Advanced Programming and Algorithms

Responsible for the Module: Prof. Dr. Gunnar Klau (gunnar.klau@hhu.de)			**Date:** 1.05.2019
Lecturer(s) Dr. Timo Dickscheid			**Semester:** 1.
			Modus: Obligatory Course
Work Load 300 h	**Credits** 10 CP	**Contact Time** 100 h	**Self-study** 200 h
Course Lecture: 4 SWS Exercises: 2 SWS	**Turnus** each winter term	**Group Size** 40	**Duration** 1 Semester

Learning results & Competences

Students know the basic toolbox of algorithm design and analysis. They can prove correctness of algorithms and analyze their running time and space requirements using O-Notation. They know the differences between basic complexity classes and can prove NP-completeness using reduction techniques. They know and can apply the major algorithmic design principles. They know algorithms for classic problems such as sorting, searching and pattern matching as well as important data structures for dictionaries and text indexing. They are able to work with graphs and understand and can apply and analyze classic graph algorithms.

On the practical side, students can work with the Unix shell, implement algorithms in Python and create data science workflows using Snakemake. Students can use a version control system (e.g. git) and docker to create reproducible execution environments. Students know how to test their code and are able to apply test driven development. Students can evaluate the quality of a given piece of code and provide feedback for improvement. Students are able to apply refactoring techniques in order to improve code quality. They are able to use a debugger to identify errors in code.

Teaching

Lecture with (theoretical and practical) exercises

Content

Lecture:

Algorithmic Problems. Algorithms and algorithmic problems, correctness proofs and running time analysis, O-Notation, computational complexity. The traveling salesman problem.
Programming and Software Engineering. Introduction to Unix, shell programming and the Python programming language. Data science workflows with Snakemake. Quality Assurance: Version Control Systems, Docker, Creating reproducible execution environments, Testing and Test Driven Development, Code Review, Code Quality, Refactoring, Debugging.
Algorithmic design principles. Brute force, recursion, divide-and-conquer, dynamic programming, branch-and-bound, greedy algorithms, heuristics. Approximation.
Classic algorithms and data structures. Quicksort/Mergesort/Heapsort, binary search, search trees, splay trees, B-trees, pattern matching, suffix trees, hashing.
Graph theory and graph algorithms. Graphs, topological sort, DFS/BFS, connectivity, shortest paths, minimum spanning trees

Exercises:
In the exercises the content of the lecture is applied and deepened in theoretical exercises. In addition, the students will implement selected algorithms and data structures in Python and will build algorithmic workflows using Snakemake. They will apply basic software engineering tools.

Prerequisites for attending
Formal: Admission to master studies in „Artificial Intelligence and Data Science".
Contentual**:** none

Examination
(1) Written examination about content of lectures (80% of grade)
(2) Assessment of practical work (20% of grade)

Prerequisites for receiving credit points

(3) Regular and active participation in the exercises
(4) Passing the examination

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
M.Sc. Computer Science

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points

Language
☐ Deutsch
☒ Englisch
☐ Deutsch und Englisch
☐ Deutsch, Englisch bei Bedarf

Further Information

Algorithmic GameTheory

Responsible for the Module: Prof. Dr. Jörg Rothe	**Date:** 17.06.2019
Lecturer(s) Prof. Dr. Jörg Rothe	**Semester:** variable
	Modus: Elective course

Work Load	**Credits**	**Contact Time**	**Self-study**
300 h	10 CP	100 h	200 h
Course Lecture: 4 SWS Exercises: 2 SWS	**Turnus** irregular	**Group Size** –	**Duration** 1 Semester

Learning results & Competences

The goal of this module is to introduce into the most important topics, results, models, and methods of algorithmic game theory, which is a central theoretical foundation of numerous applications in artificial intelligence and multiagent systems. The students will get to know central game-theoretic problems and algorithms solving them; they will be able to modify and apply these algorithms; they learn how to describe strategic scenarios by cooperative or noncooperative games, and to formally characterize concepts of stability and equilibria in these games. They will also be able to analyse the corresponding decision and optimization problems (in suitable compact representations) in terms of their computational complexity.

Teaching

Lecture „Algorithmic Game Theory“: 4 SWS, Exercises: 2 SWS

Content

- Noncooperative Game Theory:
  - Foundations
    - Normal form games, dominant strategies, and equilibria
    - Two-person games
  - Nash equilibria in mixed strategies
    - Definition and properties of mixed Nash equilibria
    - Existence of Nash equilibria in mixed strategies
  - Checkmate: Trees for games with perfect information
    - Sequential two-player games
    - Equilibria in game trees
  - Full house: Games with incomplete information
    - The Monty Hall problem
    - Analysis of a simple poker variant
  - How hard is it to find a Nash equilibrium?
    - Nash equilibria in zero-sum games
    - Nash equilibria in general normal form games
- Cooperative Game Theory

- Foundations
  - Cooperative games with transferable utility
  - Superadditive games
  - Stability concepts for cooperative games
- Simple games
  - The core of a simple game
  - Counting and representing simple games
  - Weighted voting games
  - Dimensionality
  - Power indices
  - The Shapley-Shubik index and the Shapley value
  - The Banzhaf indices
- Complexity of problems for succinctly representable games
  - Games on graphs
  - Weighted voting games
  - Hedonic games

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science“.
Contentual: none

Examination

(1) written examination

Prerequisites for receiving credit points

(1) Regular and active participation in the exercises
(2) Passing the examination

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
M.Sc. Computer Science

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points

Language
☐ German
☒ English
☐ German and English
☐ German, English on demand

Further Information
Literature

- Jörg Rothe (ed.): Economics and Computation: An Introduction to Algorithmic Game Theory, Computational Social Choice, and Fair Division, Springer-Verlag, 2015.

A shorter German version of this book appeared as:

- Jörg Rothe, Dorothea Baumeister, Claudia Lindner und Irene Rothe: Einführung in Computational Social Choice. Individuelle Strategien und kollektive Entscheidungen beim Spielen, Wählen und Teilen, Spektrum Akademischer Verlag (Springer), 2011.

<u>Additional literature</u>

- Bezalel Peleg and Peter Sudhölter: Introduction to the Theory of Cooperative Games, Kluwer Academic Publishers, 2003.
- Martin J. Osborne and Ariel Rubinstein: A Course in Game Theory, MIT Press, 1994.
- Georgios Chalkiadakis, Edith Elkind, and Michael Wooldridge: Computational Aspects of Cooperative Game Theory, Morgan and Claypool Publishers, 2011.
- Noam Nisan, Tim Roughgarden, Eva Tardos, and Vijay V. Vazirani (eds.): Algorithmic Game Theory, Cambridge University Press, 2008.

CAUSALITY

Responsible for the Module: Prof. Dr. Stefan Harmeling	**Date:** 17.06.2019
Lecturer(s) Prof. Dr. Stefan Harmeling	**Semester:** variable
	Modus: Elective Course

Work Load	**Credits**	**Contact Time**	**Self-study**
150h	5 CP	64h	86h
Course Lecture: 2 SWS Exercises: 2 SWS	**Turnus** yearly	**Group Size** 40	**Duration** 1 Semester

Learning results & Competences

After successfully finishing the course, the student
* can understand and can explain the theoretical foundations of causal inference
* can implement and apply algorithms of causal inference

Teaching

Lecture with theoretical and practical exercises

Content

This module teaches foundational knowledge about:
* Directed acyclic graphs, causal graphs
* Conditional independence
* PC algorithm
* Structural equation models
* Additive noise models
* Interventions
* Counterfactuals
* Markov equivalence
* Faithfulness
* Distinguishing cause and effect

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science“.
Contentual: none

Examination

(1) Written examination

Prerequisites for receiving credit points

(1) Regular and active participation in the exercises
(2) Passing the examination

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
M.Sc. Computer Science

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points

Language
☐ German
☒ English
☐ German and English
☐ German, English on demand

Further Information

Literature:
Main text book is:
* Peters/Janzing/Schölkopf, Elements of Causal inference, MIT
Additionally, the following books are helpful:
* Spirtes/Glymour/Scheines, Causation, Prediction, and Search, MIT 2000
* Pearl: Causality, Cambridge 2000

Computational Linguistics

Responsible for the Module: Prof. Dr. Laura Kallmeyer (kallmeyer@phil.hhu.de)	**Date:** 17.05.2019
Lecturer(s) the lecturers of the Department of Computational Linguistics, Prof. Dr. Stefan Conrad	**Semester:** 2. – 3.
	Modus: Elective Course

Work Load	**Credits**	**Contact Time**	**Self-study**
150 h	5 CP	60 h	90 h
Course	**Turnus**	**Group size**	**Duration**
Seminar: 4 SWS	yearly	–	1 Semester

Learning results & Competences

Students will understand the intricacies of modeling a specific linguistic phenomenon in such a way that it can be processed automatically. Furthermore, they will get to know different techniques

a) for learning such a model from language data,
b) for applying it to new data and
c) for evaluating it in order to assess its adequacy with respect to the phenomenon one wanted to model.

This can include frameworks and representation formats for modeling syntax (the structure of sentences and texts) and semantics (the meaning of sentences and text) and various machine learning and deep learning techniques applied to this.

Teaching

Advanced seminar (depending on the topic including practical exercises besides theoretical sessions)

It is possible to take two seminars of 2 SWS each instead of a single one of 4 SWS

Prerequisites for attending

Formal**:** Admission to master studies in „Artificial Intelligence and Data Science“.

Inhaltlich: none

Examination

(1) Written examination or oral examination or term paper

Prerequisites for receiving credit points

(1) Passing examination

Study Program

M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs

Weight in overall rating

The mark given will contribute to the final grade in proper relation to its credit points

Language

- [ ] Deutsch
- [x] Englisch
- [ ] Deutsch und Englisch
- [ ] Deutsch, Englisch bei Bedarf

Further Information

Relational Databases and Data Analysis

Responsible for the Module: Prof. Dr. Stefan Conrad (stefan.conrad@uni-duesseldorf.de)	**Date:** 17.04.2019
Lecturer(s) Prof. Dr. Stefan Conrad	**Semester:** 3. – 4.
	Modus: Elective Course

Work Load	**Credits**	**Contact Time**	**Self-study**
150 h	5 CP	60 h	90 h
Course Lecture: 2 SWS Exercises: 2 SWS	**Turnus** irregular	**Group Size** –	**Duration** 1 Semester

Learning results & Competences

Relational Databases. Students understand the relational model for databases together with its foundations (e.g. relational algebra). They are able to design relational databases and to express simple and complex database queries using SQL.

Data warehouses. Students know the basic architecture and central concepts of data warehouses and can explain them. They can design relational data warehouses using multi-dimensional modelling.

OLAP and complex database queries.
Students are able to understand, analysis and formulate complex OLAP and database queries using the SQL query language and its OLAP extension.

Teaching
Lecture with (theoretical and practical) exercises

Content
Lecture:

– Introduction into the relational database model and relational data warehouses;
– Design of relational databases
– Multi-dimensional modelling for (relational) data warehouses
– SQL
– OLAP
– Complex OLAP queries in SQL for data analysis

Exercises:
In the exercises the content of the lecture is applied and deepened. For that the exercises contain thoeretical as well as practical elements. In particular, the development of complex OLAP and database queries using the language SQL can practically be carried out using a database system provided to the students.

Prerequisites for attending
<u>Formal:</u> Admission to master studies in „Artificial Intelligence and Data Science“.
<u>Contentual:</u> none

Examination

(1) Written examination or oral examination

Prerequisites for receiving credit points

(1) Regular and active participation in the exercises
(2) Passing the examination

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
M.Sc. Computer Science

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points

Language
☐ German
☒ English
☐ German and English
☐ German, English on demand

Further Information

Data & Knowledge Engineering (DKE)

Responsible for the Module: Prof. Dr. Stefan Dietze	**Date:** 17.06.2019
Lecturer(s) Prof. Dr. Stefan Dietze	**Semester:** 2.-3.
	Modus: Elective Course

Work Load	**Credits**	**Contact Time**	**Self-study**
150 h	5 CP	60 h	90 h
Course Lecture: 2 SWS Exercises: 2 SWS	**Turnus** irregular	**Group Size** --	**Duration** 1 Semester

Learning results & Competences

- Application of W3C Standards (RDF, SPARQL) for using and extracting Knowledge Graphs, Linked Data and structured Data in the Web
- Basic understanding of Information- und Knowlege Extraction Methods
- Generation of formal Knowledge Representions and Knowledge Databases using Description Logics
- Understanding and applying structured Web Markup (RDFa, Microdata, schema.org)

Teaching

Lecture „Data & Knowledge Engineering“, 2 SWS (in English)

Excercise, 2 SWS (in English)

Content

Understanding and interpreting heterogeneous data, in particular in distributed settings such as the Web, remains a challenging task. State-of-the-art Web applications such as Web search engines rely on a combination of approaches for making sense of data, involving both explicit knowledge, for instance, through knowledge graphs such as Wikidata or the Google knowledge graph and semi-structured Web markup, as well as statistical and machine-learning based approaches.

This course provides an introduction to data and knowledge engineering methods and principles, with a particular focus on the Web. This includes methods related to knowledge graphs and formal data & knowledge representation (RDF, OWL, Description Logics), data integration and linking, information extraction, Web data sharing practices (Linked Data, Semantic Web and affiliated W3C standards such as RDF, RDFa, Microdata), as well as emerging approaches in the context of distributional semantics, such as word and entity embeddings. Attention will also be paid to applications of taught techniques to facilitate data sharing and reuse on the Web.

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science“.

Contentual: none

Examination

(1) written examination

Prerequisites for receiving credit points

(1) Regular and active participation in the exercises
(2) Passing the examination

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
M.Sc. Computer Science

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points

Language
☐ German
☒ English
☐ German and English
☐ German, English on demand

Further Information

Literature:

- “Artificial Intelligence: A Modern Approach” by Stuart Russell and Peter Norvig (2nd edition, Prentice-Hall, 2003)
- “A Semantic Web Primer” by Grigoris Antoniou and Frank van Harmelen (MIT Press, 2004)
- “Foundations of Semantic Web Technologies”, P. Hitzler, M. Krötzsch, S. Rudolph:, CRC Press, 2009.
- “Linked Data – Evolving the Web into a Global Data Space”, T. Heath, Ch. Bizer, Morgan & Claypool, 2011.
- Doing Data Science – Straight Talk from the Frontline, Cathy O’Neil, Rachel Schutt, O’Reilly Media

Deep Learning

Responsible for the Module: Prof. Dr. Stefan Harmeling			**Date:** 17.06.2019
Lecturer(s) Prof. Dr. Stefan Harmeling			**Semester:** 2./3.
			Modus: Obligatory Course
Work Load 150h	**Credits** 5 CP	**Contact Time** 60h	**Self-study** 90 h
Course Lecture: 2 SWS Exercises: 2 SWS	**Turnus** yearly	**Group Size** --	**Duration** 1 Semester

Learning results & Competences

After successfully finishing the course, the student

* can understand and can explain the theoretical foundations of deep learning
* can implement and apply algorithms of deep learning

Teaching

Lecture with theoretical and practical exercises

Content

This module teaches foundational knowledge about:

* Loss functions and optimization
* Neural networks / backpropagation
* Deep learning software
* Convolutional neural networks
* Generative models
* Recurrent neural networks

Prerequisites for attending

<u>Formal</u>: Admission to master studies in „Artificial Intelligence and Data Science".
<u>Contentual</u>: none

Examination

(1) written examination

Prerequisites for receiving credit points

(1) Regular and active participation in the exercises
(2) Passing the examination

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
M.Sc. Computer Science?

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points

Language
- ☐ German
- ☒ English
- ☐ German and English
- ☐ German, English on demand

Further Information

No special text book is used, the following book is helpful:

* Goodfellow et al, "Deep learning", MIT

Markov Chains

Responsible for the Module: Prof. Dr. Peter Kern (kern@hhu.de)	**Date:** 01.04.2019
Lecturer(s) Prof. Dr. Peter Kern, Prof. Dr. Axel Bücher	**Semester:** 2./3.
Contact and organization Prof. Dr. Peter Kern (kern@hhu.de)	**Modus:** Elective Course

Work Load	**Credits**	**Contact Time**	**Self-study**
150 h	5 CP	45 h	105 h
Course Lecture: 2 SWS Exercises: 1 SWS	**Turnus** Summer term, irregular	**Group Size** 20	**Duration** 1 semester

Learning results & Competences

The students overcome with the basic principles and the basic mathematical theory of Markov chains. They are able to argue on the basis of mathematical definitions and theorems to solve selected problems independently and to present their solution. They gain methods of systematic and efficient knowledge acquisition. The students will reach a deep understanding of basic techniques and convergence results for Markov models. They will be able to adapt algorithms based on Markov chains to data, to apply these and to discuss the results critically.

Teaching

Lecture with exercise course.

Content

Lecture

The first part of the lecture covers the basic mathematical theory of Markov chains: Markov property, random walk, transition matrices, transition graphs, Chapman-Kolmogorov equation, classification of states, irreducibility, periodicity, recurrence and transience, renewal equation, strong Markov property, equilibrium distribution, ergodic theorems. The second part of the lecture focusses on practical aspects of these methods: branching processes, time to absorption, Markov chain Monte Carlo (MCMC) method, Metropolis sampler, Gibbs sampler, Ising model, simulated annealing, cooling schedules.

Exercise course

The lectures are accompanied by weekly exercise courses in which exercises concerned with the practical applications of selected problems and with the aim of a deeper understanding of the mathematical theory of Markov chains are discussed. These problems are first solved by the students independently, and afterwards the corrected homework is presented and discussed in the exercise courses.

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science“.

Contentual: Passed exam in „Mathematical and Statistical Foundations in Data Science“. It is further recommended to have taken a course on stochastics previous to this course.

Examination

Learning portfolio consisting of:

(1) Competence area knowledge (100% of final mark): Written exam on the contents of lectures and exercise classes.

(2) Application of acquired knowledge (40% of exercise points as admission to the final exam): Practical exercises during the semester.

Prerequisites for receiving credit points (1) Passing the exam. (2) Regular and active attendance to exercises.
Study Program M.Sc. Artificial Intelligence and Data Science
Modul accessible for other Study Programs B.Sc. Mathematik und Anwendungsgebiete, B.Sc. Finanz- und Versicherungsmathematik
Weight in overall rating The mark will contribute to the final grade in relation to its credit points.
Language ☐ Deutsch ☒ English ☐ Deutsch und Englisch ☐ Deutsch, Englisch bei Bedarf
Further Information

Methods of Artificial Intelligence in Life Sciences

Responsible for the Module: Prof. Dr. Markus Kollmann	**Date:** 01.05.2019
Lecturer(s) Prof. Dr. Markus Kollmann	**Semester:** 2.
	Modus: Elective course

Work Load	**Credits**	**Contact Time**	**Self-study**
300 h	10 CP	100 h	200 h
Course Lecture: 4 SWS Exercises: 8 SWS	**Turnus** each summer term	**Group Size** 40	**Duration** 1 Semester

Learning results & Competences

Students know how to implement machine learning algorithms in Pytorch and to run it on HPC. They understand the concepts of Deep Learning and are familiar with common Neural Network architectures, such as Convolutional Neural Networks, Autoregressive Models, and Transformer Networks. They are familiar with the predominant sampling methods, such as Important Sampling, MCMC, and Monte Carlo Tree search. They understand the basics of the protein biosynthesis and the problem of predicting 3d RNA/Protein Structure from DNA sequence. They understand the concept of multiple sequence alignments, their relation to Evolutionary Biology, and how it can be used to increase prediction of 3d folding structure of Biomolecules.

Teaching

Lecture with (theoretical and practical) exercises

Content

Lectures and Practicum:

We start with an introduction to convolutional Neural Networks and show how to apply them in the search for overrepresented motifs in DNA. We introduce the necessary data preprocessing steps and illustrate how motif information can be extracted out of the learned weights. We then introduce deep generative models, in particular Variational Autoencoders and autoregessive Models in combination with important deep learning concepts, such as Attention. We introduce the problem of RNA folding and the basics of the biophysical and biochemical mechanisms involved. We use a variant of Monte Carlo Tree Search to efficiently sample the space of possible folding structures and introduce various scoring functions that serve as reward signal. We show that the problem of RNA/Protein folding is tightly related to reinforcement learning. We introduce the concept of self-supervised learning and how it can be applied to detect anomalies in time series data that have been recorded by wearables for high risk patients.

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science“.
Contentual: none

Examination

(1) written examination

Prerequisites for receiving credit points

(1) Regular and active participation in the exercises
(2) Passing the examination

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
M.Sc. Computer Science, M.Sc. Biology, M.Sc Biochemistry

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points.

Language
☐ German
☒ English
☐ German and English
☐ German, English on demand

Further Information
Students from Biology and Biochemistry will be assigned 14CP for the course as it takes them significantly more time to carry out the programming exercises

Neuroimaging and Precision Medicine

Responsible for the Module Prof. Dr. S. B. Eickhoff (S.Eickhoff@fz-juelich.de) Prof. Dr. S. Caspers (svenja.caspers@hhu.de) PD Dr. S. Weis (S.Weis@fz-juelich.de)	**Date:** 01.04.2019
Lecturer(s) Prof. Dr. S. Eickhoff, Prof. Dr. C. Caspers, PD Dr. S. Weis	**Semester:** 3.
	Modus: Elective Course

Worl Load 150 h	**Credits** 5 CP	**Contact Time** 45 h	**Self-study** 105 h
Course Vorlesung: 2 SWS Seminar: 1 SWS	**Turnus** Every Summer Term	**Group Size** 25	**Duration** 1 Semester

Learning results & Competences

Neuroimaging

Students will be able to describe the basic principles of cognitive neuroimaging of the human brain as a basis for the subsequent application of Big Data and AI approaches. For all important imaging modalities, they can explain the relationship between neuronal activity and the measured signal. They will be able to evaluate strengths and weaknesses of the different modalities to address specific research questions. They will be able to explain the basics of experimental design and the statistical analysis of neuroimaging studies. In particular, they will be able to decide which approaches to the data analysis of brain imaging data are suitable for answering specific questions.

Precision Medicine

Students will have an understanding of how the collection and analysis of very large datasets (so-called "big data") can be used to study functional brain organization in the healthy brain and its disorders. They will understand how AI and data science can be used to draw conclusions about individual differences in the brain organization and identify biomarkers. Students will have an overview of clinical applications of the above methods for specific neurological and psychiatric disorders such as Parkinson's disease, Alzheimer's disease or schizophrenia.

Teaching

Lectures and Seminars

Content

Lectures

Lectures start with an introduction to the main methods of structural and functional neuroimaging. Students learn the necessary steps for pre-processing and statistical analysis of the data. The usual methods of data analysis, such as case studies, group studies and correlation analyses, are discussed to give students an insight into what conclusions can be drawn from the various types of analysis and which methodological approaches are suitable for addressing which questions. In the second part of the lectures methodical approaches for the analysis of "Big Data" and for conclusions about individual differences in the structural and functional brain organization are discussed. In particular, prediction and classification analyses are presented using brain imaging data. The lecture also deals with applications and results of these methods in the clinical context as well as with studies on the identification of individual biomarkers.

Seminars

It is the aim of the seminars to familiarize students with current research questions in the field of AI / Data Sciences in the Neuroscience and in Precision Medicine, and to encourage critical reflection of such issues. To this end, a series of current research topics in these areas will be discussed in the form of presentations prepared by the students themselves. The possible subject areas are varied, and the individual interests of the students can be taken into account. To give a comprehensive overview of the topic, the articles will be suggested by the lecturers.

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science".
Contentual: none

Examination

Oral examination

Prerequisites for receiving credit points

(1) Oral Presentation
(2) Active presence in seminars

Study Program

M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs

Weight in overall rating

The mark given will contribute to the final grade in proper relation to its credit points.

Language

Englisch

Furher Information

Philosophy of Intelligence

Responsible for the Module	Date:
Prof. Dr. Gottfried Vosgerau (vosgerau@hhu.de)	01.03.2019

Lecturer(s)	Semester:
Prof. Dr. Gottfried Vosgerau, Prof. Dr. Frank Dietrich, and further staff of the Institute of Philosophy	2./3.

Contact and organization	Modus:
Prof. Dr. Gottfried Vosgerau (vosgerau@hhu.de)	Elective Course

Work Load	Credits	Contact Time	Self-study
150 h	5 CP	60 h	90 h
Course	**Turnus**	**Group Size**	**Duration**
Übung: 2 SWS Vorlesung: 2 SWS	Every Summer term	20	1 Semester

Learning results & Competences

Concepts and Measurements of Intelligence. Students are able to explain and criticize different conceptions of intelligence in Psychology and Philosophy. Students are able to connect the different conceptions to specific ways of measuring intelligence and to evaluate the theoretical soundness of the measurements in relation to the different conceptions.

Cognitive Models of Intelligence. Students are able to explain the theoretical foundations of cognitive modelling and cognitive architecture. They are able to name the most important cognitive faculties and to describe functional interdependencies. They are able to explain and criticize representationalist and anti-representationalist conceptions of the mind.

Goals and Limits of Cognitive Modelling. Students are able to describe the different possible goals of cognitive modelling within the cognitive sciences. They are able to identify the limits of different approaches in relation to the according epistemological goals.

The Ethics of Artificial Intelligence. Students know the most important ethical questions arising in the context of developing and implementing AI systems. They are able to discuss these questions against the background of different ethical theories.

Teaching

Vorlesung mit Lektüre-Übungen

Content

Lectures

The lecture starts with an historical overview of the different conceptions of intelligence in Psychology and Philosophy. The theoretical basis of these conceptions is introduced along with the proposed measurement of intelligence. The students learn to criticize the different approaches on the basis of the theoretical conceptions and to name their limits. Then, the relation between theories in Cognitive Science and cognitive modelling is introduced and discussed. A focus will be set on connectionist models in contrast to classical symbol- and rule-based models. The discussion of the different models will especially highlight the different cognitive faculties that favor one or the other model of explanation. With concrete examples, the interdependency between the explanatory goals and the virtues and limits of cognitive modelling are introduced. Finally, a systematic overview of the most important ethical questions arising in the context of developing and implementing AI systems will be given. Based on prominent examples, different ethical theories are illustrated.

Exercise
The exercise will consist in the critical reading and discussion of key texts pertinent to the topics of and in parallel with the lecture.

Prerequisites for attending
Formal: Admission to master studies in „Artificial Intelligence and Data Science“.
Contentual: none

Examination
Portfolio consisting of:
(1) A written online-exam (80%) and
(2) Skillful participation in the discussions of the exercise, which can be documented orally or in writing according to the choice of the exercise instructor (20%).

Prerequisites for receiving credit points
(1) Passing grade in the exam and successful documentation of participation in the exercise

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points.

Language
☐ Deutsch
☒ Englisch
☐ Deutsch und Englisch
☐ Deutsch, Englisch bei Bedarf

Further Information

Statistical Data Analysis

Responsible for the Module Prof. Dr. Holger Schwender (holger.schwender@hhu.de)	**Date:** 01.04.2019
Lecturer(s) Prof. Dr. Holger Schwender, Prof. Dr. Axel Bücher	**Semester:** 2./3.
Contact and organization Prof. Dr. Holger Schwender (holger.schwender@hhu.de)	**Modus:** Elective Course

Work Load	**Credits**	**Contact Time**	**Self-study**
150 h	5 CP	45 h	105 h
Course Lecture: 2 SWS Exercises: 1 SWS	**Turnus** About every fourth semester	**Group Size** 20	**Duration** 1 Semester

Learning results & Competences

The students will be able to perform statistical analyses of different types of data and to use the statistical software environment and language R for these data analyses. The students will acquire knowledge on different types of statistical methods such as testing procedures, analysis of variance, and regression methods, on how to use these methods for a statistical data analysis, and on good practice in planning a study, in preparing data sets for a statistical analysis, as well as in presenting the results of a statistical analysis using, e.g., graphical data presentations. They will be able to decide which of the statistical methods to use in which situation and to apply these procedures to the data.

Teaching

Lecture with exercise course.

Content

Lecture

The lecture covers a wide range of statistical methods focusing on the practical aspects of these methods and their application to different types of data. Since the statistical software environment and language R is the most popular, advanced software for statistical analysis, R is mainly used in the lecture to exemplify the application of the statistical procedures. Therefore, the lecture starts with a basic, practical introduction to R. This knowledge on R is successively extended during the semester (in both the lectures and the exercise courses). It is discussed how graphics and descriptive statistics can be generated in R and should be generated in general to present and summarizing the data and the results of a data analysis in a best practice way. Moreover, good practice in preparing a data set for a statistical data analysis in, e.g., R is discussed. Prior to the actual data analysis an important step is the preprocessing of the data including checking the data for plausibility or errors, determining whether input variables should be transformed and how they could be transformed, as well as handling missing values in the data. Therefore, these issues will be discussed in the lecture in a practical way. Afterwards, the general principle of statistical testing and multiple statistical testing as well as testing procedures for the most important testing situations are taught. It is discussed how to apply these tests to data, how to check the assumptions of these tests, and how to select the most appropriate test for a particular testing situations. The rest of the course is dedicated to one- and multi-way analysis of variance as wells as different regression methods including linear regression, generalized linear models (especially, logistic regression), regularized regression (e.g., ridge regression and Lasso), (generalized) linear mixed models, Cox proportional hazard models, and nonparametric regression models (e.g., kernel smoothing, smoothing splines, or neural nets from a regression perspective). Besides the Cox regression, survival analysis is also considered in general. Again, in the discussion of the analysis of variance and the regression methods, emphasis will be placed on practical aspects of the application of these methods to data, considering different types of data sets.

Exercise course

The lectures are accompanied by exercise courses in which exercises concerned with the practical application of the statistical procedures taught in the lectures to data sets from different fields of application are discussed. These data analysis problems are solved by the students independently, and afterwards, presented and discussed in the exercise courses.

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science“.

Contentual: Passed exam in „Mathematical and Statistical Foundations in Data Science“. It is recommended to have taken a course on stochastics previous to this course.

Examination

Typically, a written examination about the content of this course.

Prerequisites for receiving credit points

(1) Passing the exam.
(2) Regular and active attendance of the practicals.

Study Program

M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs

B.Sc. Mathematics

Weight in overall rating

The mark given will contribute to the final grade in proper relation to its credit points.

Language

☐ Deutsch
☒ English
☐ Deutsch und Englisch
☐ Deutsch, Englisch bei Bedarf

Further Information

Statistical Learning

Responsible for the Module Prof. Dr. Axel Bücher (axel.buecher@hhu.de)	**Date:** 20.06.2019
Lecturer(s) Prof. Dr. Axel Bücher, Prof. Dr. Holger Schwender	**Semester:** 2./3.
Contact and organization Prof. Dr. Axel Bücher	**Modus:** Elective Course

Work Load	**Credits**	**Contact Time**	**Self-study**
150 h	5 CP	45 h	105 h
Course Lecture: 2 SWS Exercises: 1 SWS	**Turnus** irregular	**Group Size** 20	**Duration** 1 Semester

Learning results & Competences

The students will acquire knowledge on different types of statistical learning methods, with an emphasis on dimensionality reduction, clustering and classification. They will be able to apply those methods independently to different types of data, to present their solution and to discuss the results critically. The students gain profound knowledge in using the statistical software environment and language R for the data analyses. They gain methods of systematic and efficient knowledge acquisition.

Teaching

Lecture with exercise course.

Content

Lecture

The lecture covers some of the most important statistical learning methods, with an emphasis on dimensionality reduction, clustering and classification, as well as on the application to different types of data. The lecture serves as a complement to the module „Statistical Data Analysis", but may be attended without any knowledge from that module.

The lecture starts by discussing the most common approaches to dimensionality reduction, in particular principal component analysis and factor analysis based on latent variable models. The second part covers clustering methods, in particular hierarchical clustering algorithms based on similarity and dissimilarity measures and k-means clustering. The third part covers basic supervised learning methods for classification: classical approaches like linear and quadratic discriminant analysis and logistic regression, K-nearest Neighbors, classification trees (CART algorithm, weakest link pruning), ensemble methods like bagging and random forests, support vector machines, as well as model evaluation based on cross-validation.

Throughout the course, the presented methods will be illustrated by exemplarily applications carried out within the statistical software environment and language R, the nowadays most popular software for advanced statistical analysis. The knowledge on R is successively extended during the semester (in both the lectures and the exercise courses).

Exercise course

The lectures are accompanied by exercise courses in which exercises concerned with the practical application of the statistical learning methods to data sets from different fields of application are discussed. These data analysis problems are solved by the students independently, and are afterwards presented and discussed in the exercise courses.

Prerequisites for attending Formal: Admission to master studies in „Artificial Intelligence and Data Science“. Contentual: Passed exam in „Mathematical and Statistical Foundations in Data Science“. It is further recommended to have taken a course on stochastics previous to this course.**Contentual:** Passed exam in „Mathematical and Statistical Foundations in Data Science“. It is recommended to have taken a course on stochastics previous to this course.
Examination Typically, a written examination about the content of this course.
Prerequisites for receiving credit points (1) Passing the exam. (2) Regular and active attendance of the practical work.
Study Program M.Sc. Artificial Intelligence and Data Science
Modul accessible for other Study Programs B.Sc. Mathematics
Weight in overall rating The mark given will contribute to the final grade in proper relation to its credit points.
Language ☐ Deutsch ☒ English ☐ Deutsch und Englisch ☐ Deutsch, Englisch bei Bedarf
Further Information

Generative Models and Sampling Methods

Responsible for the Module: Prof. Dr. Markus Kollmann	**Date:** 01.05.2019
Lecturer(s) Prof. Dr. Markus Kollmann	**Semester:** 2./3.
	Modus: Elective course

Work Load	**Credits**	**Contact Time**	**Self-study**
150 h	5 CP	60 h	90 h
Course Lecture: 2 SWS Exercises: 2 SWS	**Turnus** irregular	**Group Size** 40	**Duration** 1 Semester

Learning results & Competences

Students know the basic concepts of deep generative models and manifold learning. They understand the concepts of Variational Autoencoders, Autoregressive Networks, and Generative Adversarial Networks and can point out their pros and cons. The can implement generative models in Tensorflow/Pytorch. They understand the concepts of sampling methods, such as importance sampling, MCMC sampling, Gibbs sampling, and can implement these concepts in Python. They understand how deep generative models can strongly improve sampling efficiency and understand the connection to reinforcement learning

Teaching

Lecture with (theoretical and practical) exercises

Content

Lecture:

Variational Autoencoders: Variational objectives, Posterior, Encoder, Decoder, Latent space models, manifold learning,
Autoregressive Models: autoregressive concept (PixelCNN, Transformer), exposure bias
Generative Adversarial Networks: Discriminators, Stability Problems, Progressive growing GANs. Sampling Methods: (Hamilton) MCMC, Metropolis Hastings, Gibbs, Importance Sampling, Monte Carlo Tree Seach.

Exercises:

In the exercises the content of the lecture is applied and deepened in theoretical exercises. In addition, the students will implement the central concepts in Python and apply them to real and self-generated data.

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science“.
Contentual: none

Examination

(1) written examination

Prerequisites for receiving credit points

(1) Regular and active participation in the exercises
(2) Passing the examination

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
M.Sc. Computer Science

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points.

Language
☐ German
☒ English
☐ German and English
☐ German, English on demand

Further Information

Lecture Series in Data Science

Responsible for the Module: Prof. Dr. Markus Kollmann	**Date:** 01.05.2019
Lecturer(s) All group leaders offering Lab Rotations	**Semester:** 2.
	Modus: Obligatory course

Work Load	**Credits**	**Contact Time**	**Self-study**
150 h	5 CP	60h	90 h
Course Lecture: 2 SWS Seminar: 2 SWS	**Turnus** each summer term	**Group Size** 40	**Duration** 1 Semester

Learning results & Competences

Students know types of data structures, preprocessing concepts, and data analysis results of real problems in data science. They understand the difficulties in extracting and cleaning of data for practical applications. They understand the fundamental differences and similarities how to analyze image, text, audio, video, and life science data.

Teaching

Lecture with seminar

Content

Different group leaders present their specific data science problems to give the students an impression how the data looks like and what analysis methods are required. Emphasis is given to understand the details of the data structures, the sources of noise, data preprocessing techniques, error correction techniques, data augmentation techniques, and statistical analysis concepts.

The lectures hand out related papers about their data sciences problems for which selected students have to prepare a short presentation.

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science".
Contentual: none

Examination

(1) Graded seminar talk

Prerequisites for receiving credit points

(1) Regular and active participation in seminar talks
(2) Giving a seminar talk

Study Program

M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs M.Sc. Computer Science
Weight in overall rating The mark given will contribute to the final grade in proper relation to its credit points.
Language ☐ German ☒ English ☐ German and English ☐ German, English on demand
Further Information

Introduction to Logic Programming

Responsible for the Module: Prof. Dr. Michael Leuschel (michael.leuschel@hhu.de)	**Date:** 10.4.2019
Lecturer(s) Prof. Dr. Michael Leuschel (michael.leuschel@hhu.de)	**Semester:** 3.
Contact and organization Prof. Dr. Michael Leuschel (michael.leuschel@hhu.de)	**Modus:** Elective Course

Work Load	**Credits**	**Contact Time**	**Self-study**
150 h	5 CP	90 h	60 h
Course Praktika: 4 SWS Lectures: 2 SWS	**Turnus** Every winter term	**Group Size** 30	**Duration** 1 Semester

Learning results & Competences

To understand and be able to use the main concepts of propositional and predicate logic
To understand the logic programming paradigm and be able to use it for problem solving
To be able to write Prolog programs in a logical style
To be able to use informed search algorithms (A*) and develop AI algorithms for game playing (Minimax)

Content

An important part of this unit is devoted to the study of logic. The discipline of logic is concerned both with proving theorems and also with drawing inferences from existing knowledge. The unit covers basic programming concepts of logical systems, resolution logic and horn clauses. This logical development provides a foundation for introducing the main concepts of logic programming. The unit also includes a practical introduction to the main features of Prolog, the language which implements this style of programming. Theoretical and practical topics are interleaved, the course as a whole dividing roughly equally between logic and theory and practical programming. The course covers many AI topics such as informed search algorithms (A*), constraint satisfaction and game playing (Minimax, Alpha-Beta pruning).

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science".
Contentual: Foundations of software development and programming

Examination

(1) Written examination (80% of grade)
(2) Assessment of practical work (20% of grade)

Prerequisites for receiving credit points

(1) Successful participation at the practical work
(2) Passed written examination

Study Program

M.Sc. Data Science and AI

Modul accessible for other Study Programs

B.Sc. Informatik

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points

Language
- ☐ German
- ☒ English
- ☐ German and English
- ☐ German, English on demand

Further Information

MACHINE LEARNING

Responsible for the Module: Prof. Dr. Stefan Harmeling	**Date:** 17.06.2019
Lecturer(s) Prof. Dr. Stefan Harmeling	**Semester:** 1.
	Modus: Obligatory Course

Work Load	**Credits**	**Contact Time**	**Self-study**
300 h	10 CP	100 h	200 h
Course Lecture: 4 SWS Exercises: 2 SWS	**Turnus** each winter term	**Group Size** 40	**Duration** 1 Semester

Learning results & Competences

After successfully finishing the course, the student
* can understand and can explain the theoretical foundations of machine learning.
* can explain the foundations in mathematical terms and can do proofs about it
* can implement and apply algorithms of machine learning

Teaching

Lecture with theoretical and practical exercises

Content

This module teaches foundational knowledge about the following topics:
* Probability, frequentist statistics, Bayesian statistics
* Supervised learning, unsupervised learning
* Generative vs discriminative models
* Linear regression, linear discriminant analysis
* Gaussian processes
* Support vector machines
* Kernel trick, kernel PCA
* Graphical models
* Neural networks

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science“.
Contentual: none

Examination

(1) written examination

Prerequisites for receiving credit points

(1) Regular and active participation in the exercises
(2) Passing the examination

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
M.Sc. Computer Science

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points.

Language
☐ German
☒ English
☐ German and English
☐ German, English on demand

Further Information

No special text book is used, the following books are helpful:
* Murphy, Machine Learning: A Probabilistic Perspective
* MacKay, Information Theory, Inference, and Learning Algorithms, Cambridge 2003
* Barber, Bayesian Reasoning and Machine Learning, Cambridge 2012
* Rasmussen/Williams, Gaussian Processes for Machine Learning, MIT 2006
* Bishop, Pattern Recognition and Machine Learning, Springer 2007
* Schölkopf/Smola, Learning with Kernels, MIT 2001
* Jaynes, Probability Theory – the Logic of Science, Cambridge 2003

Master Seminar Advances in Data Science

Responsible for the Module: Prof. Dr. Stefan Dietze	**Date:** 01.05.2019
Lecturer(s) Prof. Dr. Stefan Dietze	**Semester:** 2./3.
	Modus: Elective Course

Work Load 60 h	**Credits** 2 CP	**Contact Time** 30 h	**Self-study** 30 h
Course Seminar: 2 SWS	**Turnus** not regular	**Group Size** --	**Duration** 1 Semester

Learning results & Competences

Students have in depth understanding about actual methods and their applications in Data Science.

Teaching

Seminar „Advances in Data Science“

Content

Learning from data in order to gain useful insights is an important task, generally covered under the data science umbrella. This involves a wide variety of fields such as statistics, artificial intelligence, effective visualization, as well as efficient (big) data engineering, processing and storage, where efficiency and scalability often play crucial roles in order to cater for the quantity and heterogeneity of data.
The goal of this seminar is to deepen the understanding about data science & engineering techniques through studying and critically evaluating state-of-the-art literature in the field. Participants will be introduced to the critical assessment and discussion of recent scientific developments, thereby learning about emerging technologies as well as gaining the ability to evaluate and discuss focused scientific works. Participants will be given recent literature covering relevant data science areas. Each participant will review independently 1-2 publications and present and discuss its content and contribution, which are then presented and discussed with the entire student participants.

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science“.
Contentual: none

Examination

Assessment of presentation

Prerequisites for receiving credit points

Active presence in seminar

Study Program

M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
M.Sc. Computer Science

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points.

Language
☐ German
☒ English
☐ German and English
☐ German, English on demand

Further Information

Literature:

- R for Data Science (by Garrett Grolemund and Hadley Wickham) O'Reilly Media
- Statistics in a Nutshell, 2nd Edition, A Desktop Quick Reference, Sarah Boslaugh, O'Reilly Media
- Doing Data Science – Straight Talk from the Frontline, Cathy O'Neil, Rachel Schutt, O'Reilly Media
- Data Analytics with Hadoop, Benjamin Bengfort & Jenny Kim, O'Reilly Media
- Deep Learning by Ian Goodfellow and Yoshua Bengio and Aaron Courville http://www.deeplearningbook.org/

Foundations of Mathematical and Statistical Methods in Data Science

Responsible for the Module: Prof. Dr. Markus Kollmann, Prof. Dr. Holger Schwender	**Date:** 01.05.2019
Lecturer(s) Dr. Peter Arndt	**Semester:** 1.
	Modus: Obligatory course

Work Load	**Credits**	**Contact Time**	**Self-study**
300 h	10 CP	100 h	200 h
Course Lecture: 4 SWS Exercises: 2 SWS	**Turnus** each winter term	**Group Size** 40	**Duration** 1 Semester

Learning results & Competences

Students know the basic concept of linear algebra, convex optimization, Bayesian statistics, and information theory. They understand the difference between likelihood and posterior probability and can apply these concepts to solve (generalized) linear regression problems. They can apply Gaussian process priors to regression problems and understand the concept of functionals. They are familiar with different regularization techniques to control overfitting. They know convex optimization problems and understand the techniques to solve them efficiently. The students are familiar with the basic concepts of information theory. They understand the concept of discrete stochastic processes and their applications to sequential data. They are familiar with sampling methods and their application to Bayesian statistics. They know the basics of functional derivatives and stochastic differential equations.

Teaching

Lecture with (theoretical and practical) exercises

Content

Lecture:

Linear Algebra. Singular value decomposition, eigenvalue problems, generalized linear models, matrix differential calculus.
Regression. Linear models, generalized linear models, regularization.
Stochastic Processes. Markov property, Markov chains, state space models.
Convex Optimisation. Primal-dual-problem, Lagrangian, duality-gap, KKT conditions, regularizing conditions, mixture models and EM-algorithm.
Bayesian Statistics. A priori and a posteriori distributions, conjugate priors, Gaussian Process regression/classification, importance sampling rejection sampling, Markov Chain Monte Carlo, Metropolis Hastings, Gibbs sampling.
Information Theory. Jenson's inequality, Entropy, KL-divergence, Rate distortion theory, differential entropy, minimum description length.

Exercises:

In the exercises the content of the lecture is applied and deepened in theoretical exercises. In addition, the students will implement the central concepts in Python and apply them to real and self-generated data.

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science".
Contentual: none

Examination

(1) written examination

Prerequisites for receiving credit points

(1) Regular and active participation in the exercises
(2) Passing the examination

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
M.Sc. Computer Science

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points.

Language
☐ German
☒ English
☐ German and English
☐ German, English on demand

Further Information

Natural Language Processing

Responsible for the Module: Prof. Dr. Stefan Conrad (stefan.conrad@uni-duesseldorf.de)	**Date:** 17.04.2019
Lecturer(s) Prof. Dr. Stefan Conrad	**Semester:** 2./3.
	Modus: Elective Course

Work Load	**Credits**	**Contact Time**	**Self-study**
150 h	5 CP	60 h	90 h
Course Lecture: 2 SWS Exercises: 2 SWS	**Turnus** irregular	**Group Size** –	**Duration** 1 Semester

Learning results & Competences

Natural Language Processing (NLP). Students understand basic methods and algorithms for NLP and can explain them. They are able to design a NLP pipeline for a dedicated task and to implement it using adequate libraries. The students know how to evaluate NLP algorithms and whole pipelines and are able to interpret the results of such evaluations.

Information Retrieval. Students know basic retrieval models and information retrieval concepts and can explain them in the context of natural language processing.

Teaching
Lecture with (theoretical and pratical) exercises

Content

Lecture:

– Introduction into Natural Language Processing (NLP) and Information Retrieval (IR) concepts
– NLP pipeline and basic NLP methods/algorithms
– Evaluation principles and measurements
– Selected applications for NLP

Exercises:
In the exercises the content of the lecture is applied and deepened. For that the exercises contain theoretical as well as practical elements. In particular, the development of NLP algorithms and the design of NLP pipelines can be practically carried out.

Prerequisites for attending
Formal: Admission to master studies in „Artificial Intelligence and Data Science“.
Contentual: none

Examination:

(1) Written or oral examination

Prerequisites for receiving credit points

(1) Regular and active participation in the exercises
(2) Passing the examination

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
M.Sc. Computer Science

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points.

Language
☐ Deutsch
☒ Englisch
☐ Deutsch und Englisch
☐ Deutsch, Englisch bei Bedarf

Further Information

Numerical Methods for Data Science

Responsible for the Module: Prof. Dr. Christiane Helzel (christiane.helzel@hhu.de)	**Date:** 01.05.2019
Lecturer(s) Prof. Dr. Christiane Helzel	**Semester:** 2./3.
	Modus: Elective course

Work Load	**Credits**	**Contact Time**	**Self-study**
150 h	5 CP	45 h	105 h
Course Lecture: 2 SWS Exercises: 1 SWS	**Turnus** irregular	**Group Size** 20	**Duration** 1 Semester

Learning results & Competences

The students will acquire knowledge on different numerical methods that are used to compute the solution of linear systems, least square problems, eigenvalue problems and the singular value decomposition. They will learn which algorithms are used in various situations.

Teaching

Lecture with (theoretical and practical) exercises

Content

Lecture:

The class covers several powerful numerical linear algebra techniques that are used in various applications in data mining and pattern recognition. We first review basic linear algebra concepts and matrix decompositions, in particular the LU and the QR decomposition and use these techniques to solve linear systems and least square problems. Furthermore, we study different algorithms for computing eigenvalues and the singular value decomposition. Finally we will see how these concepts are used in different applications such as text mining, page ranking and face recognition. Throughout the course, the presented methods will be illustrated by test problems that are carried out in Matlab or Python.

Exercises:

The lectures are accompanied by exercise courses in which the students apply the different numerical methods that are covered in the lectures. Exercise problems are solved by the students independently, and are afterwards presented and discussed in the exercise courses.

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science“.
Contentual: none

Examination

(1) written examination

Prerequisites for receiving credit points

(1) Regular and active participation in the exercises
(2) Passing the examination

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
B.Sc. Mathematics

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points.

Language
☐ German
☒ English
☐ German and English
☐ German, English on demand

Further Information
Literature:
J.W.Demmel, Applied Numerical Linear Algebra, SIAM
L.Elden, Matrix Methods in Data Mining and Pattern Recognition, SIAM

Introduction to Linear Optimization

Responsible for the Module: Prof. Dr. Gunnar Klau (gunnar.klau@hhu.de)	**Date:** 1.05.2019
Lecturer(s) Prof. Dr. Gunnar Klau	**Semester:** 2./3.
	Modus: **Elective Course**

Work Load	**Credits**	**Contact Time**	**Self-study**
150 h	5 CP	60 h	90 h
Course Lecture: 2 SWS Exercises: 2 SWS	**Turnus** irregular	**Group Size** –	**Duration** 1 Semester

Learning results & Competences

Foundations of Linear Programming. Students know the definitions of linear programs (LPs), and their standard forms. They can solve low-dimensional LPs geometrically. They understand and can apply the Simplex method and the fundamental theorem of Linear Programming. They understand and can apply the concept and proofs of weak and strong duality.
Integer Linear Programming. Students know the definition of integer linear programs (ILPs) and the fundamental difference to LPs in terms of computational complexity. They understand the relation to combinatorial optimization problems. They know and can apply different methods to solve ILPs: Branch-and-Bound based on the LP relaxation, cutting planes, Branch-and-Cut and Lagrangian relaxation. They understand the concept of separation.
Network Flows. Students understand the concepts of networks and flows in networks. They can distinguish different variants and special cases of flow problems. They can compute maximum flows with the augmented path method (Ford-Fulkerson) and can prove why the method works. They understand the relation to duality in form of the max-flow-min-cut theorem.
Applications. Students can apply different modeling techniques to develop ILP formulations for combinatorial optimization problems. Examples include maximum clique, phylogeny reconstruction and the traveling salesman problem. They can solve real-world instances of these problems with self-written Python code using external optimization libraries.

Teaching
Lecture with theoretical and practical exercises

Content

Lecture:
Foundations of Linear Programming. Linear Programs and their geometric interpretation. Duality. The Simplex method.
Integer Linear Programming. Linear programming-based Branch-and-Bound. Cutting planes. Branch-and-Cut. Lagrange relaxation.
Network Flows. Theory and algorithms.
Applications. Selected applications of linear optimization techniques from bioinformatics and other fields.

Exercises:
In the exercises the content of the lecture is applied and deepened. For that the exercises contain theoretical as well as practical elements. The students use professional linear and integer linear programming modeling software and solvers to build solve applied programming exercises.

Prerequisites for attending
Formal: Admission to master studies in „Artificial Intelligence and Data Science".
Contentual: none

Examination

(1) written examination or oral examination

Prerequisites for receiving credit points

(1) Regular and active participation in the exercises
(2) Passing the examination

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Program
M.Sc. Computer Science

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points.

Language
☐ Deutsch
☒ Englisch
☐ Deutsch und Englisch
☐ Deutsch, Englisch bei Bedarf

Further Information

REINFORCEMENT LEARNING

Responsible for the Module: Prof. Dr. Stefan Harmeling	**Date:** 17.06.2019
Lecturer(s) Prof. Dr. Stefan Harmeling	**Semester:** 2./3.
	Modus: Elective Course

Work Load	**Credits**	**Contact Time**	**Self-study**
150 h	5 CP	60 h	90 h
Course Lecture: 2 SWS Exercises: 2 SWS	**Turnus** irregular	**Group Size** --	**Duration** 1 Semester

Learning results & Competences

After successfully finishing the course, the student

* can understand and can explain the theoretical foundations of reinforcement learning.
* can implement and apply algorithms of reinforcement learning.

Teaching

Lecture with theoretical and practical exercises

Content

* The reinforcement learning problem
* Multi-armed bandits
* Markov Decision processes
* Dynamic programming
* Monte Carlo Methods
* Temporal-difference learning
* On- and off-policy methods
* Elligibility traces
* Policy gradients

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science“.
Contentual: none

Examination

(1) written examination

Prerequisites for receiving credit points

(1) Regular and active participation in the exercises?
(2) Passing the examination?

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
M.Sc. Computer Science

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points.

Language
☐ German
☒ English
☐ German and English
☐ German, English on demand

Further Information

Literature
Richard Sutton, Andrew Barto, "Reinforcement Learning: An Introduction", 2018, MIT press, draft online available

Spoken Dialogue Systems

Responsible for the Module: Prof. Dr Milica Gasic	**Date:** 25.06.2019
Lecturer(s) Prof. Dr Milica Gasic	**Semester:** 2./3.
	Modus: Elective Course

Work Load	**Credits**	**Contact Time**	**Self-study**
150 h	5 CP	60 h	90 h
Course Lecture: 2 SWS Exercises: 1 SWS	**Turnus** irregular	**Group Size** 40	**Duration** 1 Semester

Learning results & Competences

On completion of this module, students should understand:

The purpose and operation of the main components of a spoken dialogue system

How the framework of partially observable Markov decision processes can be used to model a spoken dialogue system

How classification, regression, sequence-to-sequence models and reinforcement learning can be used to implement a spoken dialogue system. The various options for optimizing and adapting a statistical spoken dialogue system, both off-line and on-line, and how deep learning can be utilised to achieve state of the art results in dialogue modelling.

Teaching

Lecture with (theoretical and practical) exercises

Content

Introduction: architecture of a spoken dialogue system, dialogue acts, turn management issues

Semantic decoding: representing and decoding meaning from user inputs, semantic decoding as a classification task, semantic decoding as a sequence-to-sequence learning task

Dialogue state tracking: tracking beliefs over multiple turns, classical generative and discriminative approaches, recent deep learning approaches, integration of decoding and tracking.

Dialogue Management: modelling via Markov Decision Processes, reinforcement learning, gradient methods, Gaussian Processes

Response Generation: template methods, generative models, recent neural network approaches

Current research topics: incremental dialogue, towards open-domain systems, end-to-end neural network architectures

Practical Work:

Students will be provided with a set of Python tools which will enable them to configure and test a simple spoken dialogue system. They will be asked to implement a simple dialogue state tracker and a reinforcement learning algorithm and optimize the dialogue manager in interaction with a simulated user. This will give them an opportunity to explore a practical example of reinforcement learning.

Prerequisites for attending

Formal: none
Contentual: none

Examination

Assessment:
Written report of 2000 words covering the practical [100%]

Prerequisites for receiving credit points

(1) Regular and active participation in the exercises
(2) Passing the examination

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs
M.Sc. Computer Science

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points

Language
☐ German
☒ English
☐ German and English
☐ German, English on demand

Further Information
Recommended Reading Page:

S. Young (2013). "Talking to Machines" Royal Academy of Engineering Ingenia, 54:40-46
S. Young, M. Gasic, B. Thomson and J. Williams (2013). "POMDP-based Statistical Spoken Dialogue Systems: a Review." Proc IEEE, 101(5):1160-1179

Master Thesis

Responsible for the Module: Prof. Dr. Markus Kollmann			Date: 01.11.2019
Supervisors All group leaders offering projects for Master Thesis			**Semester:** 4th
			Modus: Obligatory course
Work Load 900 h	**Credits** 30 CP	**Contact Time** 60h	**Self-study** 840 h
Course Practical Work	**Turnus** NA	**Group Size** NA	**Duration** 6 Month

Learning results & Competences

With the written thesis, the students prove that they are able to carry out scientific work independently on a topic in the field of Artificial Intelligence and Data Science within a given period of time (6 months). They are able to develop their findings concisely and to evaluate or interpret them competently. The Master's thesis must be written in English and presented in an oral presentation.

Procedure

Students can apply to any research group that offers data science projects for a Master Thesis. Ideally, the thesis should be carried out in one of the two groups where a Lab Rotations has been completed. If the Master Thesis is carried out outside the computer science department the student is co-supervised by a member of the chosen research group and a lecturer that is involved in a theoretical module in the Master Program „Artificial Intelligence and Data Science“.

Content

The content of the master thesis is defined by the supervisor.

Prerequisites for attending

Formal: Starting a Master Thesis requires at least 60CP of passed courses within the program „Artificial Intelligence and Data Science“.
Contentual: none

Examination

(1) Grading of the content of Master Thesis and its oral presentation

Prerequisites for receiving credit points

(1) Successful work on the topic and on-time submission of the thesis
(2) Giving an oral presentation of the content of the thesis

Study Program

M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points.

Language
- ☐ German
- ☒ English
- ☐ German and English
- ☐ German, English on demand

Further Information

Master Thesis Seminar

Responsible for the Module: Prof. Dr. Markus Kollmann	**Date:** 01.11.2019
Supervisors All group leaders offering projects for Master Thesis	**Semester:** 4th
	Modus: Obligatory Seminar

Work Load	**Credits**	**Contact Time**	**Self-study**
120 h	4 CP	As required	120 h
Course	**Turnus**	**Group Size**	**Duration**
Practical Work	NA	NA	6 Month

Learning results & Competences

The students are able to present their scientific work in an understandable way to a broad audience. They show in depth understanding of the problem and the applied methods to solve it and can visualize the results in an appropriate way using statistical arguments.

Procedure

The presentation at the end of the Master Thesis should be given in front of the reviewers of the master thesis. The duration of the presentation should be 30min followed by 15min of questions by reviewers.

Content

The content of the master thesis seminar must be related to the content of the master thesis

Prerequisites for attending

Formal: Starting a Master Thesis Seminar requires at least 60CP of passed courses within the program „Artificial Intelligence and Data Science“.
Contentual: none

Examination

(1) Grading of the oral presentation

Prerequisites for receiving credit points

(1) Successful completion of the thesis

Study Program

M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points.

Language
☐ German
☒ English
☐ German and English
☐ German, English on demand

Further Information

Lab Rotations

Responsible for the Module: Prof. Dr. Markus Kollmann	**Date:** 01.11.2019
Supervisors All group leaders offering Lab Rotations	**Semester:** 2./3.
	Modus: Obligatory course

Work Load	**Credits**	**Contact Time**	**Self-study**
300 h	10 CP	60h	240 h
Course	**Turnus**	**Group Size**	**Duration**
Practical Work	each year	NA	6 Weeks

Learning results & Competences

Students can work independently on a specific Data Science / AI project within a larger research group. They understand how the data they work on have been generated and preprocessed. They understand the goals of the research project and how the data analysis is connected to it. They are able to identify suitable algorithms to analyse the data and know their limitations. They can benchmark algorithms against each other and can carry out statistical analysis of their performance. They are able to present the results of their work to an audience that has different scientific background.

Procedure

Students can apply to research groups that generate/analyse data to carry out a lab rotation. The group leaders offering lab rotation places may choose among applicants according to their suitability. Lab rotations can also be carried out outside the university in R&D environments that generate/analyse sufficiently large data sets. The lab rotation requires permanent physical presence of the student within the chosen research group. The student is co-supervised by a member of the chosen research group and a lecturer that is involved in a theoretical module in the Master Program „Artificial Intelligence and Data Science".

Content

The co-supervisors agree on a lab rotation project based on the tasks to be carried out. The project can involve all steps of a data analysis pipeline – e.g. data cleaning, data preprocessing, data analysis, data postprocessing, data visualization – but not data generation. Ideally, these tasks should be realized by self-written code. Special emphasis in a lab rotation should be given to sensitise students for the peculiarities of the involved data and that students give understandable presentations of their results.

Prerequisites for attending

Formal: Admission to master studies in „Artificial Intelligence and Data Science".
Contentual: none

Examination

(1) Graded seminar talk

Prerequisites for receiving credit points

(1) Permanent presence in the chosen research group
(2) Giving a seminar talk

Study Program
M.Sc. Artificial Intelligence and Data Science

Modul accessible for other Study Programs

Weight in overall rating
The mark given will contribute to the final grade in proper relation to its credit points.

Language
☐ German
☒ English
☐ German and English
☐ German, English on demand

Further Information