	30 hours
Self-study	270 hours
Workload	30 + 270 hours

Type of assessment	Portfolio
Non-graded assessment tasks	
Prerequisites	
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes	In this module, students autonomously pursue and answer a specific research question in an individual project. They, therewith, gain experience in planning and conducting data science research. **Competences** Students practice the intensive engagement with a complex data science problem, the implementa- tion of respective methods in a programming language, and the writing of a scientific thesis.
Content	The topic is chosen after consultation with the individual advisor.
Reading	References will be given.
Types of courses	Individual counselling, meetings in small groups, seminar, colloquium
Recommended prerequisites	Curriculum of first 2 semesters
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.

Module applicability	Compulsory module in degree programme „Data Science" (M.Sc.)
Module Convenor	Prof. Dr. Ralf Schenkel / Prof. Dr. Volker Schulz / Prof. Dr. Ralf Münnich plus other professors of computer sciences, mathematics and statistics/economics
Additional information	

Module Title	**Module Code**
Master's Thesis	DS.GENE.03

Semester	4th semester
Duration	One semester
Taught semesters	Every year (summer semester)
Language	English
Credits / ECTS	30 CP
Semester periods per week	2 weekly hours (research colloquium and master's thesis)
Contact hours	30 hours
Self-study	720 hours
Workload	30 + 720 hours
Type of assessment	Presentation of intermediate results; thesis
Non-graded assessment tasks	
Prerequisites	Completion of Preparation courses
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	Students learn how to write a scientific thesis and present the respective results.
	Competences
	See above.
Content	The topic is chosen after consultation with the individual advisor.
Reading	References will be given.
Types of courses	Individual counselling, research colloquium
Recommended prerequisites	Curriculum of first 3 semesters
Requirements for awarding CPs	Passing of thesis (module exam)
Module applicability	Compulsory module in degree programme „Data Science" (M.Sc.)
Module Convenor	Prof. Dr. Ralf Schenkel / Prof. Dr. Volker Schulz / Prof. Dr. Ralf Münnich plus other professors of computer sciences, mathematics

and statistics/economics

Additional information

2 Elective Modules

Preparation Courses

Module Title	Module Code
Elements of Mathematics	DS.MATH.01

Semester	1st semester
Duration	one semester
Taught semesters	every year (winter semester)
Language	English
Credits / ECTS	10 CP
Semester periods per week	6 weekly hours
Contact hours	90 hours
Self-study	210 hours
Workload	300 hours
Type of assessment	written exam (120 minutes)
Non-graded assessment tasks	exercises (Übungsaufgaben)
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	After completing the module, the students know the mathematical foundations in the areas of linear algebra and numerical mathematics. As part of the course, they acquire or deepen knowledge in the programming language Python. **Competences** Students are able to use linear and selected nonlinear mathematical models in Data Science and to treat them in a numerically sound way. They can implement basic numerical methods and know how to interpret results from advanced numerical algorithms.
Content	- Linear mappings and matrices - Matrix decompositions and linear equations - Euclidean vector spaces and linear least squares problems - Eigenvalues and singular value decomposition - Numerical interpolation and integration - Solution of nonlinear equations and least squares problems

Reading	- C. D. Meyer: Matrix analysis and applied linear algebra, SIAM 2001 - P. Deuflhard and A. Hohmann: Numerical Analysis in Modern Scientific Computing: An Introduction, 2nd Edition, Springer 2003
Types of courses	Lecture (4 weekly hours) and practical course (2 weekly hours) including exercises
Recommended prerequisites	none
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme „Data Science" (M.Sc.)

Module Convenor	Prof. Dr. Volker Schulz
Additional information	

Module Title	Module Code
Elements of Computer Science	DS.INFO.01

Semester	1st semester
Duration	one semester
Taught semesters	every year (winter semester)
Language	English
Credits / ECTS	10 CP
Semester periods per week	4 weekly hours
Contact hours	60 hours
Self-study	240 hours
Workload	300 hours
Type of assessment	2 partial written exams (120 minutes (50%) + 90 minutes (50%))
Non-graded assessment tasks	exercises
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	The course provides fundamental knowledge of computer science concepts, including foundations of programming, foundations of data management, and foundations of algorithms. Students acquire profound methodological knowledge in these topics. They are able to design programs of medium complexity and implement them with an object-oriented programming language. They are aware of typical data structures for storing information and algorithms for accessing them. Students are also prepared to represent and query information with relational databases.
Content	Foundations of Computer Science • Programming paradigms • Formal representation of algorithms • Important algorithms for representing and accessing data as sets, lists, maps Foundations of a typical programming language (Java) • Data types • Control flow • Procedural programming • Classes and object-oriented programming • Designing and testing nontrivial programs Foundations of Databases

	• Models for representing data • Conceptual data modelling with the entity-relationship model • The relational model • Query languages: relational calculus, relational algebra, SQL • Database normalization
Reading	• Robert Sedgewick, Kevin Wayne: Computer Science: An interdisciplinary Approach, Addison Wesley, 2016, ISBN 978-0134076423 • Hector Garcia-Molina, Jeffrey D. Ullman, Jennifer Widom: Database Systems – The complete book, Pearson Education, 2013, ISBN 978-1292024479
Types of courses	(a) flipped classroom with self-study of pre-recorded online courses and additional tutorial (1 weekly hour) (b) practical course (3 weekly hours) including exercises
Recommended prerequisites	none
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme „Data Science" (M. Sc.)

Module Convenor	Prof. Schenkel
Additional information	none

Module Title	Module Code
Elements of Statistics	DS.STAT.01

Semester	1st semester
Duration	One semester
Taught semesters	Every year (winter semester)
Language	English

Credits / ECTS	10 CP
Semester periods per week	4 weekly hours (programming course and tutorials)
Contact hours	60 hours
Self-study	240 hours
Workload	60 + 240 hours

Type of assessment	written exam (120 minutes)
Non-graded assessment tasks	Participation in e-tutorials as prerequisite to take exam
Prerequisites	None
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes	After completing the module, students will have a solid knowledge of core concepts of descriptive and inferential statistics as well as regression modelling. Additionally, students will be familiar with the open source statistical programming language and environment R. The module prepares students for the advanced statistics modules of the degree programme. **Competences** Students are able to adequately analyse data and present the respective results in suitable tables and graphics. Furthermore, they are able to estimate relevant parameters and test hypotheses. Students can implement standard statistical and computational methods, visualise statistical content and produce reusable programming code in R. Students improved their self-dependent learning skills using the offered e-tutorials and pre-recorded e-learning videos.

Content	The module covers statistics and statistical programming propaedeutics needed for a successful completion of the degree programme. In particular, core concepts of descriptive and inferential statistics are introduced/refreshed. These include frequency tables, measures of central tendency and variation as well as measures of association, the fundamentals of probability theory and random variables, chosen distributions, estimation and hypothesis testing. Special attention is paid to methods of regression analysis. In a first block, the basics of the open source statistical programming language and environment R are introduced. The topics covered include the basic syntax and central commands, graphics and statistical programming.
Reading	Some suggestions: Crawley, M.J. (2015): Statistics: An Introduction Using R. 2nd edition. John Wiley & Sons. Field, A.; Miles, J.; Field, Z. (2012): Discovering Statistics Using R. SAGE Publications. Wooldridge, J.M. (2013): Introductory Econometrics: A Modern Approach. Cengage Learning. More focussed references will be given in the course syllabus.
Types of courses	Programming course and tutorials (Übung) (4 weekly hours), including flipped classroom elements, accompanying e-tutorials and e-learning videos, deepening students' understanding of the topics covered in the latter
Recommended prerequisites	None
Requirements for awarding CPs	Successful completion of non-graded assessment tasks and passing of module exam
Module applicability	Elective module in degree programme „Data Science" (M.Sc.)

Module Convenor	Prof. Dr. Ralf Münnich
Additional information	

Specialization Modules

Simulation Studies

Module Name	**Module Code**
Simulation and Management	DS.INFO.11

Semester	2nd or 4th semester
Duration	One semester
Taught semesters	Every year (summer)
Language	German
Credits / ECTS	5 CP
Semester periods per week	3 weekly hours
Contact hours	45 h
Self-study	105 h
Workload	150 h
Type of assessment	Oral exam
Non-graded assessment tasks	Exercise sheets
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes

- Factual and method knowledge about foundations of decision support and simulation
- Factual and method knowledge about design, execution, and analysis of simulation experiments
- Understanding of possible applications of simulation in a business context

Content

- Decision making and decision support
  - Cognitive decision process
  - Approaches for decision support
  - Limitations of decision support
- Foundations of simulation
  - Systems and Processes
  - Simulation techniques
  - Random numbers
  - Queuing theory
  - Examples of application
- Calibration, Validation, and Verification

    - Abstraction and discretization
    - Calibration
    - Validation
    - Verification
- Process of simulation studies and experiments
    - Design
    - Execution
    - Analysis
- Simulation of business processes
    - Goals of simulating business processes
    - Discrete-event modeling of business processes
- Material flow simulation
    - Goals of material flow simulation
    - Modeling of material flow systems
    - Optimization of logistical system
    - Simulation of distributed production systems (Supply Chain)
- Agent-based Social Simulation
    - Foundations of agent-based simulation models
    - Techniques for controlling agent-based simulation
    - Modeling of social systems
    - Simulation of emergent effects
- Further concepts
    - Distributed simulation
    - Parallel simulation

Reading

- Law, A. M. (2013). Simulation modeling and analysis. McGraw-Hill, New York. [ISBN 978-0-07-340132-4]
- Montgomery, D. C. (2013). Design and Analysis of Experiments. John Wiley and Sons, Singapore. [ISBN 978-1-118-09793-9]
- Banks, J.; Carson II, J. S.; Nelson, B. L. & Nicol, D. M. (2014). Discrete-Event System Simulation. Pearson Education. [ISBN 978-1-29202-437-0]

Types of courses

Lecture (2 SWS) and exercise (1 SWS) with homework

Recommended prerequisites

none

Requirements for awarding CPs

Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.

Module applicability

Module Convenor

Prof. Dr.-Ing. Ingo J. Timm

Additional information

Module Title	Module Code
Agent-Based Modeling (Agentenbasierte Modellierung)	DS.INFO.06

Semester	2nd semester
Duration	one semester
Taught semesters	every summer semester
Language	English or German
Credits / ECTS	5 CP
Semester periods per week	3 weekly hours
Contact hours	45 hours
Self-study	105 hours
Workload	150 hours
Type of assessment	portfolio examination
Non-graded assessment tasks	none
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes

- students are familiar with methods, procedures, and tools for agent-based modeling
- students are able to explain different agent architectures and to apply them to a given modeling problem
- students are able to analyze real world application scenarios and to transfer them into computational models
- students are able to verify, calibrate, and validate agent-based models using basic methods and tools
- students are able to conduct and interpret simple simulation experiments with agent-based models

Competences

- ability to structure and aggregate new information and knowledge in the field of agent-based modeling and simulation
- self-directed and self-organized learning
- teamwork
- professional use of advanced information technology
- presentation skills

Content	• Foundations of systems and their structural abstraction into actor-oriented (i.e., agent-based) models • Representation of agents and their environments in conceptual and computational models • Agent architectures: Reactive, goal-oriented, and utility-based agents; psychological and sociological foundations of intelligent agents • Agent communication and coordination • Procedure models, requirements, and design principles for agent-based modeling • Foundations of hypotheses, model verification and validation, and agent-based simulation • Implementation of agent-based models in NetLogo • Applications of agent-based models in the social sciences, economics, and logistics
Reading	• Uri Wilensky and William Rand. *An Introduction to Agent-Based Modeling: Modeling Natural, Social, and Engineered Complex Systems with Netlogo.* The MIT Press, 2015 • Hamill, Lynne, and Nigel Gilbert. *Agent-based modelling in economics.* John Wiley & Sons, 2015.
Types of courses	(a) lecture (2 weekly hours) and practical course (1 weekly hour) including exercises
Recommended prerequisites	foundational knowledge in computer science and economics
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme "Data Science" (M. Sc.) Elective module in degree programme "Wirtschaftsinformatik" (M.Sc.)
Module Convenor	Prof. Timm
Additional information	Last edited, Nov 14,2017.

Module Title	**Module Code**
Multi-Agent-Systems (Multiagentensysteme)	DS.INFO.07

Semester	3nd semester
Duration	one semester
Taught semesters	every winter semester
Language	English
Credits / ECTS	5 CP
Semester periods per week	3 weekly hours
Contact hours	45 hours
Self-study	105 hours
Workload	150 hours
Type of assessment	oral examination
Non-graded assessment tasks	excercises
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes

- students are able to explain fundamental terms and principles of multiagent systems
- basic knowledge and basic practical experience with an agent platform
- students are able to identify applications of multiagent systems in the domain of electronic business

Competences

- ability to structure and aggregate new information and knowledge in the field of multiagent systems
- self-directed and self-organized learning
- professional use of advanced information technology
- ability to work in a team

Content

- introduction
  - concept of an (intelligent) agent, multiagent systems
  - artificial intelligence and distributed artificial intelligence
  - architectures for intelligent agents

	○ FIPA reference architecture • communication ○ foundations of agent communication ○ blackboard communication versus message passing ○ FIPA agent communication language • coordination ○ interaction protocols ○ group decisions ○ allocation of limited resources ○ auctions ○ mechanism design • architectures ○ reactive agents ○ swarm intelligence ○ deliberative agents ○ belief-desire-intention model ○ theoretical modelling of agents, agent systems and decision making • decision making ○ searching and planning ○ planning in dynamic environments • distributed cooperative problem solving ○ contract net ○ planning and learning ○ information and knowledge interchange • design and evaluation of multiagent systems ○ agent-oriented software engineering ○ agent-based simulation
Reading	• Gerhard Weiss, Multiagent Systems, MIT Press, 2nd Edition, 2013. • Michael Wooldridge, An Introduction to MultiAgent Systems, John Wiley & Sons, 2nd Edition, 2009. • G. M. P. O'Hare, N. R. Jennings, Foundations of Distributed Artificial Intelligence, Wiley, 1996.
Types of courses	(a) lecture (2 weekly hours) and practical course (1 weekly hours) including exercises
Recommended prerequisites	foundational knowledge in computer science and agent-based modeling
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam
Module applicability	Elective module in degree programme "Data Science" (M. Sc.) Elective module in degree programme "Wirtschaftsinformatik" (M.Sc.)
Module Convenor	Prof. Timm
Additional information	Last edited, Nov 14,2017.

Module Title	Module Code
Monte-Carlo-Simulation Methods	DS.STAT.03

Semester	3rd semester
Duration	One semester
Taught semesters	Usually every year (winter semester)
Language	English

Credits / ECTS	5 CP
Semester periods per week	2 + 1 weekly hours (lecture and tutorial)
Contact hours	45 hours
Self-study	105 hours
Workload	45 + 105 hours

Type of assessment	Poster presentation
Non-graded assessment tasks	
Prerequisites	
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes	After completing the module, students will have a thorough understanding of Monte-Carlo simulation methods and computer-intensive procedures. **Competences** Students are able to plan and conduct their own simulation studies. Students are able to produce a poster (a common method of result presentation at large conferences) and present the results of a small simulation study using it.
Content	The module covers the fundamentals of Monte-Carlo simulation methods and computational statistics. It introduces students to the generation of random numbers. A special focus is then laid on the planning and conducting of different types of simulation studies (i.e. model-based and design-based simulation studies) and Monte-Carlo methods.
Reading	Some suggestions: Fishman, G.S. (2006): A First Course in Monte Carlo. Itps Thompson Learning.

	Rizzo, M.L. (2008): Statistical Computing with R. Chapman & Hall/CRC. Robert, C.P.; Casella, G. (2002): Monte Carlo Statistical Methods. 2nd edition. Springer. More focussed references will be given in the course syllabus.
Types of courses	Lecture (Vorlesung) (2 weekly hours) and tutorial (Übung) (1 weekly hour)
Recommended prerequisites	Elements of Statistics, Statistical Methods of Data Science
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme "Data Science" (M. Sc.)

Module Convenor	Prof. Dr. Ralf Münnich
Additional information	Module is part of the degree programme „Survey Statistics" (M.Sc.) Mandatory R course which is part of the *original* module is part of module DS.STAT.01 (Elements of Statistics) for students in degree programme „Data Science" (M.Sc.) Specialisation is compulsory for students in the „Simulation Studies" track

Module Title	**Module Code**
Microsimulation Methods	DS.STAT.04

Semester	3rd semester
Duration	One semester
Taught semesters	Occasionally (winter semester)
Language	English
Credits / ECTS	5 CP
Semester periods per week	2 + 1 weekly hours (lecture and tutorial)
Contact hours	45 hours
Self-study	105 hours
Workload	45 + 105 hours
Type of assessment	Poster presentation
Non-graded assessment tasks	
Prerequisites	
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	After completing the module, students will have a sound knowledge of state-of-the-art methods of synthetic microdata generation and microsimulation. **Competences** Students are able to generate synthetic data. Students are able to initiate their own small microsimulation projects. Students are able to produce and present a poster (a common method of result presentation at large conferences).
Content	The module introduces microsimulation methods. A clear distinction between static and dynamic microsimulation models is made. Additionally, methods for the generation of synthetic microdata, as a prerequisite for microsimulations, is discussed.
Reading	Some suggestions:

	Lovelace, R.; Dumont, M. (2016): Spatial Microsimulation with R. Chapman and Hall/CRC. O'Donoghue, C. (Editor) (2014): Handbook of Microsimulation Modelling. Contributions to Economic Analysis Volume 293. Emerald. More focussed references will be given in the course syllabus.
Types of courses	Lecture (Vorlesung) (2 weekly hours) and tutorial (Übung) (1 weekly hour)
Recommended prerequisites	Elements of Statistics, Statistical Methods of Data Science
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme "Data Science" (M. Sc.)

Module Convenor	Prof. Dr. Ralf Münnich
Additional information	Specialisation is compulsory for students in the „Simulation Studies" track

Data and Knowledge Systems

Module Title	Module Code
Digital Libraries and Foundations of Information Retrieval	DS.INFO.09

Semester	3rd semester
Duration	one semester
Taught semesters	every year (winter semester)
Language	German or English
Credits / ECTS	5 CP
Semester periods per week	3 weekly hours
Contact hours	45 hours
Self-study	105 hours
Workload	150 hours
Type of assessment	written exam (90 minutes) or oral (individual) exam
Non-graded assessment tasks	exercises
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	The students have acquired factual knowledge about the publication system with a focus on computer science publications. They are able to apply methods for estimating the importance of publications, publication venues, and authors. The students have acquired factual knowledge about typical retrieval tasks and important retrieval models. They are able to apply search engine technology for text search. They know how to evaluate the result quality of retrieval models and can design simple evaluation tasks. They can generalize this knowledge to other data domains.
Content	• Scientific publications in computer science. Institutions, typical conferences & journals, ranking, digital bibliographies • Digital libraries: user interfaces, organization, typical services • Data, information, knowledge • Search tasks, information seeking behavior • Preprocessing of documents • Retrieval models (including Boolean model, vector space model, probabilistic models, algebraic models) • Assessment of retrieval systems

	• Web search engines: crawling, Pagerank, HITS • Meta search engines, distributed search engines • Recommender Systems • Advanced topics in IR, for example multimodal search, search in social networks, text mining, sentiment analysis, text summarization) • Search engine optimization • Application of search engine technology with an open-source search engine (e.g., Lucene)
Reading	• Christopher Manning, Prabhakar Raghavan, Hinrich Schütze: Introduction to Information Retrieval, Cambridge University Press, 2008.
Types of courses	(a) lecture (2 weekly hours) (b) practical course (1 weekly hour) including exercises
Recommended prerequisites	None
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam
Module applicability	Elective module in degree programme "Data Science" (M.Sc.) Elective module in degree programme "Informatik" (M.Sc.) Elective module in degree progamme "Wirtschaftsinformatik" (M.Sc.) Elective module in degree programme "Digital Humanities" (M.Sc.)

Module Convenor	Prof. Schenkel
Additional information	none

Module Title	Module Code
Distributed Databases	DS.INFO.10

Semester	3rd semester
Duration	one semester
Taught semesters	every year (winter semester)
Language	German or English
Credits / ECTS	5 CP
Semester periods per week	3 weekly hours
Contact hours	45 hours
Self-study	105 hours
Workload	150 hours
Type of assessment	oral (individual) exam
Non-graded assessment tasks	exercises
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	The students have acquired factual knowledge about important architectures for distributed databases. They are able to design a distributed relational database in different application scenarios. The students have acquired factual knowledge about algorithms for guaranteeing transactional properties in distributed databases. They are able to apply this knowledge in deployed systems. The students have acquired factual knowledge about integration methods and their application in federated systems. Given a set of databases, they are able to define a federation schema and to define mappings of the local schemas to the federation schema. The students have acquired factual knowledge about advanced distributed data management methods, including processing of data streams and crowdsourcing computations. They are able to apply this knowledge in simple application examples.
Content	• Distributed relational databases – fragmentation, allication, query processing • Replication methods • Distributed transactions, two-phase commit procotocol, serializability • Cloud computing, cloud databases, multi-tenant systems

	• Information integration • Federated information systems • Processing of data streams • Crowdsourcing methods, social games
Reading	• M. Tamer Özsu, Patrick Valduriez: Principles of Distributed Database Systems, Third Edition. Springer 2011, ISBN 978-1-4419-8833-1
Types of courses	(a) lecture (2 weekly hours) (b) practical course (1 weekly hour) including exercises
Recommended prerequisites	none
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme "Data Science" (M.Sc.) Elective module in degree programme "Informatik" (M.Sc.) Elective module in degree progamme "Wirtschaftsinformatik" (M.Sc.)

Module Convenor	Prof. Schenkel
Additional information	none

Module Title	Module Code
Knowledge and Experience Management (Wissens- und Erfahrungsmanagement)	DS.INFO.04

Semester	3nd semester
Duration	one semester
Taught semesters	every winter semester
Language	German
Credits / ECTS	5 CP
Semester periods per week	3 weekly hours
Contact hours	45 hours
Self-study	105 hours
Workload	150 hours
Type of assessment	oral examination
Non-graded assessment tasks	excercises
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes

- students are able to explain the models, methods, and tools for knowledge and experience management
- students are able to analyze and evaluate the benefit of different knowledge management tools for specific applications
- students are able to explain and apply the principle of case-based reasoning for experience management
- students are able to explain the various algorithms involved in structural case-based reasoning and to evaluate them with respect to their advantages and shortcomings.

Competences

- ability to structure and aggregate new information and knowledge in the field of knowledge and experience management
- self-directed and self-organised learning
- professional use of advanced information technology
- presentation skills

Content	• introduction to the basic terms knowledge, experience, knowledge management (KM), experience management, and knowledge organization • basic KM models: SECI, components of KM, KM Tasks, Knowledge Market, process-oriented KM • KM methods for sharing & reuse, representation & acquisition, planning & analysis, evaluation • KM tools: groupware and social software, content-based systems, knowledge-based systems, business intelligence, organizational memory, integrated KM systems • case-based reasoning: cycle and knowledge containers, case representation, similarity, retrieval, adaptation, retainment • experience management applications
Reading	• Franz Lehner, Wissensmanagement – Grundlagen, Methoden und technische Unterstützung. Hansa Verlag, 4. Auflage, 2012. • Ralph Bergmann. *Experience Management: Foundations, Development Methodology, and Internet-based Applications*. LNAI 2432, Springer, 2002. • Michael Richter, Rosina Weber. Case-Based Reasoning – A Textbook. Springer, 2013.
Types of courses	(a) lecture (2 weekly hours) and practical course (1 weekly hours) including exercises
Recommended prerequisites	foundational knowledge in computer science and algorithms
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam
Module applicability	Elective module in degree programme "Data Science" (M. Sc.) Elective module in degree programme "Wirtschaftsinformatik" (M.Sc.)
Module Convenor	Prof. Bergmann
Additional information	Last edited, Oct 19,2017.

Module Title	Module Code
Semantic Information Systems (Semantische Informationssysteme)	DS.INFO.05

Semester	2nd semester
Duration	one semester
Taught semesters	every summer semester
Language	English
Credits / ECTS	5 CP
Semester periods per week	3 weekly hours
Contact hours	45 hours
Self-study	105 hours
Workload	150 hours
Type of assessment	portfolio
Non-graded assessment tasks	excercises
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes

- students are able to explain and apply the principles of semantic modelling for information systems
- students are able to explain and apply the introduced standards of the semantic web and are able to evaluate their benefit in specific application scenarios
- students have obtained a basic understanding of ontological reasoning and terminological logic
- students are able to program simple applications using a semantic web framework in JAVA.

Competences

- ability to structure and aggregate new information and knowledge in the field of semantic technologies
- self-directed and self-organised learning
- professional use of advanced information technology
- presentation skills

Content

- principles of the semantic web and semantic information systems
- basic standards: XML-schema, RDF, RDFS
- semantics of RDF/RDFS

	• SPARQL query language • foundations of terminological logic for ontology representation • ontologies in OWL and RDFS • linked open data • ontology engineering and tools • applications of semantic technologies
Reading	• Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph. Foundations of Semantic Web Technologies. Chapman & Hall/CRC, 2009 • Gomez-Perez, Fernandez-Lopez, Corcho.Ontological Engineering. Springer, 2004. • Andreas Dengel. Semantische Technologien. Spektrum Akademischer Verlag. 2004.
Types of courses	(a) lecture (2 weekly hours) and practical course (1 weekly hours) including exercises
Recommended prerequisites	foundational knowledge in computer science and algorithms
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam
Module applicability	Elective module in degree programme "Data Science" (M. Sc.) Elective module in degree programme "Wirtschaftsinformatik" (M.Sc.) Elective module in degree programme "Informatik" (M.Sc.) Elective module in degree programme "Digital Humanities" (M.Sc.)

Module Convenor	Prof. Bergmann
Additional information	Last edited, Oct 19,2017.

Module Title	Module Code
Information Visualization	DS.INFO.08

Semester	2nd or 4th semester
Duration	one semester
Taught semesters	every year (summer semester)
Language	German or English
Credits / ECTS	5 CP
Semester periods per week	3 weekly hours
Contact hours	45 hours
Self-study	105 hours
Workload	150 hours
Type of assessment	written exam (90 minutes) or portfolio or oral (individual) exam
Non-graded assessment tasks	exercises
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	The students acquire factual knowledge of basic visualization techniques. They know physiological and psychological factors. They understand important applications of visualization techniques (with a focus on software visualization). The students are able to apply visualization techniques to simple application cases.
Content	• Visualization of textual and numerical data • Visualization of hierarchical information • Visualization of graphs • Visual perception • Software visualization • Evaluation of visualization techniques
Reading	Slides and additional material provided by the lecturer
Types of courses	(a) lecture or reading course (2 weekly hours) (b) practical course (1 weekly hour) including exercises
Recommended prerequisites	none
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.

Module applicability	Elective module in degree programme "Data Science" (M.Sc.) Elective module in degree programme "Informatik" (M.Sc.) Elective module in degree progamme "Wirtschaftsinformatik" (M.Sc.) Elective module in degree programme "Digital Humanities" (M.Sc.)
Module Convenor	Prof. Diehl
Additional information	none

Algorithmic Optimization

Module Title	Module Code
Advanced Course in Algorithmic Optimization	DS.MATH.03

Semester	3rd semester
Duration	one semester
Taught semesters	every year (winter or summer)
Language	English
Credits / ECTS	10 CP
Semester periods per week	6 weekly hours
Contact hours	90 hours
Self-study	210 hours
Workload	300 hours
Type of assessment	written exam (120 minutes) (Klausur) or oral exam (mündliche Prüfung)
Non-graded assessment tasks	exercises (Übungsaufgaben)
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	The students know specific mathematical tools in the field of algorithmic optimization. They know, how to model an optimization problem in a form that it is accessible for specific tools and how to interpret results generated by the tools. Furthermore, they know the conceptual, theoretical and practical limitations of the respective tools.
Content	One lecture from: - Nonlinear optimization - Optimization on graphs - Integer optimization - Stochastic optimization - Numerical solution of differential equations - Optimization with differential equations - Iterative solvers - similar
Reading	-
Types of courses	Lecture (4 weekly hours) and practical course (2 weekly hours) including exercises

Recommended prerequisites	none
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme „Data Science" (M.Sc.)

Module Convenor	Prof. Dr. Volker Schulz
Additional information	The specific lecture chosen must be different from the lecture chosen within the module special topics in Algorithmic Optimization

Module Title	Module Code
Special Topics in Algorithmic Optimization	DS.MATH.04

Semester	3rd semester
Duration	one semester
Taught semesters	every year (winter or summer)
Language	English
Credits / ECTS	10 CP
Semester periods per week	6 weekly hours
Contact hours	90 hours
Self-study	210 hours
Workload	300 hours
Type of assessment	written exam (120 minutes) (Klausur) or oral exam (mündliche Prüfung)
Non-graded assessment tasks	exercises (Übungsaufgaben)
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	The students know specific advanced topics in the field of algorithmic optimization. They know, how to model an optimization problem in a form that it is accessible for specific tools and how to interpret results generated by the tools. Furthermore, they know the conceptual, theoretical and practical limitations of the respective tools.
Content	One lecture from: - Nonlinear optimization - Optimization on graphs - Integer optimization - Stochastic optimization - Numerical solution of differential equations - Optimization with differential equations - Iterative solvers - similar
Reading	-
Types of courses	Lecture (4 weekly hours) and practical course (2 weekly hours) including exercises
Recommended prerequisites	none

Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme „Data Science" (M.Sc.)

Module Convenor	Prof. Dr. Volker Schulz
Additional information	The specific lecture chosen must be different from the lecture chosen within the module advanced course in Algorithmic Optimization

Applied Statistics

In each of the following two elective modules sections of the degree programme „M.Sc. Survey Statistics" 10 CP (accordingly, a total of 20 CP) have to be reached: Survey Statistics (Survey Statistics) and Statistics (Statistik). See also module handbook of the degree programme „Survey Statistics".

Financial Economics

Module Title	Module Code
Quantitative Trading with R	DS.ECON.01

Semester	3rd semester
Duration	One semester
Taught semesters	Every year (winter semester)
Language	English
Credits / ECTS	10 CP
Semester periods per week	4 weekly hours (lecture, tutorial and seminar)
Contact hours	60 hours
Self-study	240 hours
Workload	60 + 240 hours
Type of assessment	Exam or term paper
Non-graded assessment tasks	Exercises
Prerequisites	None
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	After completing the module, students will have a thorough understanding of algorithmic trading rules and which methods are used in this field. They can identify, gather and import data into R and use and develop code to apply technical trading rules. Further, they are able to evaluate them with respect to speed and efficiency and report on their findings. **Competences** Students are able to identify and acquire required data and use R for a specific task. Students understand the concept of algorithmic trading rules and are able to apply and evaluate them.
Content	The module introduces technical trading rules both from a theoretical perspective and as an application. The topics covered include: - An overview on R, data management and statistics - Spreads, betas and risk

	- Backtesting with quantstrat - Global macro investing - Trend-following investing - Pairs trading and statistical arbitrage - Optimization and portfolio construction - Reporting and speed
Reading	Some suggestions: Berlinger, E. (2015): Mastering R for Quantitative Finance. PACKT Publishing. Daroczi, G. (2013): Introduction to R for Quantitative Finance. PACKT Publishing. Georgakopoulos, H. (2015): Quantitative Trading with R – Understanding Mathematical and Computational Tools from a Quant's Perspective. Palgrave Macmillan US. More focussed references will be given in the course syllabus.
Types of courses	Lecture, tutorial and seminar (4 weekly hours)
Recommended prerequisites	None
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme „Data Science" (M.Sc.)

Module Convenor	Prof. Dr. Christian Bauer
Additional information	Creditable in degree programme „Economics" (M.Sc.)

Module Title	Module Code
Applied Time Series and Financial Econometrics	DS.ECON.02

Semester	3rd semester
Duration	One semester
Taught semesters	Every year (winter semester)
Language	English

Credits / ECTS	10 CP
Semester periods per week	4 weekly hours (lecture and tutorial)
Contact hours	60 hours
Self-study	240 hours
Workload	60 + 240 hours

Type of assessment	Written exam
Non-graded assessment tasks	
Prerequisites	None
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes

Outcomes and competences

After having followed the course the students should be able to (i) formulate an interesting economic problem to be analyzed empirically by time series methods, (ii) collect relevant data and evaluate their quality, clean them, and apply appropriate transformations (if necessary), (iii) specify appropriate models to analyze the economic problem under study, and (iv) apply econometric software (R) to estimate the specified model and to produce statistical inference.

Content

The purpose of the course is to provide students with theoretical and practical experience in statistical and computational techniques in time series and financial econometrics. Models for stationary and non-stationary stochastic processes as well as special models for financial market data are introduced.

Reading

Some suggestions:

Enders, W. (2014): Applied econometric times series. 4th edition. Wiley.

Kirchgässner, G.; Wolters, J.; Hassler, U. (2013): Introduction to modern time series analysis. 2nd edition. Springer.

	Lütkepohl, H.; Krätzig, M. (2004): Applied time series econometrics. Cambridge University Press. More focussed references will be given in the course syllabus.
Types of courses	Lecture and tutorial (4 weekly hours)
Recommended prerequisites	First course in econometrics
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme „Data Science" (M.Sc.)

Module Convenor	Jun. Prof. Dr. Matthias Neuenkirch
Additional information	Creditable in degree programmes „Economics" (M.Sc.) and "Survey Statistics" (M.Sc.)

Geoinformatics

Module Title	**Module Code**
Fundamentals of Environmental Remote Sensing	DS.GEOI.01

Semester	3rd semester
Duration	One semester
Taught semesters	Occasionally (winter semester)
Language	English

Credits / ECTS	5 CP
Semester periods per week	2 + 2 weekly hours (lecture and lab exercise)
Contact hours	60 hours
Self-study	90 hours
Workload	150 hours

Type of assessment	Written exam
Non-graded assessment tasks	
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes	The course provides expert knowledge and hands-on experience of multi-scale remote sensing. Lecture and lab exercise cover the introduction to multi-scale remote sensing systems, advanced radiometric processing of multispectral data, derivation of qualitative surface characteristics with different spectral and radiometric properties **Competences** The course concludes with instruction and best practices for conducting an image processing and interpretation workflow (implementation of digital image processing concepts and specific analysis techniques in the frame of a case study. Use of vegetation indices and linear transformations). Software used during the course will include: Erdas Imagine, R-Programming Language.
Content	Introduction to multi-scale remote sensing systems - Specific sensor characteristics - Object signatures, scaling effects - Data archives Advanced radiometric processing of multi-spectral data

	- Sensor calibration - Radiative transfer models - Integration of topography- and Minnaert correction - Procurement of long-term time series Derivation of qualitative surface characteristics - Land use classification and land cover archives (MODIS, CORINE) - Land use change detection based on time series (e.g. MODIS) Biophysical parameters - Vegetation (e.g. cover, LAI, biomass) - Soil (e.g. organic and inorganic carbon, mineral content) - Indicators of productivity and disturbance Development of a processing and interpretation workflow - Implementation of digitale image processing concepts and specific analysis techniques in the frame of a case study - Vegetation indices and linear transformations (e.g. PCA, Tasseled Cap, Spectral Mixture Analysis)
Reading	Some suggestions: Jensen, J.R. (2006): Remote Sensing of the Environment: An Earth Resource Perspective (2nd Edition). Pearson Schönermark et al., 2004. (2004): Reflection Properties of Vegetation and Soil. WTV More focussed references will be given in the course syllabus.
Types of courses	Lecture (Vorlesung) (2 weekly hours) and lab excercise (Übung) (2 weekly hour)
Recommended prerequisites	None
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme „Data Science" (M.Sc.)

Module Convenor	Prof. Dr. Joachim Hill
Additional information	Specialisation is compulsory for students in the „Geoinformatics" track

Module Title	Module Code
Introduction to Geoinformatics	DS.GEOI.02

Semester	3rd semester
Duration	One semester
Taught semesters	Occasionally (winter semester)
Language	English

Credits / ECTS	5 CP
Semester periods per week	2 + 1 weekly hours (lab exercise and e-learning)
Contact hours	45 hours
Self-study	105 hours
Workload	150 hours

Type of assessment	Written exam (60 minutes)
Non-graded assessment tasks	
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes	The course provides theoretical background (raster and vector data, geodata processing and analys) and practical skills on geographic information science and geodata processomg. Computer lab exercise and e-learning cover the introduction to geodate models and concepts, introduction to coordinate systems and projections, geodata analysis and visualization. Concepts are illustrated in lab exercises using the ArcGIS software package. **Competences** The course concludes with instruction and best practices for conducting geodata integration, analysis and visualization.
Content	Geodata concepts and models Coordinate systems and projections Global navigation satellite systems – theory and data integration Geodatabase concepts Vector overlay processing Geospatial data analysis Data visualization
Reading	Some suggestions:

	Heywood, I. (2011): An Introduction to Geographical Information Systems. Prentice Hal. Jensen JR and Jensen RR (2012): Introductory Geographic Information Systems. Pearson More focussed references will be given in the course syllabus.
Types of courses	Lab excercise (Übung) (2 weekly hour) and e-learning (E-Learning) (1 weekly hour)
Recommended prerequisites	None
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme „Data Science" (M.Sc.)

Module Convenor	Prof. Dr. Thomas Udelhoven
Additional information	Specialisation is compulsory for students in the „Geoinformatics" track

Module Title	Module Code
Geostatistics	DS.GEOI.03

Semester	3rd semester
Duration	One semester
Taught semesters	Occasionally (winter semester)
Language	English

Credits / ECTS	5 CP
Semester periods per week	2+ 2 weekly hours (lecture and lab exercise)
Contact hours	60 hours
Self-study	90 hours
Workload	150 hours

Type of assessment	Written exam (90 min.)
Non-graded assessment tasks	
Prerequisites	
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.

Learning outcomes

Introduction to geostatistical methods and applications with emphasis on spatial point patterns, areal statistics, geostatistical concepts as well as geostatistical interpolation techniques

Competences

Concepts in lectures are illustrated in lab exercises using R-Programming Language and ArcGIS software package. Recommended previous knowledge: multivariate statistics.

Content

Introduction:

- Geostatistical concepts
- Obtaining data via geo-services
- Download and preparation of auxiliary satellite data

Spatial point patterns:

- Analysis of spatial point patterns: independence/randomness and interaction, spatial Poisson processes
- Segregation probability, mapping segregation
- Statistical tests for the assessment of spatial point patterns
- Statistical modelling: integrating spatial autocorrelation in regression models
- Geostatistical simulations
- Space-time clustering

	Areal statistics: • Generalized linear models in space (Poisson GLM and Bayesian GLM) • Residual analysis • Adding spatially autocorrelation effects Statistical spatial prediction models • Variogramm analysis and modelling • Environmental correlation • Spatial trend analysis • Regionalisation: Kriging and its variants (Simple and Ordinary Kriging, co-Kriging, Universal Kriging) • Regression Kriging, • Model validation Geostatistial workout examples: (e.g. species distribution modelling, analysis of spatial crime and health data, soil mapping applications, interpolation of climatic and meteorological data and heavy metal concentrations)
Reading	Some suggestions: Bivand, R.S., Pebesma, E.J., Gomez-Rubio, V. and Pebesma, E.J., 2008. Applied spatial data analysis with R (Vol. 747248717). New York: Springer. Wackernagel, H., 2013. Multivariate geostatistics: an introduction with applications. Springer Science & Business Media. More focussed references will be given in the course syllabus.
Types of courses	Lab excercise (Computerübung) (3 weekly hours) and field course (Übung) (2 days during the semester)
Recommended prerequisites	None
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme „Data Science" (M.Sc.)

Module Convenor	Prof. Dr. Thomas Udelhoven
Additional information	

Module Title	Module Code
Advanced Remote Sensing Data Processing and Interpretation	DS.GEOI.04

Semester	4th semester
Duration	One semester
Taught semesters	Occasionally (summer semester)
Language	English
Credits / ECTS	5 CP
Semester periods per week	3 + 1 weekly hours (lab exercise and field course)
Contact hours	55 hours
Self-study	90 hours
Workload	55 + 90 hours
Type of assessment	Graded term paper
Non-graded assessment tasks	
Prerequisites	Fundamentals of environmental remote sensing
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	Extends the fundamentals of environmental remote sensing focusing on integrated lab- and field-work. **Competences** A special focus lies in: radiative transfer modelling of multi- and hyperspectral data using Landsat-TM / ETM / OLI and Hyspex data sets (water vapor estimation and sensor recalibration). Different transformation (e.g. PCA, SMA, SA;) techniques are revised. Classification strategies are extended to non-parametric methods (e.g. SVM). Statistical models based on field data are applied to image data to estimate or classify environmental variables (e.g. soil moisture levels organic-carbon contents). The field work includes planning and execution of a hyperspectral field campaign (e.g. field survey of reference data and atmospheric measurements). Both proprietary software (e.g. ENVI (Harris Geospatial)) and open-source software/programming languages (e.g. QGIS / R programming Language, Python) are used for data handling.
Content	Lab exercise: Parametric geocoding of hyperspectral imagery Radiometric processing of hyperspectral imagery

	Radiative transfer modelling (Photometer measurements, Cross-Track Illumination Correction) Water vapour estimation, sensor recalibration Compression and transformation of hyperspectral data Spectral Mixture Analysis Principal Component Analysis vs. Partial Least Square-Regression Minimum Noise Fraction Classification and interpretation strategies Parametric and non-parametric methods (e.g. Maximum Likelihood, Support Vector Machines, Spectral Angle Mapper, Spectral Feature Fitting) Empirical approaches (e.g. hierarchical or support vector regression models) Multisensor approaches (algorithms und applications) Sensor intercalibration Data fusion Field course: Field survey of reference data Atmospheric measurements
Reading	Some suggestions: Liang, S. (2004): Quantitative Remote Sensing of Land Surfaces, Wiley/New York Richards, J.R. & Jia, X. (1999): Remote Sensing Digital Image Analysis More focussed references will be given in the course syllabus.
Types of courses	Lab excercise (Computerübung) (3 weekly hours) and field course (Übung) (2 days during the semester)
Recommended prerequisites	None
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme „Data Science" (M.Sc.)
Module Convenor	Prof. Dr. Thomas Udelhoven
Additional information	

Module Title	Module Code
Pattern Recognition in long-term global satellite archives	DS.GEOI.05

Semester	4th semester
Duration	One semester
Taught semesters	Occasionally (summer semester)
Language	English
Credits / ECTS	5 CP
Semester periods per week	2 + 2 weekly hours (lecture and lab exercise)
Contact hours	60 hours
Self-study	120 hours
Workload	180 hours
Type of assessment	Graded term paper
Non-graded assessment tasks	
Prerequisites	None
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	Competent handling of time-series analysis methods, concepts and techniques **Competences** First part of the course focuses on global satellite archives, related data formats and metadata concepts. Students will work with different software environments and will learn relevant techniques to detect and extract spatio-temporal patterns from long-term global satellite archives.
Content	Introduction: • Overview about major long-term global satellite data archives (eg MODIS,SPOT VGT, NOAA-AVHRR, Sentinel) • The problem of scale and mixed land-used information in satellite data • Introduction in relevant software environment for the analysis of satellite data (IDL/ENVI, Erdas Imagine) Pattern recognition: • The problem of homogeneity and consistency of satellite based time-series • Introduction and definitions of time-series analysis methods

	and concepts (analysing temporal/spatial autocorrelation, long-term and seasonal trend analysis, anomaly detection and analysis, supervised/unsupervised land-use classification, ARIMA modelling and simulation, (cross-) spectral analysis and wavelet transform) Lining spatiotemporal patterns with environmental processes: • Analysing land surface dynamics • Linking satellite based time-series to auxiliary information and other time-series data: linear mixed effect models and distributed lag models • Practical examples using different regional/global long-term satellite archives
Reading	Some suggestions: Kuenzer, C., Dech, S. and Wagner, W., 2015. Remote Sensing Time Series. Springer International Publishing: Imprint: Springer. Chatfield, Chris. The analysis of time series: an introduction. CRC press, 2016. More focussed references will be given in the course syllabus.
Types of courses	Lecture (Vorlesung) (2 weekly hours) and lab-excercise (Übung) (2 weekly hour)
Recommended prerequisites	None
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme „Data Science" (M.Sc.)

Module Convenor	Prof. Dr. Thomas Udelhoven
Additional information	

Others (without Specialization)

Module Title	Module Code
Advanced Course in Mathematics	DS.MATH.05

Semester	3rd semester
Duration	one semester
Taught semesters	every year (winter or summer)
Language	English
Credits / ECTS	10 CP
Semester periods per week	6 weekly hours
Contact hours	90 hours
Self-study	210 hours
Workload	300 hours
Type of assessment	written exam (120 minutes) (Klausur) or oral exam (mündliche Prüfung)
Non-graded assessment tasks	exercises (Übungsaufgaben)
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	The students know advanced mathematical methods in general mathematical fields like analysis or stochastics. They know modern high level mathematical methods and their rigorous theoretical foundation. Furthermore, they acquire deep capacities in mathematical abstraction and argumentation.
Content	One lecture from: - Functional analysis - Complex analysis - Mathematical statistics - Stochastic processes - similar
Reading	-
Types of courses	Lecture (4 weekly hours) and practical course (2 weekly hours) including exercises
Recommended prerequisites	none
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded

	assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme „Data Science" (M.Sc.)

Module Convenor	Prof. Dr. Volker Schulz
Additional information	The specific lecture chosen must be different from the lecture chosen within the module Special Topics in Mathematics

Module Title	Module Code
Special Topics in Mathematics	DS.MATH.06

Semester	3rd semester
Duration	one semester
Taught semesters	every year (winter or summer)
Language	English
Credits / ECTS	10 CP
Semester periods per week	6 weekly hours
Contact hours	90 hours
Self-study	210 hours
Workload	300 hours
Type of assessment	written exam (120 minutes) (Klausur) or oral exam (mündliche Prüfung)
Non-graded assessment tasks	exercises (Übungsaufgaben)
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	The students know special topics in general mathematical fields like analysis or stochastics. They know modern high level mathematical methods and their rigorous theoretical foundation. Furthermore, they acquire highly advanced capabilities in mathematical abstraction and argumentation.
Content	One lecture from: - Functional analysis - Complex analysis - Differential equations - Topology - Algebra - Approximation theory - Equilibrium theory - Mathematical statistics - Nonparametric statistics - Stochastic analysis - Time series analysis - similar
Reading	-

Types of courses	Lecture (4 weekly hours) and practical course (2 weekly hours) including exercises
Recommended prerequisites	none
Requirements for awarding CPs	Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.
Module applicability	Elective module in degree programme „Data Science" (M.Sc.)

Module Convenor	Prof. Dr. Volker Schulz
Additional information	The specific lecture chosen must be different from the lecture chosen within the module Advanced Course in Mathematics

Module Title	Module Code
Seminar Mathematics	DS.MATH.07

Semester	3rd semester
Duration	one semester
Taught semesters	every year (winter semester)
Language	English
Credits / ECTS	10 CP
Semester periods per week	4 weekly hours
Contact hours	60 hours
Self-study	240 hours
Workload	300 hours
Type of assessment	Presentation
Non-graded assessment tasks	
Prerequisites	none
Assessment weighting	The module grade counts towards the final grade according to the number of awarded credit points.
Learning outcomes	The students know mathematical aspects in a research related field. They acquire competence in the presentation of mathematical content and the proper oral and written argumentation foundations in the areas of linear algebra and numerical mathematics. They know how to discuss mathematical research topics in a meaningful way.
Content	The module contains two seminars in mathematical fields chosen by the student.
Reading	-
Types of courses	2 Seminar courses (2 weekly hours each)
Recommended prerequisites	none
Requirements for awarding CPs	Regular attendance at the seminar, successful and convincing presentation, submission of acceptable term paper.
Module applicability	Elective module in degree programme „Data Science" (M.Sc.)
Module Convenor	Prof. Dr. Volker Schulz

Additional information