Module Handbook

Master Degree Programme
M.Sc. Data Science

28/11/2017
# Curriculum

## M.Sc. Data Science

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<th>1st Semester</th>
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<th>3rd Semester / Mobility window</th>
<th>4th Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 LP 6 SWS</td>
<td>10 LP 6 SWS</td>
<td>10 LP 2 SWS</td>
<td>Master’s Thesis</td>
</tr>
<tr>
<td><strong>Compulsory modules</strong></td>
<td></td>
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<tr>
<td>Introduction to Data Science</td>
<td>Numerical Optimization for Data Science</td>
<td>Research Case Studies</td>
<td></td>
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<tr>
<td>Statistical Methods of Data Science</td>
<td>Data and Web Mining</td>
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<tr>
<td>Big Data Analytics</td>
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| Elective modules | | | |
| 10 LP 6 SWS | | | |
| Elements of Mathematics | | | |
| 10 LP 4 SWS | | | |
| Elements of Computer Science | | | |
| 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

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<tr>
<td>Introduction to Data Science</td>
<td>DS.GENE.01</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Semester</th>
<th>1st semester</th>
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</thead>
<tbody>
<tr>
<td>Duration</td>
<td>One semester</td>
</tr>
<tr>
<td>Taught semesters</td>
<td>Every year (winter semester)</td>
</tr>
<tr>
<td>Language</td>
<td>English</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Credits / ECTS</th>
<th>10 CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester periods per week</td>
<td>4 weekly hours (lecture)</td>
</tr>
<tr>
<td>Contact hours</td>
<td>60 hours</td>
</tr>
<tr>
<td>Self-study</td>
<td>240 hours</td>
</tr>
<tr>
<td>Workload</td>
<td>60 + 240 hours</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of assessment</th>
<th>exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-graded assessment tasks</td>
<td>None</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>The module grade counts towards the final grade according to the number of awarded credit points.</td>
</tr>
</tbody>
</table>

### 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 Münich

Additional information
Module Title | Module Code
---|---
Numerical Optimization for Data Science | DS.MATH.02

<table>
<thead>
<tr>
<th>Semester</th>
<th>2nd semester</th>
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</thead>
<tbody>
<tr>
<td>Duration</td>
<td>one semester</td>
</tr>
<tr>
<td>Taught semesters</td>
<td>every year (summer semester)</td>
</tr>
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</table>

| Language | English |

<table>
<thead>
<tr>
<th>Credits / ECTS</th>
<th>10 CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester periods per week</td>
<td>6 weekly hours</td>
</tr>
<tr>
<td>Contact hours</td>
<td>90 hours</td>
</tr>
<tr>
<td>Self-study</td>
<td>210 hours</td>
</tr>
<tr>
<td>Workload</td>
<td>300 hours</td>
</tr>
</tbody>
</table>

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

Types of courses
Lecture (4 weekly hours) and practical course (2 weekly hours) including exercises

Recommended prerequisites | none
<table>
<thead>
<tr>
<th>Requirements for awarding CPs</th>
<th>Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module applicability</td>
<td>Compulsory module in degree programme „Data Science“ (M.Sc.)</td>
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</table>

<table>
<thead>
<tr>
<th>Module Convenor</th>
<th>Prof. Dr. Volker Schulz</th>
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</thead>
<tbody>
<tr>
<td>Additional information</td>
<td></td>
</tr>
</tbody>
</table>
Module Title | Module Code
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Statistical Methods of Data Science | DS.STAT.02

<table>
<thead>
<tr>
<th>Semester</th>
<th>2nd semester</th>
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</thead>
<tbody>
<tr>
<td>Duration</td>
<td>One semester</td>
</tr>
<tr>
<td>Taught semesters</td>
<td>Every year (summer semester)</td>
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<tr>
<td>Language</td>
<td>English</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Credits / ECTS</th>
<th>10 CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester periods per week</td>
<td>4 weekly hours (2 + 2, lecture and presentations)</td>
</tr>
<tr>
<td>Contact hours</td>
<td>60 hours</td>
</tr>
<tr>
<td>Self-study</td>
<td>240 hours</td>
</tr>
<tr>
<td>Workload</td>
<td>60 + 240 hours</td>
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</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Learning outcomes</th>
<th>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.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competences</td>
<td>Students are able to extract data from the internet and analyse such data, taking their collection into account.</td>
</tr>
<tr>
<td></td>
<td>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.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Content</th>
<th>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.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>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.</td>
</tr>
</tbody>
</table>
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:


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
Different chairs/departments

Module Title | Module Code
---|---
Data and Web Mining | DS.INFO.03

<table>
<thead>
<tr>
<th>Semester</th>
<th>2nd semester</th>
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</thead>
<tbody>
<tr>
<td>Duration</td>
<td>one semester</td>
</tr>
<tr>
<td>Taught semesters</td>
<td>every summer semester</td>
</tr>
<tr>
<td>Language</td>
<td>English</td>
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<table>
<thead>
<tr>
<th>Credits / ECTS</th>
<th>5 CP</th>
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</thead>
<tbody>
<tr>
<td>Semester periods per week</td>
<td>3 weekly hours</td>
</tr>
<tr>
<td>Contact hours</td>
<td>45 hours</td>
</tr>
<tr>
<td>Self-study</td>
<td>105 hours</td>
</tr>
<tr>
<td>Workload</td>
<td>150 hours</td>
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</table>

<table>
<thead>
<tr>
<th>Type of assessment</th>
<th>written exam (90 minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-graded assessment tasks</td>
<td>excercises</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>none</td>
</tr>
</tbody>
</table>

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
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M.Sc. Data Science

- 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

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

<table>
<thead>
<tr>
<th>Semester</th>
<th>2nd semester</th>
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<tbody>
<tr>
<td>Duration</td>
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Language | English

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<td>45 hours</td>
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<tr>
<td>Self-study</td>
<td>105 hours</td>
</tr>
<tr>
<td>Workload</td>
<td>150 hours</td>
</tr>
</tbody>
</table>

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
- Tom White: Hadoop: The Definitive Guide. O’Reilly UK Ltd,

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 | Research Case Studies
---|---
Module Code | 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 implementation 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 Münich plus other professors of computer sciences, mathematics and statistics/economics

Additional information
Module Title | Master's Thesis
---|---
Module Code | 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 Münich plus other professors of computer sciences, mathematics |
Universität Trier
M.Sc. Data Science

Different chairs/departments

and statistics/economics

Additional information
2 Elective Modules

Preparation Courses

<table>
<thead>
<tr>
<th>Module Title</th>
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<tbody>
<tr>
<td>Elements of Mathematics</td>
<td>DS.MATH.01</td>
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<table>
<thead>
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<th>Semester</th>
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<tr>
<td>Duration</td>
<td>one semester</td>
</tr>
<tr>
<td>Taught semesters</td>
<td>every year (winter semester)</td>
</tr>
<tr>
<td>Language</td>
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</table>

<table>
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<tr>
<th>Credits / ECTS</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Semester periods per week</td>
<td>6 weekly hours</td>
</tr>
<tr>
<td>Contact hours</td>
<td>90 hours</td>
</tr>
<tr>
<td>Self-study</td>
<td>210 hours</td>
</tr>
<tr>
<td>Workload</td>
<td>300 hours</td>
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</table>

<table>
<thead>
<tr>
<th>Type of assessment</th>
<th>written exam (120 minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-graded assessment tasks</td>
<td>exercises (Übungsaufgaben)</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>none</td>
</tr>
<tr>
<td>Assessment weighting</td>
<td>The module grade counts towards the final grade according to the number of awarded credit points.</td>
</tr>
</tbody>
</table>

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
Universität Trier

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Reading
- C. D. Meyer: Matrix analysis and applied linear algebra, SIAM 2001

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

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:


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**

<table>
<thead>
<tr>
<th>Module Name</th>
<th>Module Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation and Management</td>
<td>DS.INFO.11</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Semester</th>
<th>2nd or 4th semester</th>
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<tbody>
<tr>
<td>Duration</td>
<td>One semester</td>
</tr>
<tr>
<td>Taught semesters</td>
<td>Every year (summer)</td>
</tr>
<tr>
<td>Language</td>
<td>German</td>
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<table>
<thead>
<tr>
<th>Credits / ECTS</th>
<th>5 CP</th>
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<tbody>
<tr>
<td>Semester periods per week</td>
<td>3 weekly hours</td>
</tr>
<tr>
<td>Contact hours</td>
<td>45 h</td>
</tr>
<tr>
<td>Self-study</td>
<td>105 h</td>
</tr>
<tr>
<td>Workload</td>
<td>150 h</td>
</tr>
</tbody>
</table>

**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

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 Convenor
Prof. Dr.-Ing. Ingo J. Timm

Additional information
Agent-Based Modeling
(Agentenbasierte Modellierung)

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

<table>
<thead>
<tr>
<th>Credits / ECTS</th>
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</tr>
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<td>105 hours</td>
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<tr>
<td>Workload</td>
<td>150 hours</td>
</tr>
</tbody>
</table>

**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


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

Module Title | Multi-Agent-Systems (Multiagentensysteme) | Module Code | 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 | exercises |  | 
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 |  | 

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Universität Trier
M.Sc. Data Science

- 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

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
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: |


More focussed references will be given in the course syllabus.

<table>
<thead>
<tr>
<th>Types of courses</th>
<th>Lecture (Vorlesung) (2 weekly hours) and tutorial (Übung) (1 weekly hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended prerequisites</td>
<td>Elements of Statistics, Statistical Methods of Data Science</td>
</tr>
<tr>
<td>Requirements for awarding CPs</td>
<td>Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.</td>
</tr>
<tr>
<td>Module applicability</td>
<td>Elective module in degree programme “Data Science“ (M. Sc.)</td>
</tr>
</tbody>
</table>

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:


More focussed references will be given in the course syllabus.

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<tr>
<td>Requirements for awarding CPs</td>
<td>Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.</td>
</tr>
<tr>
<td>Module applicability</td>
<td>Elective module in degree programme “Data Science” (M. Sc.)</td>
</tr>
</tbody>
</table>

**Module Convenor**

Prof. Dr. Ralf Münich

**Additional information**

Specialisation is compulsory for students in the „Simulation Studies“ track
Data and Knowledge Systems

<table>
<thead>
<tr>
<th>Module Title</th>
<th>Module Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Libraries and Foundations of Information Retrieval</td>
<td>DS.INFO.09</td>
</tr>
</tbody>
</table>

**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

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 programme "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, allocation, query processing
- Replication methods
- Distributed transactions, two-phase commit protocol, serializability
- Cloud computing, cloud databases, multi-tenant systems
• Information integration
• Federated information systems
• Processing of data streams
• Crowdsourcing methods, social games

Reading

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 programme “Wirtschaftsinformatik” (M.Sc.)

Module Convenor
Prof. Schenkel

Additional information
none
Module Title | Module Code
-------------|-------------
Knowledge and Experience Management (Wissens- und Erfahrungsmanagement) | DS.INFO.04

<table>
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<th>Semester</th>
<th>3nd semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>one semester</td>
</tr>
<tr>
<td>Taught semesters</td>
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</tr>
<tr>
<td>Language</td>
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<tr>
<td>Self-study</td>
<td>105 hours</td>
</tr>
<tr>
<td>Workload</td>
<td>150 hours</td>
</tr>
</tbody>
</table>

Type of assessment | oral examination
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
- 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, retention
- experience management applications

Reading


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

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

<table>
<thead>
<tr>
<th>Semester</th>
<th>2nd semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>one semester</td>
</tr>
<tr>
<td>Taught semesters</td>
<td>every summer semester</td>
</tr>
<tr>
<td>Language</td>
<td>English</td>
</tr>
</tbody>
</table>

| 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 | exercises

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


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

Module Title: Information Visualization  
Module Code: DS.INFO.08

<table>
<thead>
<tr>
<th>Semester</th>
<th>2nd or 4th semester</th>
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</thead>
<tbody>
<tr>
<td>Duration</td>
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</tr>
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<td>Taught semesters</td>
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<tr>
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<td>Workload</td>
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</tr>
</tbody>
</table>

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 programme "Wirtschaftsinformatik" (M.Sc.)
- Elective module in degree programme "Digital Humanities" (M.Sc.)

### Module Convenor
- Prof. Diehl

### Additional information
- none
Algorithmic Optimization

<table>
<thead>
<tr>
<th>Module Title</th>
<th>Module Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Course in Algorithmic Optimization</td>
<td>DS.MATH.03</td>
</tr>
</tbody>
</table>

**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

**Special Topics in Algorithmic Optimization**

<table>
<thead>
<tr>
<th>Module Title</th>
<th>Module Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special Topics in Algorithmic Optimization</td>
<td>DS.MATH.04</td>
</tr>
</tbody>
</table>

### 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

<table>
<thead>
<tr>
<th>Module Title</th>
<th>Module Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantitative Trading with R</td>
<td>DS.ECON.01</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Credits / ECTS</th>
<th>10 CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester periods per week</td>
<td>4 weekly hours (lecture, tutorial and seminar)</td>
</tr>
<tr>
<td>Contact hours</td>
<td>60 hours</td>
</tr>
<tr>
<td>Self-study</td>
<td>240 hours</td>
</tr>
<tr>
<td>Workload</td>
<td>60 + 240 hours</td>
</tr>
</tbody>
</table>

- **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:


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.)
<table>
<thead>
<tr>
<th>Module Title</th>
<th>Module Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applied Time Series and Financial Econometrics</td>
<td>DS.ECON.02</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Semester</th>
<th>3rd semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>One semester</td>
</tr>
<tr>
<td>Taught semesters</td>
<td>Every year (winter semester)</td>
</tr>
<tr>
<td>Language</td>
<td>English</td>
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<table>
<thead>
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<th>Credits / ECTS</th>
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</thead>
<tbody>
<tr>
<td>Semester periods per week</td>
<td>4 weekly hours (lecture and tutorial)</td>
</tr>
<tr>
<td>Contact hours</td>
<td>60 hours</td>
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<td>Self-study</td>
<td>240 hours</td>
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<td>Workload</td>
<td>60 + 240 hours</td>
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<table>
<thead>
<tr>
<th>Type of assessment</th>
<th>Written exam</th>
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</table>

<table>
<thead>
<tr>
<th>Non-graded assessment tasks</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Prerequisites</th>
<th>None</th>
</tr>
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<tbody>
<tr>
<td>Assessment weighting</td>
<td>The module grade counts towards the final grade according to the number of awarded credit points.</td>
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</table>

<table>
<thead>
<tr>
<th>Learning outcomes</th>
<th>Outcomes and competences</th>
</tr>
</thead>
</table>

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.

<table>
<thead>
<tr>
<th>Content</th>
</tr>
</thead>
</table>

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.

<table>
<thead>
<tr>
<th>Reading</th>
</tr>
</thead>
</table>

Some suggestions:


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

<table>
<thead>
<tr>
<th>Module Title</th>
<th>Module Code</th>
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</thead>
<tbody>
<tr>
<td>Fundamentals of Environmental Remote Sensing</td>
<td>DS.GEOI.01</td>
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</table>

### Semester

<table>
<thead>
<tr>
<th>Semester</th>
<th>3rd semester</th>
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</thead>
</table>

### Duration

<table>
<thead>
<tr>
<th>Duration</th>
<th>One semester</th>
</tr>
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</table>

### Taught semesters

<table>
<thead>
<tr>
<th>Taught semesters</th>
<th>Occasionally (winter semester)</th>
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</table>

### Language

<table>
<thead>
<tr>
<th>Language</th>
<th>English</th>
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### Credits / ECTS

<table>
<thead>
<tr>
<th>Credits / ECTS</th>
<th>5 CP</th>
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</table>

### Semester periods per week

<table>
<thead>
<tr>
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<th>2 + 2 weekly hours (lecture and lab exercise)</th>
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### Contact hours

<table>
<thead>
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<th>Contact hours</th>
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### Self-study

<table>
<thead>
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<th>Self-study</th>
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### Workload

<table>
<thead>
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<th>Workload</th>
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### Type of assessment

<table>
<thead>
<tr>
<th>Type of assessment</th>
<th>Written exam</th>
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</table>

### Non-graded assessment tasks

<table>
<thead>
<tr>
<th>Prerequisites</th>
<th>none</th>
</tr>
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### Assessment weighting

<table>
<thead>
<tr>
<th>Assessment weighting</th>
<th>The module grade counts towards the final grade according to the number of awarded credit points.</th>
</tr>
</thead>
</table>

### 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:


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 prerequisits**

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

<table>
<thead>
<tr>
<th>Semester</th>
<th>3rd semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>One semester</td>
</tr>
<tr>
<td>Taught semesters</td>
<td>Occasionally (winter semester)</td>
</tr>
<tr>
<td>Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Credits / ECTS</th>
<th>5 CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester periods per week</td>
<td>2 + 1 weekly hours (lab exercise and e-learning)</td>
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<tr>
<td>Contact hours</td>
<td>45 hours</td>
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<td>Self-study</td>
<td>105 hours</td>
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<tr>
<td>Workload</td>
<td>150 hours</td>
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</table>

Type of assessment | Written exam (60 minutes) |
---|---|

Non-graded assessment tasks

<table>
<thead>
<tr>
<th>Prerequisites</th>
<th>none</th>
</tr>
</thead>
</table>

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 analysis) and practical skills on geographic information science and geodata processing. Computer lab exercise and e-learning cover the introduction to geodata 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:


More focussed references will be given in the course syllabus.

**Types of courses**

Lab exercise (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

<table>
<thead>
<tr>
<th>Module Title</th>
<th>Module Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geostatistics</td>
<td>DS.GEOI.03</td>
</tr>
</tbody>
</table>

### 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

### 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

Geostatistical 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:

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:
More focussed references will be given in the course syllabus.

Types of courses
Lab exercise (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:

More focussed references will be given in the course syllabus.

Types of courses
Lecture (Vorlesung) (2 weekly hours) and lab-exercise (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)

<table>
<thead>
<tr>
<th>Module Title</th>
<th>Module Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Course in Mathematics</td>
<td>DS.MATH.05</td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Module applicability</th>
<th>Elective module in degree programme „Data Science“ (M.Sc.)</th>
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</table>

<table>
<thead>
<tr>
<th>Module Convenor</th>
<th>Prof. Dr. Volker Schulz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional information</td>
<td>The specific lecture chosen must be different from the lecture chosen within the module Special Topics in Mathematics</td>
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</tbody>
</table>
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 | -
<table>
<thead>
<tr>
<th>Types of courses</th>
<th>Lecture (4 weekly hours) and practical course (2 weekly hours) including exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended prerequisites</td>
<td>none</td>
</tr>
<tr>
<td>Requirements for awarding CPs</td>
<td>Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.</td>
</tr>
<tr>
<td>Module applicability</td>
<td>Elective module in degree programme „Data Science“ (M.Sc.)</td>
</tr>
</tbody>
</table>

**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 | Seminar Mathematics  
---|---
Module Code | 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