Module Handbook

for the

Master Programme “Computer Science”

at

Rheinischen Friedrich-Wilhelms-Universität Bonn

revised version: April 7, 2024

The curriculum of the master programme is divided into four sub-curricula, each corresponding to one of the four main areas of competence in research of the Bonn Institute of Computer Science:

1. Algorithmics
2. Graphics, Vision, Audio
3. Information and Communication Management
4. Intelligent Systems

Module numbers **MA-INF ASXY** have been assigned according to the following key: vergeben:

- **A** = number of the area of competence
- **S** = semester within the master curriculum
- **XY** = sequential number within the semester and the respective area of competence (two digits)

According to the curriculum, all modules ought to be taken between the first and the third semester. The fourth semester is reserved for preparing the master thesis.

Contents

1 Algorithmics

MA-INF 1102 Combinatorial Optimization

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	at least every year

Module coordinator	Lecturer(s)
Prof. Dr. Jens Vygen	All lecturers of Discrete Mathematics

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1. or 2.

Learning goals: technical skills

Advanced knowledge of combinatorial optimization. Modelling and development of solution strategies for combinatorial optimization problems

Learning goals: soft skills

Mathematical modelling of practical problems, abstract thinking, presentation of solutions to exercises

Contents

Matchings, b-matchings and T-joins, optimization over matroids, submodular function minimization, travelling salesman problem, polyhedral combinatorics, NP-hard problems

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

- B. Korte, J. Vygen: Combinatorial Optimization: Theory and Algorithms. Springer, 6th edition, 2018
- A. Schrijver: Combinatorial Optimization: Polyhedra and Efficiency. Springer, 2003
- W. Cook, W. Cunningham, W. Pulleyblank, A. Schrijver: Combinatorial Optimization. Wiley, 1997
- A. Frank: Connections in Combinatorial Optimization. Oxford University Press, 2011

MA-INF 1103 Cryptography

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Michael Nüsken	Dr. Michael Nüsken

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1. or 2.

Learning goals: technical skills

Understanding of security concerns and measures, and of the interplay between computing power and security requirements. Mastery of the basic techniques for cryptosystems and cryptanalysis

Learning goals: soft skills

Oral presentation (in tutorial groups), written presentation (of exercise solutions), team collaboration in solving homework problems, critical assessment

Contents

Basic private-key and public-key cryptosystems: AES, RSA, group-based. Security reductions. Key exchange, cryptographic hash functions, signatures, identification; factoring integers and discrete logarithms; lower bounds in structured models.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. Each student must present twice in the tutorial.

Literature

- Jonathan Katz & Yehuda Lindell (2015/2008). Introduction to Modern Cryptography, CRC Press.
- Course notes

MA-INF 1105 Algorithms for Data Analysis

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Petra Mutzel	Prof. Dr. Petra Mutzel

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1. or 2.

Learning goals: technical skills

Deeper insights into selected methods and techniques of modern algorithmics with respect to big data and/or analytics tasks

Learning goals: soft skills

Presentation of solutions and methods, critical discussion of applied methods and techniques.

Contents

Advanced algorithmic techniques and data structures relevant to analytic tasks for big data, i.e., algorithms for graph similarity, parallel algorithms, I/O-data structures, and streaming algorithms.

Prerequisites

Required:
none

Recommended:
Introductory knowledge of foundations of algorithms and data structures is essential.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

MA-INF 1107 Foundations of Quantum Computing

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every 2 years

Module coordinator	Lecturer(s)
Prof. Dr.-Ing. Christian Bauckhage	Prof. Dr.-Ing. Christian Bauckhage

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1. or 3.

Learning goals: technical skills

Upon successful completion of this module, students should be able to describe fundamental concepts and techniques (qubits, quantum registers, quantum gates, quantum circuits) in quantum computing. Students will be equipped with specific, quantum computing related programming know-how; based on knowledge and skills acquired, students should be able to

- devise quantum computing algorithms for basic computational tasks
- run these algorithms on (simulated) quantum computers

Learning goals: soft skills

In the exercises, students will have the opportunity to put their knowledge into practice, since they will realize small projects on computing with quantum gates and their solutions using quantum inspired methods or genuine quantum methods. This requires teamwork; upon successful completion of the module, students should be able to

- draft and implement basic quantum computing algorithms
- apply quantum computing (simulations) to test these algorithms
- prepare and give oral presentations about their work in front of an audience

Contents

Boolean algebras and Boolean lattices; cellular automata; classical digital computing; classical reversible computing; mathematical foundations of quantum computing (complex vector spaces, tensor products, unitary operators, Hermitian operators, qubits, superposition, entanglement); quantum gate computing; quantum circuits

Prerequisites

Recommended:
Good working knowledge of theory and practice of linear algebra

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Forms of media

- lecture slides / lecture notes are made available online
- notebooks with programming examples are made available online

Literature

- L. Susskind, A. Friedman, “Quantum Mechanics: The Theoretical Minimum”, Penguin, 2015
- M.A. Nielsen, I.L Chuang, “Quantum Computation and Quantum Information”, Cambridge University Press, 10th Anniversary edition, 2010
- P. Wittek, “Quantum Machine Learning”, Academic Press, 2016
- M. Schuld, F. Petruccione, “Machine Learning with Quantum Computers”, Springer, 2nd edition, 2021
- S. Ganguly, “Quantum Machine Learning: An Applied Approach”, Apress, 2021

MA-INF 1108 Introduction to High Performance Computing: Architecture Features and Practical Parallel Programming

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Estela Suarez	Prof. Dr. Estela Suarez

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1-3.

Learning goals: technical skills

Understanding principles of computer architecture of modern HPC systems at component (processor, accelerators) and system level (system architecture, network, memory hierarchy) and their implication for application programming. Ability to program parallel computers, employing multi-core and multi-node features. Programming CPU and GPUs. Understanding the quality of performance .and scaling behaviour, and applying the measures needed to improve them.

Learning goals: soft skills

Ability to select a specific HPC topic and present it in a clear and comprehensive manner suitable for a lightning talk (10min)

Contents

Computer architectures, system components (CPU, memory, network) and their interrelation.

Software environment

Access to HPC compute resources at the Jülich Supercomputing Centre

Practical use of parallel programming paradigms (MPI, OpenMP, CUDA)

Performance of applications and scaling behavior, understanding and strategies for improvement

Current challenges in HPC

Prerequisites

Required:
Knowledge of a modern programming language (ideally C/C++ and Python).

Interest in High Performance Computing

Cannot be taken after completing MA-INF 1106.

Recommended:
Bachelor lecture on computer architecture

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful participation in the exercises

Forms of media

Laptop and projector

Literature

• John L. Hennessy, David A. Patterson: Computer Architecture - A Quantitative Approach. Morgan Kaufmann Publishers, 2012
• David A. Patterson, John L. Hennessy: Computer Organization and Design - The Hardware / Software Interface. Morgan Kaufmann Publishers, 2013
• Message Passing Interface Forum: MPI: A Message-Passing Interface Standard, Version 3.1
• OpenMP Application Programming Interface, Version 4.5, November 2015

MA-INF 1201 Approximation Algorithms

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	at least every year

Module coordinator	Lecturer(s)
Prof. Dr. Jens Vygen	All lecturers of Discrete Mathematics, Senior Prof. Dr. Marek Karpinski

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Introduction to design and analysis of most important approximation algorithms for NP-hard combinatorial optimization problems, and various techniques for proving lower and upper bounds, probabilistic methods and applications

Learning goals: soft skills

Presentation of solutions and methods, critical discussion of applied methods and techniques

Contents

Approximation Algorithms and Approximation Schemes. Design and Analysis of Approximation algorithms for selected NP-hard problems, like Set-Cover, and Vertex-Cover problems, MAXSAT, TSP, Knapsack, Bin Packing, Network Design, Facility Location. Introduction to various approximation techniques (like Greedy, LP-Rounding, Primal-Dual, Local Search, randomized techniques and Sampling, and MCMC-Methods), and their applications. Analysis of approximation hardness and PCP-Systems.

Prerequisites

Recommended:
Introductory knowledge of foundations of algorithms and complexity theory is essential.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions twice.

Literature

- S. Arora, C. Lund: Hardness of Approximations. In: Approximation Algorithms for NP-Hard Problems (D. S. Hochbaum, ed.), PWS, 1996
- M. Karpinski: Randomisierte und approximative Algorithmen für harte Berechnungsprobleme, Lecture Notes (5th edition), Universität Bonn, 2007
- B. Korte, J. Vygen: Combinatorial Optimization: Theory and Algorithms (6th edition), Springer, 2018
- V. V. Vazirani: Approximation Algorithms, Springer, 2001
- D. P. Williamson, D. B. Shmoys: The Design of Approximation Algorithms, Cambridge University Press, 2011

MA-INF 1202 Chip Design

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Jens Vygen	All lecturers of Discrete Mathematics

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1. or 2.

Learning goals: technical skills

Knowledge of the central problems and algorithms in chip design. Competence to develop and apply algorithms for solving real-world problems, also with respect to technical constraints. Techniques to develop and implement efficient algorithms for very large instances.

Learning goals: soft skills

Mathematical modelling of problems occurring in chip design, development of efficient algorithms, abstract thinking, presentation of solutions to exercises

Contents

Problem formulation and design flow for chip design, logic synthesis, placement, routing, timing analysis and optimization

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions twice.

Literature

• C.J. Alpert, D.P. Mehta, S.S. Sapatnekar: The Handbook of Algorithms for VLSI Physical Design Automation. CRC Press, New York, 2008.
• S. Held, B. Korte, D. Rautenbach, J. Vygen: Combinatorial optimization in VLSI design. In: "Combinatorial Optimization: Methods and Applications" (V. Chvátal, ed.), IOS Press, Amsterdam 2011, pp. 33-96
• S. Held, J. Vygen: Chip Design. Lecture Notes (distributed during the course)
• L. Lavagno, I.L. Markov, G. Martin, and L.K. Scheffer, eds.: Electronic Design Automation for IC Implementation, Circuit Design, and Process Technology. CRC Press, 2nd edition, 2016

MA-INF 1203 Discrete and Computational Geometry

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Anne Driemel	Prof. Dr. Anne Driemel, PD Dr. Elmar Langetepe, Dr. Herman Haverkort

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1-4.

Learning goals: technical skills

Knowledge of fundamental theorems and concepts in the area of discrete and computational geometry; design and analysis of geometric algorithms; combinatorial analysis of the complexity of geometric configurations; to apply this knowledge autonomously in solving new problems.

Learning goals: soft skills

Social competence (communication, presenting one's own solutions, goal-oriented discussions in teams), methodical competence (analysis, abstraction, proofs), individual competence (commitment and willingness to learn, creativity, endurance).

Contents

Fundamentals of convex sets, Voronoi diagrams, hyperplane arrangements, well-separated pair decomposition, spanners, metric space embedding, dimension reduction, VC-dimension, epsilon-nets, visibility, point location, range searching, randomized incremental construction, geometric distance problems in dimension two and higher.

Prerequisites

Recommended:
BA-INF 114 – Grundlagen der algorithmischen Geometrie

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

• Jiri Matousek. Lectures on Discrete Geometry. Springer Graduate Texts in Mathematics. ISBN 0-387-95374-4.
• Mark de Berg, Otfried Cheong, Marc van Kreveld, and Mark Overmars. Computational Geometry — Algorithms and Applications (Third Edition). Springer. ISBN 978-3-540-77973-5.
• Narasimhan/Smid, Geometric Spanner Networks
• Klein, Concrete and Abstract Voronoi Diagrams

MA-INF 1205 Graduate Seminar Discrete Optimization

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Jens Vygen	All lecturers of Discrete Mathematics

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Competence to understand new research results based on original literature, to put such results in a broader context and present such results and relations.

Learning goals: soft skills

Ability to read and understand research papers, abstract thinking, presentation of mathematical results in a talk

Contents

A current research topic in discrete optimization will be chosen each semester and discussed based on original literature.

Prerequisites

Recommended:
MA-INF 1102 – Combinatorial Optimization

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	4	60 T / 120 S	6

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The topics and the relevant literature will be announced towards the end of the previous semester.

MA-INF 1206 Seminar Randomized and Approximation Algorithms

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Heiko Röglin	Prof. Dr. Anne Driemel, Prof. Dr. Thomas Kesselheim, Prof. Dr. Heiko Röglin, PD Dr. Elmar Langetepe, Dr. Herman Haverkort, Senior Prof. Dr. Marek Karpinski

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Ability to perform individual literature search, critical reading, understanding, and clear presentation.

Learning goals: soft skills

Presentation of solutions and methods, critical discussion of applied methods and techniques

Contents

Current topics in design and analysis of randomized and approximation algorithms based on lastest research literature

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The relevant literature will be announced in time.

MA-INF 1207 Lab Combinatorial Algorithms

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Jens Vygen	All lecturers of Discrete Mathematics

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Competence to implement advanced combinatorial algorithms, handling nontrivial data structures, testing, documentation. Advanced software techniques.

Learning goals: soft skills

Efficient implementation of complex algorithms, abstract thinking, documentation of source code

Contents

Certain combinatorial algorithms will be chosen each semester. The precise task will be explained in a meeting in the previous semester.

Prerequisites

Recommended:
MA-INF 1102 – Combinatorial Optimization

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The topics and the relevant literature will be announced towards the end of the previous semester

MA-INF 1209 Seminar Advanced Topics in Cryptography

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Dr. Michael Nüsken	Dr. Michael Nüsken

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Understanding research publications, often written tersely. Distilling this into a presentation. Determination of relevant vs. irrelevant material. Developing a presentation that fascinates fellow students.

Learning goals: soft skills

Understanding and presenting material both orally and in visual media. Motivating other students to participate. Critical assessment of research results.

Contents

A special topic within cryptography, changing from year to year, is studied in depth, based on current research literature

Prerequisites

Recommended:
Basic knowledge in cryptography is highly recommended, eg. by MA-INF 1103 – Cryptography.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

Current cryptographic literature.

MA-INF 1213 Randomized Algorithms and Probabilistic Analysis

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Heiko Röglin	Prof. Dr. Heiko Röglin

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 4.

Learning goals: technical skills

Understanding of models and techniques for the probabilistic analysis of algorithms as well as for the design and analysis of randomized algorithms

Learning goals: soft skills

Oral and written presentation of solutions and methods, abstract thinking

Contents

Design and analysis of randomized algorithms

- complexity classes
- Markov chains and random walks
- tail inequalities
- probabilistic method

smoothed and average-case analysis

- simplex algorithm
- local search algorithms
- clustering algorithms
- combinatorial optimization problems
- multi-objective optimization

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to three students. A total of 25% of the points must be achieved.

Literature

- lecture notes
- research articles
- Motwani, Raghavan, Randomized Algorithms, Cambridge University Press, 1995
- Mitzenmacher, Upfal, Probability and Computing, Cambridge University Press, 2nd edition, 2017

MA-INF 1217 Seminar Theoretical Foundations of Data Science

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Heiko Röglin	Prof. Dr. Anne Driemel, Prof. Dr. Thomas Kesselheim, Prof. Dr. Heiko Röglin, PD Dr. Elmar Langetepe, Dr. Herman Haverkort

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current conference and journal papers

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 1218 Algorithms and Uncertainty

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Thomas Kesselheim	Prof. Dr. Thomas Kesselheim

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Understanding approaches for modeling uncertainty in algorithmic theory. Designing and analyzing algorithms with performance guarantees in the context of uncertainty.

Learning goals: soft skills

Oral and written presentation of solutions and methods

Contents

- Advanced Online Algorithms
- Markov Decisions Processes
- Stochastic and Robust Optimization
- Online Learning Algorithms and Online Convex Optimization

Prerequisites

Recommended:
Solid background in algorithms, calculus, and probability theory. Specialized knowledge about certain algorithms is not necessary.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

lecture notes, research articles

MA-INF 1219 Seminar Algorithmic Game Theory

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Thomas Kesselheim	Prof. Dr. Thomas Kesselheim

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to perform individual literature search, critical reading, and clear didactic presentation

Contents

Advanced topics in Algorithmic Game Theory and Algorithmic Mechanism Design based on current conference and journal papers

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 1220 Seminar Algorithms for Computational Analytics

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	at least every year

Module coordinator	Lecturer(s)
Prof. Dr. Petra Mutzel	Prof. Dr. Petra Mutzel

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Ability to perform individual literature search, critical reading, understanding, and clear didactic presentation.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current topics in algorithms for computational analytics based on recent research literature.

Prerequisites

Recommended:
Interest in Algorithms

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The relevant literature will be announced in time.

MA-INF 1221 Lab Computational Analytics

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Petra Mutzel	Prof. Dr. Petra Mutzel

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Ability to design, analyze and implement efficient algorithms for computational analytics problems. The LAB also includes experimental evaluation and documentation of the implemented software.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Design of efficient exact and approximate algorithms and data structures for computational analytics problems.

Prerequisites

Recommended:
Interest in algorithms

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The relevant literature will be announced in time.

MA-INF 1222 Lab High Performance Optimization

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Petra Mutzel	Prof. Dr. Petra Mutzel, Dr. Sven Mallach

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Ability to design, analyze and implement algorithms for computational analytics and optimization problems. The lab also includes experimental evaluation and documentation of the implemented software.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The relevant literature will be announced in time.

MA-INF 1223 Privacy Enhancing Technologies

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Michael Nüsken	Dr. Michael Nüsken

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Knowledge: Cryptographic schemes for enhancing privacy, underlying security notions, applications and restrictions.

Skills: Secure application of sophisticated cryptographic schemes. Evaluation of their correctness, efficiency and security in an application setting.

Learning goals: soft skills

Competences: Ability to assess schemes and their use in applications. Critical assessment of applications.

Contents

With more and more data available a clear separation of sensitive data is necessary and needs to be protected. Some of that data must stay within strict environments, for examples hospitals must store certain highly sensitive medical information about patients but they are not allowed to store it outside its own facilities. Some of that data is stored or collected in a cloud environment in encrypted form, say data from a medical device or a smart home. But it shall still be possible to derive important conclusions from it, for example to send immediate help to a patient suffering a heart attack.

Innovative solutions are needed in this area of tension. The research in cryptography provides some highly sophisticated tools for solving the like problems.

- Fully homomorphic encryption (FHE).
- Zero-Knowledge techniques, in particular: Non-interactive zero-knowledge proof (NIZKs).
- Secure multi-party computations (MPC).
- Anonymisation, TOR. Pseudonymization. Blinding.
- Weaker privacy notions, like differential privacy.

Prerequisites

Recommended:
Basic knowledge in cryptography is highly recommended.

A profound mathematical background does help. In particular, precise mathematical formulation and reasoning are important, but also topics like elementary number theory and discrete mathematics, especially lattices, are interesting.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. Each student must present twice in the tutorial.

MA-INF 1224 Quantum Computing Algorithms

Workload	Credit points	Duration	Frequency
150 h	5 CP	1 semester	every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Christian Bauckhage	Prof. Dr. Christian Bauckhage

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 4.

Learning goals: technical skills

Upon successful completion of this module, students should be able to describe fundamental concepts behind working quantum algorithms.

Students acquire quantum computing programming know-how; based on knowledge and skills acquired, students should be able to

- run quantum algorithms on (simulated) quantum computing platforms
- devise their own algorithms for optimization or classification problems that can be solved on quantum computers

Learning goals: soft skills

In the exercises, students can put their quantum computing knowledge into practice and realize small projects involving the implementation of quantum algorithm. This requires teamwork; upon successful completion of the module, students should be able to

- draft and implement basic quantum computing algorithms
- apply quantum computing (simulations) to test these algorithms
- prepare and give oral presentations about their work in front of an audience

Contents

quantum gate algorithms such as Deutsch-Jozsa, Bernstein-Vazirani, Simon, Shor, Grover; phase kick-back, amplitude amplification; swap tests; Hamiltonian simulation, Trotterization, variational quantum computing for optimization

Prerequisites

Required:
MA-INF 1107 “Fondations of Quantum Computing“

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		1	15 T / 60 S	2.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Forms of media

- lecture slides / lecture notes are made available online
- notebooks with programming examples are made available online

Literature

M.A. Nielsen, I.L Chuang, “Quantum Computation and Quantum Information”, Cambridge University Press, 10th Anniversary edition, 2010

P. Wittek, “Quantum Machine Learning”, Academic Press, 2016

M. Schuld, F. Petruccione, “Machine Learning with Quantum Computers”, Springer, 2nd edition, 2021

S. Ganguly, “Quantum Machine Learning: An Applied Approach”, Apress, 2021

MA-INF 1225 Lab Exploring HPC technologies

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Estela Suarez	Prof. Dr. Estela Suarez

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Understanding a use case from complex code developed. Adapting and running applications to different kinds of processing units, taking into account their specific architecture characteristic and programming environments. Understanding and using parallel programming paradigms and high-level programming languages. Designing and executing a benchmarking campaign. Using performance analysis tools, understanding performance bottlenecks and measures to improve them. Software development skills and standards.

Learning goals: soft skills

Collaborating and interacting with application developers, tools developers, and system administrators in a solution oriented manner, taking into account their different “work language” and expertise. Presenting performed work and results obtained and classifying own results into the state-of-the-art. Preparing software documentation.

Contents

The students carry out a practical task (project) in High Performance Computing (HPC), including test of different hardware architectures and software tools, documentation of the implemented software/system. Contents: HPC systems: access/use of compute resources at Jülich Supercomputing Centre; Use of different processor architectures; Software environment, performance analysis tools; Parallel programming; Benchmarking tools/procedures; Performance of applications and scaling behavior, strategies for improvement

Prerequisites

Required:
-Passed the exam of MA-INF 1106 or MA-INF 1108.

-Knowledge modern programming languages (C/C++, Python).

-Willing to stay for at least 2 days per week during 4 weeks at the Jülich Supercomputing Centre, dates to be discussed.

Remarks

Registration first via direct mail communication with the lecturer, in order to identify suitable dates for the stay at JSC.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	2	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Forms of media

Own laptop to connect and program on the supercomputers.

Literature

• John L. Hennessy, David A. Patterson: Computer Architecture - A Quantitative Approach. Morgan Kaufmann Publishers, 2012
• David A. Patterson, John L. Hennessy: Computer Organization and Design - The Hardware / Software Interface. Morgan Kaufmann Publishers, 2013
• Message Passing Interface Forum: MPI: A Message-Passing Interface Standard, Version 3.1
• OpenMP Application Programming Interface, Version 4.5, November 2015

MA-INF 1301 Algorithmic Game Theory

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Thomas Kesselheim	Prof. Dr. Thomas Kesselheim, Senior Prof. Dr. Marek Karpinski

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Knowledge of fundamental results in (algorithmic) game theory and (algorithmic) mechanism design. Techniques and methods related to mathematical modeling of strategic agents. Analyzing and designing systems of strategic agents, with a focus on computational efficiency and performance guarantees.

Learning goals: soft skills

Presentation of solutions and methods, critical discussion of applied methods and techniques

Contents

- basic game theory
- computability and hardness of equilibria
- convergence of dynamics of selfish agents
- (bounds on the) loss of performance due to selfish behavior
- designing incentive-compatible auctions
- maximizing revenue
- designing mechanisms for stable and fair allocations without money

Prerequisites

Recommended:
Introductory knowledge of foundations of algorithms and complexity theory is essential.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. Each student must present a solution to an exercise in the exercise sessions once.

Literature

- N. Nisan, T. Roughgarden, E. Tardos, V.V. Vazirani (ed.): Algorithmic Game Theory, Cambridge Univ. Press, 2007
- T. Roughgarden, Twenty Lectures on Algorithmic Game Theory, Cambridge Univ. Press, 2016
- A. Karlin, Y. Peres, Game Theory, Alive, AMS, 2017
- Y. Shoham, K. Leyton-Brown, Multiagent Systems, Cambridge Univ. Press, 2009
- D. M. Kreps: A Course in Microeconomic Theory, Princeton Univ. Press, 1990
- M. J. Osborne, A. Rubinstein: A Course in Game Theory, MIT Press, 2001

MA-INF 1304 Seminar Computational Geometry

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Anne Driemel	Prof. Dr. Anne Driemel, PD Dr. Elmar Langetepe, Dr. Herman Haverkort

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2-4.

Learning goals: technical skills

To independently study problems at research level, based on research publications, to prepare a concise summary, to present the summary in a scientific talk, to lead a critical discussion with other seminar participants.

Learning goals: soft skills

Contents

Current topics in computational geometry.

Prerequisites

Recommended:
BA-INF 114 – Grundlagen der algorithmischen Geometrie
MA-INF 1203 – Discrete and Computational Geometry

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Forms of media

Multimedia projector, black board.

Literature

The relevant literature will be announced.

MA-INF 1305 Graduate Seminar on Applied Combinatorial Optimization

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Jens Vygen	All lecturers of Discrete Mathematics

Programme	Mode	Semester
M. Sc. Computer Science	Optional	3.

Learning goals: technical skills

Competence to understand new theoretical results and practical solutions in VLSI design and related applications, as well as presentation of such results

Learning goals: soft skills

Ability to read and understand research papers, abstract thinking, presentation of mathematical results in a talk

Contents

Current topics in chip design and related applications

Prerequisites

Recommended:
At least 1 of the following:

MA-INF 1102 – Combinatorial Optimization

MA-INF 1202 – Chip Design

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	4	60 T / 120 S	6

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The topics and the relevant literature will be announced towards the end of the previous semester

MA-INF 1307 Seminar Advanced Algorithms

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Thomas Kesselheim	Prof. Dr. Anne Driemel, Prof. Dr. Thomas Kesselheim, Prof. Dr. Heiko Röglin, PD Dr. Elmar Langetepe, Dr. Herman Haverkort

Programme	Mode	Semester
M. Sc. Computer Science	Optional	3.

Learning goals: technical skills

Presentation of selected advanced topics in algorithm design and various applications

Learning goals: soft skills

Ability to perform individual literature search, critical reading, understanding, and clear didactic presentation

Contents

Advanced topics in algorithm design based on newest research literature

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The relevant literature will be announced in time.

MA-INF 1308 Lab Algorithms for Chip Design

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Jens Vygen	All lecturers of Discrete Mathematics

Programme	Mode	Semester
M. Sc. Computer Science	Optional	3.

Learning goals: technical skills

Competence to implement algorithms for VLSI design, efficient handling of very large instances, testing, documentation. Advanced software techniques.

Learning goals: soft skills

Efficient implementation of complex algorithms, abstract thinking, modelling of optimization problem in VLSI design, documentation of source code

Contents

A currently challenging problem will be chosen each semester. The precise task will be explained in a meeting in the previous semester.

Prerequisites

Recommended:
At least 3 of the following:

MA-INF 1102 – Combinatorial Optimization

MA-INF 1202 – Chip Design

MA-INF 1205 – Graduate Seminar Discrete Optimization

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The topics and the relevant literature will be announced towards the end of the previous semester

MA-INF 1309 Lab Efficient Algorithms: Design, Analysis and Implementation

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	at least every year

Module coordinator	Lecturer(s)
Prof. Dr. Heiko Röglin	Prof. Dr. Anne Driemel, Prof. Dr. Thomas Kesselheim, Prof. Dr. Heiko Röglin, PD Dr. Elmar Langetepe, Dr. Herman Haverkort

Programme	Mode	Semester
M. Sc. Computer Science	Optional	3.

Learning goals: technical skills

Ability to design, analyze and implement efficient algorithms for selected computational problems.

Learning goals: soft skills

ability to work on advanced algorithmic implementation projects, to work in small teams, clear didactic presentation and critical discussion of results

Contents

Design of efficient exact and approximate algorithms and data structures for selected computational problems.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The relevant literature will be announced in time.

MA-INF 1314 Online Motion Planning

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
PD Dr. Elmar Langetepe	Prof. Dr. Rolf Klein, PD Dr. Elmar Langetepe

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1-4.

Learning goals: technical skills

To acquire fundamental knowledge on topics and methods in online motion planning

Learning goals: soft skills

Contents

Search and exploration in unknown environments (e.g., graphs, cellular environmwents, polygons, strets), online algorithms, competitive analysis, competitive complexity,functional optimization, shortest watchman route, tethered robots, marker algorithms, spiral search, approximation of optimal search paths.

Prerequisites

Recommended:
BA-INF 114 – Grundlagen der algorithmischen Geometrie

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to three students. A total of 25% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions once.

Forms of media

Java applets of geometry lab

Literature

Scientific research articles will be recommended in the lecture.

MA-INF 1315 Lab Computational Geometry

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Anne Driemel	Prof. Dr. Anne Driemel, PD Dr. Elmar Langetepe, Dr. Herman Haverkort

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Ability to design, analyze, implement and document efficient algorithms for selected problems in computational geometry.

Learning goals: soft skills

Ability to properly present, defend and discuss design and implementation decisions, to document software according to given rules and to collaborate with other students in small groups.

Contents

Various problems in computational geometry.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The relevant literature will be announced in time.

MA-INF 1316 Lab Cryptography

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Michael Nüsken	Dr. Michael Nüsken

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of Cryptography, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend
design decisions, to prepare readable documentation of software;
skills in constructively collaborating with others in small teams
over a longer period of time; ability to classify ones own results
into the state-of-the-art of the resp. area

Contents

Prerequisites

Recommended:
Basic knowledge in cryptography is highly recommended, eg. by MA-INF 1103 - Cryptography, MA-INF 1223 - PETs, MA-INF 1209 - Seminar Advanced Topics in Cryptography.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 1320 Lab Advanced Algorithms

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Thomas Kesselheim	Prof. Dr. Thomas Kesselheim, Prof. Dr. Heiko Röglin

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Implementation of algorithms from advanced algorithmic theory, evaluating these algorithm on suitably chosen instances, and discussing how theoretical results transfer to practice.

Learning goals: soft skills

Ability to properly present, defend and discuss design and implementation decisions and observed conclusions, and to collaborate with other students in small groups.

Contents

Various problems from current research and courses on algorithmic theory.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The relevant literature will be announced in time.

MA-INF 1321 Binary Linear and Quadratic Optimization

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Dr. Sven Mallach	Dr. Sven Mallach

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Deeper understanding of computational methods to solve potentially large-scale mixed-integer programs in practice. Application-specific modelling and reformulation of combinatorial optimization problems, handling quadratic objective functions, algorithm design.

Learning goals: soft skills

Social, methodological, and analytical competences via communication, own development, presentation, and critical assessment of problem formulations, algorithms, and solutions covered in the course or the excercises. Learning to abstract, but also learning the limitations of abstraction.

Contents

Computational methods in (mixed-)integer programming such as cutting plane separation and branch-and-bound along with a short and accessible introduction into their theoretical basis. Study of practically relevant binary linear and binary quadratic optimization problems, e.g., Maximum Cut, Linear Ordering and variants of the Traveling Salesman problem, along with the particular separation problems arising there. If there is time, linearizations of quadratic objective functions and more sophisticated formulations of binary quadratic problems are discussed.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

MA-INF 1322 Seminar Focus Topics in High Performance Computing

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Estela Suarez	Prof. Dr. Estela Suarez

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Ability to perform individual literature search, critical reading, understanding, prepare a concise summary, and clear didactic presentation

Learning goals: soft skills

Ability to present and critically discuss these results in the framework of the corresponding area

Contents

General topics and trends in high performance computing, based on recent review and research literature

Prerequisites

Recommended:
Interest in High Performance Computing

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

Literature and further information about this seminar will be announced in time in the website of lecturer.

MA-INF 1323 Computational Topology

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Anne Driemel	Prof. Dr. Anne Driemel, Dr. Benedikt Kolbe

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Knowledge of fundamental theorems and concepts in the area of computational topology in particular, persistent homology and topological data analysis; design and analysis of combinatorial algorithms in topological contexts; analysis of the complexity; to apply this knowledge autonomously to solving new problems and analysing new data sets.

Learning goals: soft skills

Social competence (communication, presenting one's own solutions, goal-oriented discussions in teams), methodical competence (analysis, abstraction, proofs), individual competence (commitment and willingness to learn, creativity, perseverance).

Contents

Fundamental concepts of relative homology and cohomology theory and persistence theory in computational settings, category theory in this context, algorithms for the computation of (persistent) homology, (extended) persistence modules and their decompositions, Morse theory, duality theorems, quiver representation theory, stability of persistence diagrams and barcodes, algebraic stability, topological filtrations, multiparameter persistence, invariants of persistence, topological data analysis, applications to shape pattern recognition, machine learning, identification of geometric objects.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

- Herbert Edelsbrunner, John Harer (2010). Computational Topology: An Introduction. American Mathematical Society.
- Steve Oudot (2015). Persistence Theory: From Quiver Representations to Data Analysis (Vol. 209). American Mathematical Society.
- Magnus Bakke Botnan, Michael Lesnick (2022). An Introduction to Multiparameter Persistence.
- Allen Hatcher (2002). Algebraic Topology (Vol. 44). Cambridge University Press.

2 Graphics, Vision, Audio

MA-INF 2113 Foundations of Audio Signal Processing

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
apl. Prof. Dr. Frank Kurth	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1.

Learning goals: technical skills

- Introduction to basic concepts of analog and digital signal processing;
- Applications in the field of Audio Signal Processing;
- Signal Processing Algorithms;
- Implementing basic Signal Processing Algorithms

Learning goals: soft skills

Solving basic Signal Processing Problems; Implementing Signal Processing Algorithms using state-of-the-art software frameworks; Capability to analyze; Time management; Presentation skills; Discussing own solutions and solutions of others, and working in groups.

Contents

Theoretical introduction to analog and digital Signal Processing; Fourier Transforms; Analog to digital Conversion; Digital Filters; Audio Signal Processing Applications; Filter banks; Windowed Fourier Transform; 2D-Signal Processing

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Forms of media

Slides, Blackboard, Whiteboard

MA-INF 2201 Computer Vision

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Jürgen Gall	Prof. Dr. Jürgen Gall

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1. or 2.

Learning goals: technical skills

Students will learn about various mathematical methods and their applications to computer vision problems.

Learning goals: soft skills

Productive work in small teams, development and realization of individual approaches and solutions, critical reflection of competing methods, discussion in groups.

Contents

The class will cover a number of mathematical methods and their applications in computer vision. For example, linear filters, edges, derivatives, Hough transform, segmentation, graph cuts, mean shift, active contours, level sets, MRFs, expectation maximization, background subtraction, temporal filtering, active appearance models, shapes, optical flow, 2d tracking, cameras, 2d/3d features, stereo, 3d reconstruction, 3d pose estimation, articulated pose estimation, deformable meshes, RGBD vision.

Prerequisites

Recommended:
Basic knowledge of linear algebra, analysis, probability theory, Python programming

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

- R. Hartley, A. Zisserman: Multiple View Geometry in Computer Vision
- R. Szeliski: Computer Vision: Algorithms and Applications
- S. Prince: Computer Vision: Models, Learning, and Inference

MA-INF 2202 Computer Animation

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Björn Krüger	Prof. Dr. Björn Krüger

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Students will learn fundamental paradigms used in computer animation. They will learn to use mathematical models of motions to come up with algorithmic solutions of problems of the synthesis of motions of virtual characters.

Learning goals: soft skills

Social competences (work in groups), communicative skills (written and oral presentation)

Contents

Fundamentals of computer animation; kinematics; representations of motions; motion capturing; motion editing; motion synthesis; facial animations

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to three students. A total of 50% of the points must be achieved.

Literature

- Dietmar Jackel, Stephan Neunreither, Friedrich Wagner: Methoden der Computeranimation, Springer 2006
- Rick Parent: Computer Animation: Algorithms and Techniques, Morgan Kaufman Publishers 2002
- Frederic I. Parke , Keith Waters: Computer Facial Animation. A K Peters, Ltd. 1996

MA-INF 2203 Selected Topics in Signal Processing

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
apl. Prof. Dr. Frank Kurth	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Learning advanced as well as state of the art topics and techniques in digital signal processing. Study examples from the field of digital audio signal processing with a focus on music audio. Develop skills for analysing audio signals and designing audio features for selected application scenarios. Mathematical modelling of signal processing problems in practical applications. Design and implementation of corresponding algorithms and data structures solving those problems. Efficiency issues.

Learning goals: soft skills

Capability to analyze. Time management. Strength of purpose. Discussing own solutions and solutions of others.

Contents

Advanced techniques for filter design, design and extraction of features describing multimedia signals, efficient DSP algorithms, general concepts for content-based analysis of multimedia signals. Selected signal processing applications, for example content-based music analysis, signal compression, denoising, source separation.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

- Lecture script and selected research publications
- Hayes: Statistical Digital Signal Processing and Modelling, John Wiley, 1996
- Proakis, Manolakis: Digital Signal Processing, Prentice Hall, 1996
- Klapuri, Davy: Signal Processing, Methods for Music Transcription, Springer, 2006

MA-INF 2206 Seminar Vision

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Jürgen Gall	Prof. Dr. Jürgen Gall

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current conference and journal papers.

Prerequisites

Required:
MA-INF 2201 – Computer Vision

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 2207 Seminar Graphics

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Reinhard Klein	Prof. Dr. Reinhard Klein

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current conference and journal papers.

Prerequisites

Recommended:
Mathematical background (multidimensional analysis and linear algebra, basic numerical methods)

Basic knowledge in Computer Graphics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 2208 Seminar Audio

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every semester

Module coordinator	Lecturer(s)
apl. Prof. Dr. Frank Kurth	apl. Prof. Dr. Frank Kurth, Dr. Michael Clausen

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current conference and journal papers.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 2209 Advanced Topics in Computer Graphics I

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Reinhard Klein	Prof. Dr. Reinhard Klein

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Analytical formulation of problems related to rendering. Knowledge of principles, techniques and algorithms to

- recognize and understand the physical quantities of light transport
- explain a range of surface and volumetric material models
- explain the rendering and radiative transfer equations
- design and implement methods to solve these equations, especially Monte Carlo methods
- Assess / Evaluate the performance and conceptual limits of the implemented simulation code

Learning goals: soft skills

Based on the knowledge and skills acquired students should be able to

- read and judge current scientific literature in the area of rendering
- identify the major literature concerning a given problem in rendering and gain an overview of the current state of the art
- discuss problems concerning rendering with researchers from different application fields
- present, propose and communicate different solutions and work in a team to solve a rendering problem

Contents

This course introduces the basic physical quantities as well as the mathematical and algorithmic tools required to understand and simulate the light interaction with objects and different materials in a 3D scene. We will discuss how to solve the mathematical problem numerically in order to create realistic images. Advanced topics include participating media, material models for sub-surface light transport, and Markov Chain Monte Carlo Methods. Topics among others will be

- rendering and radiative transfer equation
- methods and algorithms to solve these equations, radiosity, Monte Carlo, photon mapping
- analytical and data driven surface and subsurface material models, especially BRDF, BSSRDF models
- differentiable rendering

In addition, results from state-of-the-art research will be presented.

Prerequisites

Recommended:
Recommended but not enforced: basic knowledge in computer graphics, (numerical) analysis and linear algebra, C++

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved. For 70% of the exercise sheets, 50% of the points must be achieved for each sheet. The exercises are divided into theoretical and practical exercises, and the points to be achieved apply separately to both categories.

Literature
• M. Pharr, W. Jakob, and G. Humphreys, Physically Based Rendering: From Theory to Implementation (3rd edition), 2018 • L. Szirmay-Kalos: Monte-Carlo Methods in Global Illumination, Institute of Computer Graphics, Vienna University of Technology, Vienna, 1999 URL: https://cg.iit.bme.hu/~szirmay/script.pdf • P. Dutre, K. Bala, P. Bekaert: Advanced Global Illumination, 2nd ed., B&T, 2006 • D'Eon, Eugene. A Hitchhiker's Guide to Multiple Scattering, 2016

MA-INF 2212 Pattern Matching and Machine Learning for Audio Signal Processing

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
apl. Prof. Dr. Frank Kurth	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

- Introduction into selected topics of digital signal processing;
- Applications in the field of Audio Signal Processing;
- Methods of Automatic Pattern Recognition

Learning goals: soft skills

Audio Signal Processing Applications; Extended programming skills for signal processing applications; Capability to analyze; Time management; Presentation skills; Discussing own solutions and solutions of others, and working in groups.

Contents

The lecture is presented in modular form, where each module is motivated from the application side. The presented topics are: Windowed Fourier transforms; Audio Identifications; Audio Matching; Signal Classification; Hidden Markov Models; Support Vector Machines

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to four students. A total of 50% of the points must be achieved.

Forms of media

Slides, Blackboard, Whiteboard

MA-INF 2213 Advanced Computer Vision

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Jürgen Gall	Prof. Dr. Jürgen Gall

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Students will learn about various learning methods and their applications to computer vision problems.

Learning goals: soft skills

Productive work in small teams, development and realization of individual approaches and solutions, critical reflection of competing methods, discussion in groups.

Contents

The class will cover a number of learning methods and their applications in computer vision. For example, linear methods for classification and regression, Gaussian processes, random forests, SVMs and kernels, convolutional neural networks, vision transformer, generative adversarial networks, diffusion models, structured learning, image classification, object detection, action recognition, pose estimation, face analysis, tracking, image synthesis.

Prerequisites

Required:
MA-INF 2201 – Computer Vision

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		3	45 T / 45 S	3
Exercises		1	15 T / 75 S	3

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved.

MA-INF 2214 Computational Photography

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Matthias Hullin	Prof. Dr. Matthias Hullin

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Foundations in optics and image sensors. Signal processing and inverse problems in imaging. Color spaces and perception. Image alignment and blending. High-dimensional representations of light transport (light fields, reflectance fields, reflectance distributions). Computational illumination.

Learning goals: soft skills

- to read and understand current literature in the field
- to implement standard computational photography techniques
- to propose and implement solutions to a given problem
- to follow good scientific practice by planning, documenting and communicating their work

Contents

- Image sensors
- Optics
- Panoramas
- Light fields
- Signal processing and inverse problems
- Color, perception and HDR
- Reflectance fields and light transport matrices

Prerequisites

Required:
Basic knowledge in computer graphics, data structures, multidimensional analysis und linear algebra, numerical analysis and numerical linear algebra, C++ or MATLAB

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

(i) The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved. The exercises are divided into theoretical and practical exercises, and the points to be achieved apply separately to both categories. Each student must present a solution to an exercise in the exercise sessions twice. (ii) The completion of a programming project. The work is done in groups of two to four students, depending on the total number of students taking the course. The results of the programming project must be presented in class.

MA-INF 2215 Seminar Digital Material Appearance

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Matthias Hullin	Prof. Dr. Matthias Hullin

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current conference and journal papers

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 2216 Lab Visual Computing

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Florian Bernard	Prof. Dr. Florian Bernard

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1-3.

Learning goals: technical skills

Students will carry out a practical task (project) in the context of visual computing, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area.

Contents

This lab introduces visual computing methods and applications. You will get a chance to study the methods in depth by implementing them and running experiments. At the end of the semester, you will present the method, give a short demonstration and hand in a report describing the method and experimental outcomes.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 2217 Advanced Deep Learning for Graphics

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Reinhard Klein	Dr. Michael Weinmann

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1-4.

Learning goals: technical skills

Students will be introduced to adapt and apply deep learning techniques to various applications in computer graphics.

Learning goals: soft skills

Productive work in small teams, development and realization of individual approaches and solutions, critical reflection of competing methods, discussion in groups.

Contents

This course focuses on cutting-edge Deep Learning techniques for computer graphics. After a brief review of CNNs the focus will be laid on autoencoders, generative models and the extension of these methods to graph- and manifold-structured data. Applications discussed will include inverse problems in computer graphics and the synthesis of models including data completion and super-resolution.

Prerequisites

Recommended:
The course will build upon the basics of machine learning as well as fundamentals and basic architectures of neural networks. Therefore, it is highly recommended to have taken Deep Learning for Visual Recognition or a similar course as a prerequisite. Exercises will be a mix of theory and practical (Python).

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

No required text, supplemental readings will be given in class.

MA-INF 2218 Video Analytics

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Jürgen Gall	Prof. Dr. Jürgen Gall

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2-3.

Learning goals: technical skills

Students will learn advanced techniques for analyzing video data.

Learning goals: soft skills

Productive work in small teams, development and realization of a state-of-the-art system for video analysis.

Contents

The class will discuss state-of-the-art methods for several tasks of video analysis. For example, action recognition, hidden Markov models, 3D convolutional neural networks, temporal convolutional networks, recurrent neural networks, temporal action segmentation, weakly supervised learning, self-supervised learning, anticipation and forecasting.

Prerequisites

Required:
MA-INF 2201 – Computer Vision

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to three students. A total of 50% of the points must be achieved.

MA-INF 2219 Seminar Visualization and Medical Image Analysis

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Thomas Schultz	Prof. Dr. Thomas Schultz

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss scientific results in the context of the current state of the art. Ability to perform an independent search for relevant scientific literature.

Contents

Current conference and journal papers

Prerequisites

Recommended:
At least one of the following:

- MA-INF 2222 – Visual Data Analysis
- MA-INF 2312 – Image Acquisition and Analysis in Neuroscience

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 2220 Lab Visualization and Medical Image Analysis

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Thomas Schultz	Prof. Dr. Thomas Schultz

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of data visualization and visual analytics or medical image analysis, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Prerequisites

Recommended:
At least one of the following:

- MA-INF 2222 – Visual Data Analysis
- MA-INF 2312 – Image Acquisition and Analysis in Neuroscience

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 2221 Seminar Visual Computing

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	at least every year

Module coordinator	Lecturer(s)
Prof. Dr. Florian Bernard	Prof. Dr. Florian Bernard

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current conference and journal papers.

Prerequisites

Required:
No formal requirements. Participants are expected to have some previous exposure to at least one of the following:
- visual computing (e.g. computer vision, computer graphics, 3D shape analysis, image analysis, etc.),
- mathematical optimisation (e.g. combinatorial/continuous, convex/non-convex, etc.), or
- machine learning.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 2222 Visual Data Analysis

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Thomas Schultz	Prof. Dr. Thomas Schultz

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1-4.

Learning goals: technical skills

Ability to design, implement, and make proper use of systems for visual data analysis. Knowledge of algorithms and techniques for the visualization of multi-dimensional data, graphs, as well as scalar, vector, and tensor fields.

Learning goals: soft skills

Productive work in small teams, self-dependent solution of practical problems in the area of visual data analysis, critical reflection on visualization design, presentation of solution strategies and implementations, self management

Contents

This class provides a broad overview of principles and algorithms for data analysis via interactive visualization. Specific topics include perceptual principles, luminance and color, visualization analysis and design, integration of visual with statistical data analysis and machine learning, as well as specific algorithms and techniques for the display of multidimensional data, dimensionality reduction, graphs, direct and indirect volume visualization, vector field and flow visualization, as well as tensor field visualization.

Prerequisites

Recommended:
Students are recommended to have a basic knowledge in linear algebra and calculus, as well as proficiency in programming.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to three students. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions once.

Literature

A.C. Telea, Data Visualization: Principles and Practice. CRC Press, Second Edition, 2015

M. Ward et al., Interactive Data Visualization: Foundations, Techniques, and Applications. CRC Press, 2010

T. Munzner, Visualization Analysis and Design, A K Peters, 2015

MA-INF 2223 Seminar Advances in Multimodal Learning

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Hildegard Kühne	Prof. Dr. Hildegard Kühne

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Presentation of selected advanced topics in computer vision and multimodal learning and various applications

Learning goals: soft skills

Ability to perform individual literature search, critical reading, understanding, and clear didactic presentation

Contents

This seminar will cover most recent advancements and publications in multimodal learning, which is the integration of multiple data sources or multiple modalities for more complex machine learning applications. This can also include reviews of emerging techniques, including unsupervised approaches, deep learning, transfer learning, and reinforcement learning to combine multiple modalities such as images, audio, video, joint feature learning, and natural language processing. It can further cover techniques for data fusion and the role they play in successful applications of multimodal learning. Students will have an opportunity to evaluate and experiment with public code if available. Goel is to develop a better understanding of the possibilities and challenges of multimodal learning.

Prerequisites

Required:
none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

The relevant literature will be announced in time.

MA-INF 2224 Lab Challenges in Computer Vision

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Hildegard Kühne	Prof. Dr. Hildegard Kühne

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Students will carry out a practical task (project) in the context of computer vision and/or multimodal learning, including evaluation and documentation of the implemented software/system.

Learning goals: soft skills

Ability to implement and evaluate a scientific approach; ability to classify ones own results into the state-of-the-art of the resp. area; skills in constructively collaborating with others in small teams over a longer period of time.

Contents

This Programming Project focuses on exploring the challenges in modern Computer Vision algorithms and model development. The project will track the latest progress in the field and the associated challenges in different application areas, such as video understanding as well as general computer vision topics. The project will include a hands-on implementation of various techniques in current computer vision systems to identify and resolve problems, and to evaluate results in comparison to public benchmarks. It will further provide an understanding of the characteristics of models and benchmarks such as generalization and robustness. The project should provide insights on the development of novel computer vision technology in response to upcoming challenges.

Prerequisites

Required:
Practical experience in deep learning

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Successful exercise participation

MA-INF 2225 Discrete Models for Visual Computing

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
	Prof. Dr. Florian Bernard

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 4.

Learning goals: technical skills

• Ability to implement basic visual computing algorithms, understanding their strengths and shortcomings
• Mathematical modelling of computational problems in visual computing
• Gain an intuition which algorithm is best applied for which problem in visual computing, so that practical problems in these areas can be solved

Learning goals: soft skills

• Problem solving skills: ability to identify and utilise analogies between new problems and previously seen ones
• Analytical and abstract thinking: develop a general intuition of computational problems, being able to adopt different perspectives of particular concepts

Contents

This module focuses on discrete models that frequently occur in the field of visual computing (VC).

In addition to algorithms, this module will also cover modelling aspects that are relevant for solving practical problems in VC.

The contents include:

• Graph-based models (e.g. linear and quadratic assignment, network flows, product graph formalisms, dynamic programming and their application)
• Continuous algorithms for discrete problems (e.g. convex & spectral relaxations, projection methods, path-following and their application)
• Deep Learning for discrete domains (e.g. differentiable programming, graph neural networks, deep learning on meshes)

Prerequisites

Required:
No formal prerequisites

Recommended:
Participants are expected to have a high level of mathematical maturity (in particular, a good working knowledge of linear algebra and calculus is essential). A basic understanding of graph theory is advantageous.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved.

MA-INF 2226 Lab Geometry Processing

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
	Jun. Prof. Dr. Zorah Lähner

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Students will carry out a practical task (project) in the context of visual computing, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the respective area.

Contents

This lab introduces methods and applications in the field of geometry processing. You will get a chance to study the methods in depth by implementing them and running experiments. At the end of the semester, you will present the method, give a short demonstration and hand in a report describing the method and experimental outcomes.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 2227 Lab 3D Animation

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Ina Prinz	Prof. Dr. Ina Prinz

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1-3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of 3D animation, containing modelling, preparing a screenplay, realizing an animation related to real physical laws, rendering and creating a video.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area.

Contents

Varying selected topics close to current research in the are of the history of computing and the mechanization of computing as well as deep understanding of mechanical and technical functions and its presentation in a representative 3D animation video, contains technical visualization and didactic skills.

Prerequisites

Recommended:
- BA-INF 108 Geschichte des maschinellen Rechnens I
- BA-INF 126 Geschichte des maschinellen Rechnens II

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report, presentation of the video

Ungraded coursework (required for admission to the exam)

MA-INF 2307 Lab Vision

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Jürgen Gall	Prof. Dr. Jürgen Gall

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

The students will carry out a practical computer vision task (project).

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Computer Vision: research topics and applications

Prerequisites

Required:
MA-INF 2201 – Computer Vision

Good C++ or Python programming skills

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 2308 Lab Graphics

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Reinhard Klein	Prof. Dr. Reinhard Klein

Programme	Mode	Semester
M. Sc. Computer Science	Optional	3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of geometry processing, rendering, scientific visualization or human computer interaction, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Varying selected topics close to current research in the area of geometry processing, rendering, scientific visualization or human computer interaction.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 2309 Lab Audio

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
apl. Prof. Dr. Frank Kurth	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen

Programme	Mode	Semester
M. Sc. Computer Science	Optional	3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of audio and music processing, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area.

Contents

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 2310 Advanced Topics in Computer Graphics II

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Reinhard Klein	Prof. Dr. Reinhard Klein

Programme	Mode	Semester
M. Sc. Computer Science	Optional	3.

Learning goals: technical skills

Analytical formulation of problems related to geometry processing:

- apply methods of geometry processing
- apply basic concepts of statistical shape analysis and shape spaces to real world applications
- Design and implement novel application software in this area

Learning goals: soft skills

Based on the knowledge and skills acquired students should be able to

- read and judge current scientific literature in the area of geometry processing and gain an overview of the current state of the art
- identify the major literature relevant for solving a given problem in geometry processing
- present, propose and communicate different solutions and work in a team to solve geometry processing problems
- discuss geometry processing problems with researchers from different application fields

Contents

This course will first introduce the mathematical and algorithmic tools required to represent, model, and process 3D geometric objects. The second part discusses the latest mathematical, algorithmic, and statistical tools required for the analysis and modeling of 3D shape variability, which can facilitate the creation of 3D models. Topics among others will be

- classical and discrete differential geometry of curves and surfaces
- mesh data structures and generation of meshes from point clouds
- Laplacian operator and optimization techniques with applications to denoising, smoothing, decimation, shape fitting, shape descriptors, geodesic distances
- parameterization and editing of surfaces
- point cloud registration
- correspondences
- shape spaces and statistical shape analysis

In addition, results from state-of-the-art research will be presented.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature
• M. Botsch, L. Kobbelt, M. Pauly, P. Alliez, B. Levy, Polygon Mesh, Processing, A K Peters, 2010 • Laga, Hamid, Yulan Guo, Hedi Tabia, Robert B. Fisher, and Mohammed Bennamoun. 3D Shape analysis: fundamentals, theory, and applications. John Wiley & Sons, 2018. • Solomon, Justin. Numerical Algorithms. Textbook published by AK Peters/CRC Press, 2015

MA-INF 2312 Image Acquisition and Analysis in Neuroscience

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Thomas Schultz	Prof. Dr. Thomas Schultz

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1-4.

Learning goals: technical skills

Students will learn about image acquisition and analysis pipelines which are used in neuroscience. They will understand algorithms for image reconstruction, artifact removal, image registration and segmentation, as well as relevant statistical and machine learning techniques. A particular focus will be on data from Magnetic Resonance Imaging and on mathematical models for functional and diffusion MRI data.

Learning goals: soft skills

Productive work in small teams, self-dependent solution of practical problems in the area of biomedical image processing, presentation of solution strategies and implementations, self management, critical reflection of conclusions drawn from complex experimental data.

Contents

This course covers the full image formation and analysis pipeline that is typically used in biomedical studies, from image acquisition to image processing and statistical analysis.

Prerequisites

Recommended:
Mathematical background (calculus, linear algebra, statistics); imperative programming.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		3	45 T / 45 S	3
Exercises		1	15 T / 75 S	3

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

- B. Preim, C. Botha: Visual Computing for Medicine: Theory, Algorithms, and Applications. Morgan Kaufmann, 2014
- R.A. Poldrack, J.A. Mumford, T.E. Nichols: Handbook of Functional MRI Data Analysis. Cambridge University Press, 2011
- D.K. Jones: Diffusion MRI: Theory, Method, and Applications, Oxford University Press, 2011

MA-INF 2313 Deep Learning for Visual Recognition

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Reinhard Klein	Dr. Michael Weinmann

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1-4.

Learning goals: technical skills

Students will be introduced to the theory of neural networks and study various applications in computer vision and other topics in AI.

Learning goals: soft skills

Productive work in small teams, development and realization of individual approaches and solutions, critical reflection of competing methods, discussion in groups.

Contents

Deep learning has taken over the machine learning community by storm, with success both in research and commercially. Deep learning is applicable over a range of fields such as computer vision, speech recognition, natural language processing, robotics, etc. This course will introduce the fundamentals of neural networks and then progress to state-of-the-art convolutional and recurrent neural networks as well as their use in applications for visual recognition. Students will get a chance to learn how to implement and train their own network for visual recognition tasks such as object recognition, image segmentation and caption generation.

Prerequisites

Recommended:
Students are recommended to have a basic knowledge in probability and statistics and linear algebra as well as proficiency in programming (python or Matlab or C++).

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

No required text. Supplemental readings will be provided in the lecture.

MA-INF 2315 Seminar Computational Photography

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Matthias Hullin	Prof. Dr. Matthias Hullin

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 2316 Lab Digital Material Appearance

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Matthias Hullin	Prof. Dr. Matthias Hullin

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of the corresponding area, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 2317 Numerical Algorithms for Visual Computing and Machine Learning

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Florian Bernard	Prof. Dr. Florian Bernard

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

• ability to implement basic numerical algorithms, understanding their strengths and shortcomings
• mathematical modelling of computational problems in visual computing and machine learning
• gain an intuition which algorithm is best applied for which problem in visual computing and machine learning, so that practical problems in these areas can be solved

Learning goals: soft skills

• problem solving skills: ability to identify and utilise analogies between new problems and previously seen ones
• analytical and abstract thinking: develop a general intuition of computational problems, being able to adopt different perspectives of particular concepts

Contents

This module focuses on numerical methods that frequently occur in the fields visual computing (VC) and machine learning (ML). In addition to algorithms, this module will also cover modelling aspects that are relevant for solving practical problems in VC and ML. The contents include:

• Error analysis and conditioning of problems
• Linear systems (solvability, algorithms, stability, regularisation), and applications and modelling in VC and ML (e.g. linear regression, image alignment, deconvolution)
• Spectral methods (eigenvalue decomposition, singular value decomposition, respective algorithms), and their applications and modelling in VC and ML (e.g. clustering, Procrustes analysis, point-cloud alignment, principal components analysis)
• Numerical optimisation (gradient-based methods, second-order methods, large-scale optimisation) and applications and modelling in VC and ML.

Prerequisites

Required:
No formal prerequisites.

Recommended:
Participants are expected to have a high level of mathematical maturity (in particular, a good working knowledge of linear algebra and calculus is essential). A basic understanding of mathematical optimisation is advantageous.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

3 Information and Communication Management

MA-INF 3108 Secure Software Engineering

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Christian Tiefenau	Dr. Christian Tiefenau, Mischa Meier

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

The students are introduced to the security-relevant aspects of a software-engineering lifecycle. Therefore, the main ideas of including security throughout the development process will be presented and explained by examples.

By showing common vulnerabilities throughout this course, the students will get an understanding of common vulnerabilities and attacks and how to prevent them.

Learning goals: soft skills

In groups, the students will conduct practical exercises to strengthen the understanding of vulnerabilities and attack vectors. Through this, the abilities teamwork, time management, organization and critical discussion of their own and others' results are strengthened.

Contents

- Threat modeling
- Risk analysis
- Architectural security
- Secure coding
- Applied Cryptography
- Secure configuration and deployment
- Updates and maintenance

Prerequisites

Recommended:
Fundamental knowledge in software-engineering and IT-security concepts.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

Software Security: Building Security In by Gary McGraw

MA-INF 3109 Quantum Algorithms: Introduction and Data Fusion Examples

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Wolfgang Koch	Prof. Dr. Wolfgang Koch, Dr. Felix Govaers, Dr. Martin Ulmke

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Quantum algorithms for data fusion may become game changers as soon as quantum processing kernels embedded in hybrid processing architectures with classical processors will exist. While emerging quantum technologies directly apply quantum physics, quantum algorithms do not exploit quantum physical phenomena as such, but rather use the sophisticated framework of quantum physics to deal with "uncertainty". Although the link between mathematical statistics and quantum physics has long been known, the potential of physics-inspired algorithms for data fusion has just begun to be realized. While the implementation of quantum algorithms is to be considered on classical as well as on quantum computers, the latter are anticipated as well-adapted "analog computers" for unprecedentedly fast solving data fusion and resources management problems. While the development of quantum computers cannot be taken for granted, their potential is nonetheless real and has to be considered by the international information fusion community.

Learning goals: soft skills

- Problem solving
- Adaptability
- Critical thinking

Contents

- Introduction with Examples
- Short introduction to quantum mechanics
- Introduction to quantum computing
- Quantum computing hardware
- Quantum inspired tracking
- Particle filtering and fermionic target tracking
- The data association problem
- Track extraction and sensor management
- Quantum computing for multi target tracking data association
- Quantum computing for resources management
- Quantum many particle systems and boson sampling
- Path Integrals

Prerequisites

Recommended:
One of the following:

- BA-INF 137 – Einführung in die Sensordatenfusion
- MA-INF 3310 – Introduction to Sensor Data Fusion - Methods and Applications

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

MA-INF 3140 Advanced Computer Forensics

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Christian Tiefenau	Dr. Christian Tiefenau

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1., 2. or 3.

Learning goals: technical skills

The course covers advanced research topics in computer forensics and secure software engineering.

Learning goals: soft skills

Contents

Theoretical and practical aspects of computer forensics and secure software engineering are covered.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Succesful exercise participation

MA-INF 3202 Mobile Communication

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Peter Martini	Prof. Dr. Peter Martini, Dr. Matthias Frank

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Knowledge about key concepts of mobile communication including mobility management (both technology independent and technology dependent), knowledge about wireless technologies and their interaction with other protocol layers and/or other network technologies, ability to evaluate and assess scenarios with communication of mobile devices. In-depth understanding of communication paradigms of wireless/mobile systems and network elements, productive work in small groups, strengthening skills on presentation and discussion of solutions to current challenges

Learning goals: soft skills

Theoretical exercises to support in-depth understanding of lecture topics and to stimulate discussions, practical exercises in teamwork to support time management, targeted organisation of practical work and critical discussion of own and others' results

Contents

Mobility Management in the Internet, Wireless Communication Basics, Wireless Networking Technologies, Cellular/Mobile Communication Networks (voice and data communication), Ad-hoc and Sensor Networks.

Prerequisites

Recommended:
Bachelor level knowledge of basics of communication systems (e.g. BA-INF 101 "Kommunikation in Verteilten Systemen" (German Bachelor Programme Informatik, English lecture slides available)

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to three students. A total of 50% of the points must be achieved. For 70% of the exercise sheets, 20% of the points must be achieved for each sheet.

Literature

- Jochen Schiller: Mobile Communications, Addison-Wesley, 2003
- William Stallings: Wireless Communications and Networking, Prentice Hall, 2002
- Further up-to-date literature will be announced in due course before the beginning of the lecture

MA-INF 3209 Seminar Selected Topics in Communication Management

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	at least every year

Module coordinator	Lecturer(s)
Prof. Dr. Peter Martini	Prof. Dr. Peter Martini, Prof. Dr. Michael Meier

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current conference and journal papers, current standardization drafts

Prerequisites

Required:
Successful completion of at least one of the following lectures: Principles of Distributed Systems (MA-INF3105), Network Security (MA-INF3201), Mobile Communication (MA-INF3202), IT Security (MA-INF3236)

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The relevant literature will be announced towards the end of the previous semester

MA-INF 3216 Seminar Sensor Data Fusion

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
P.D. Dr. Wolfgang Koch	P.D. Dr. Wolfgang Koch, Dr. Felix Govaers

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current conference and journal papers

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The relevant literature will be announced at the beginning of the seminar.

MA-INF 3229 Lab IT-Security

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Michael Meier	Prof. Dr. Michael Meier

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of IT Security, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 3233 Advanced Sensor Data Fusion in Distributed Systems

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
PD Dr. Wolfgang Koch	Dr. Felix Govaers

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

For challenging state estimation tasks, algorithms which enhance the situational awareness by fusing sensor information are inevitable. Nowadays it has become very popular to improve the performance of systems by linking multiple sensors. This implies some challenges to the sensor data fusion methodologies such as sensor registration, communication delays, and correlations of estimation errors. In particular, if the communication links have limited bandwidth, data reduction techniques have to be applied at the sensor sites, that is local tracks have to be computed. Once recieved at a fusion center (FC), the tracks then are fused to reconstruct a global estimate. In this lecture, methodologies to a achieve a distributed state estimation are considered. Among these are tracklet fusion, the Bar-Shalom-Campo formula, the Federated Kalman Filter, naive fusion, the distributed Kalman filter and the least squares estimate.

Learning goals: soft skills

Mathematical derivation of algorithms, application of mathematical results on estimation theory.

Contents

tracklet fusion, the Bar-Shalom-Campo formula, the Federated Kalman Filter, naive fusion, the distributed Kalman filter and the least squares estimate, Accumulated State Densities, Decorrlated fusion, product representation

Prerequisites

Recommended:
At least 1 of the following:

BA-INF 137 – Einführung in die Sensordatenfusion

MA-INF 3310 – Introduction to Sensor Data Fusion - Methods and Applications

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

50% of the maximum achievable points in the practical programming exercises are required. The delivery of the programmed solution is done individually or in group work of up to three students. A total of 10 points will be awarded, 50% of which will have been achieved if the Distributed Kalman filter has been programmed in an executable and consistent manner.

Forms of media

Power Point

Literature

W. Koch: "Tracking and Sensor Data Fusion: Methodological Framework and Selected Applications", Springer, 2014.

D. Hall, C.-Y. Chong, J. Llinas, and M. L. II: "Distributed Data Fusion for Network-Centric Operations", CRC Press, 2014.

MA-INF 3236 IT Security

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Michael Meier	Prof. Dr. Michael Meier

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1. or 2.

Learning goals: technical skills

Students are introduced to a variety of active research fields in IT security. Students learn about the motivation, challenges and objectives in these fields. Additionally, they get to know selected fundamental knowledge and methods helping them to deepen their knowledge in their upcoming studies.

Learning goals: soft skills

working in small groups on exercises, critical discussion of own and others' results, time management, transfering theoretical knowledge to practical scenarios

Contents

The contents vary but usually include

- Privacy
- Cryptographic Protocols
- Network Security
- Supply Chain Attacks
- Management of Identity Data
- Low-level software analysis
- Software testing
- Side Channel Attacks
- Anomaly Detection
- Human Factor in Security

Prerequisites

Required:
Fundamental knowledge in the following areas: operating systems, networks, security

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

MA-INF 3237 Array Signal and Multi-channel Processing

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Wolfgang Koch	Dr. Marc Oispuu

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Localization of multiple sources using passive sensors is a fundamental task encountered in various fields like wireless communication, radar, sonar, and seismology. In this lecture, a unified framework for electromagnetic and acoustic signals and signal processing techniques are presented. Furthermore, the sensor calibration, direction finding, and bearings-only localization problem are considered. Special applications are emphasized, like small airborne arrays for unmanned aerial vehicles (UAVs).

Learning goals: soft skills

Mathematical derivation of algorithms, applications of mathematical results on estimation theory

Contents

Estimation theory, Sensor model, Cramér-Rao analysis, conventional beamforming, Multiple Signal Classification (MUSIC), sensor calibration, Bearings-only localization, Direct Position Determination (DPD), Applications

Prerequisites

Recommended:
Recommended: F. Kurth: "Foundations of Audio Signal Processing" (MA-INF 2113)

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral Exam

Ungraded coursework (required for admission to the exam)

50% of the maximum achievable points in the practical programming exercises are required. The delivery of the programmed solution is done individually or in group work of up to three students. A total of 10 points will be awarded, 50% of which will have been achieved if the basic signal processing algorithms for array sensors have been implemented.

Forms of media

Power Point

Literature

H. L. van Trees, Optimum Array Processing. Part IV of Detection, Estimation, and Modulation Theory. New York: Wiley-Interscience, 2002.

MA-INF 3238 Side Channel Attacks

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Felix Boes	Dr. Felix Boes

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

- Students are introduced to theoretical and practical side channel effects of modern hardware.
- Students learn techniques to utilize these effects to circumvent security mechanisms.
- This includes covert channels as well as side channel attacks and microarchitectural attacks on modern CPUs.

Learning goals: soft skills

Theoretical exercises to support in-depth understanding of lecture topics and to stimulate discussions, practical exercises in teamwork to support time management, targeted organization of practical work and critical discussion of own and others' results.

Contents

- Theoretical foundations of side channel effects and attacks as well as
- covert channels,
- differential power analysis,
- padding oracle,
- RSA timing attacks,
- cache based side channel effects,
- microarchitectural attacks (Spectre)

Prerequisites

Recommended:
Fundamental knowledge about IT Security, operating systems and statistics is advantageous but not mandatory.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written Exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

MA-INF 3239 Malware Analysis

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Peter Martini	Prof. Dr. Elmar Padilla

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

The students should be able to analyze the functional scope of a binary file independently and to describe its damage potential. In addition, the students should be able to carry out detailed analyzes of given aspects and to partially automate these with the help of scripts.

Learning goals: soft skills

Presentation of solutions and methods, critical discussion of applied methods and techniques.

Contents

In the course, the skills acquired so far in binary analysis will first be deepened and adapted to the peculiarities of malware analysis. Different malware samples are used to explain the techniques used by malware authors. These priorities include:

- Characteristics of malware
- Persistence
- Network communication
- Encryption
- Dynamic malware analysis
- Debugging
- Behavioral obfuscation
- Virtual analysis environments
- Static malware analysis
- Control flow obfuscation
- Automation of common analysis steps
- Reconstruction of binary algorithms

The event begins with several lectures that provide the basics for the students to work independently later. In the course of this, the students will work on practical topics from the field of malware analysis during the semester. Since these subject areas can turn out to be very specific, it is necessary to be willing to deal with the subject outside of the lecture and exercise times.

Prerequisites

Required:
none

Recommended:
Basic knowledge of operating systems (kernel, threads, virtual memory), network communication (protocols, architectures), binary analysis (assembler, endianness, semantic gap, coding), software development (programming, semantics, scripting in Python)

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved.

Literature

The relevant literature will be announced at the beginning of the lecture

MA-INF 3241 Practical Challenges in Human Factors of Security and Privacy

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Matthew Smith	Prof. Dr. Matthew Smith

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

After completing the unit students will be able to conduct related work searchers to get a deep understanding into the state of the art. They will be able to design, run and evaluate scientific studies in this area.

Learning goals: soft skills

Contents

In this course we will learn about and develop solutions for a specific challenge concerning human factors in security and privacy.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		1	15 T / 45 S	2
Exercises		3	45 T / 75 S	4

T = face-to-face teaching
S = independent study

Graded exams

Project work

Ungraded coursework (required for admission to the exam)

Successful exercise participation

MA-INF 3242 Security of Distributed and Resource-constrained Systems

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Michael Meier	Dr. Thorsten Aurisch

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Ability to understand and analyse theoretical and practical cyber security challenges of distributed and ressource-constrained systems, as well as the ability to select and apply appropriate solutions.

Learning goals: soft skills

Contents

- Group communication with IP multicast
- Group key management
- Broadcast encryption
- Public key infrastructure
- Web of trust
- Multicast infrastructure protection
- Distributed security mechanisms
- Cyber resilience in groups
- Security in tactical radio networks
- Security for IoT

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

MA-INF 3304 Lab Communication and Communicating Devices

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Peter Martini	Prof. Dr. Peter Martini, Prof. Dr. Michael Meier

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of communication systems, including test and documentation of the implemented software/system.

Learning goals: soft skills

Work in small teams and cooperate with other teams in a group; ability to make design decisions in a practical task; present and discuss (interim and final) results in the team/group and to other students; prepare written documentation of the work carried out

Contents

Selected topics close to current research in the area of communication systems, network security, mobile communication and communicating devices.

Prerequisites

Required:
Successful completion of at least one of the following lectures: Principles of Distributed Systems (MA-INF3105), Network Security (MA-INF3201), Mobile Communication (MA-INF3202), IT Security (MA-INF3236)

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The relevant literature will be announced towards the end of the previous semester.

MA-INF 3305 Lab Information Systems

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	at least every year

Module coordinator	Lecturer(s)
Dr. Thomas Bode	Dr. Thomas Bode

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of information systems, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Varying selected topics close to current research in the area of database- and information systems.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The relevant literature will be announced towards the end of the previous semester.

MA-INF 3309 Lab Malware Analysis

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Peter Martini	Prof. Dr. Peter Martini, Prof. Dr. Michael Meier

Programme	Mode	Semester
M. Sc. Computer Science	Optional	3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of communication systems with a specific topic focus on Malware Analysis and Computer/Network Security, including test and documentation of the implemented software/system.

Learning goals: soft skills

Work in small teams and cooperate with other teams in a group; ability to make design decisions in a practical task; present and discuss (interim and final) results in the team/group and to other students; prepare written documentation of the work carried out

Contents

Selected topics close to current research in the area of communication systems, malware analysis, computer and network security.

Prerequisites

Required:
Successful completion of at least one of the following lectures: Principles of Distributed Systems (MA-INF3105), Network Security (MA-INF3201), Mobile Communication (MA-INF3202), IT Security (MA-INF3236)

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 3310 Introduction to Sensor Data Fusion - Methods and Applications

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Wolfgang Koch	Prof. Dr. Wolfgang Koch

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1-3.

Learning goals: technical skills

All participants shall get known to the basic theory of sensor data fusion. The lecture starts with preliminaries on how to handle uncertain data and knowledge within analytical calculus. Then, the fundamental and well-known Kalman filter is derived. Based on this tracking scheme, further approaches to a wide spectrum of applications will be shown. All algorithms will be motivated by examples from ongoing research projects, industrial cooperations, and impressions of current demonstration hardware.

Because of inherent practical issues, every sensor measures certain properties up to an error. This lecture shows how to model and overcome this error by an application of theoretical tools such as Bayes' rule and further derivations. Moreover, solutions to possible false-alarms, miss-detections, maneuvering phases, and much more will be presented.

Learning goals: soft skills

Mathematical derivation of algorithms, application of mathematical results on estimation theory.

Contents

Gaussian probability density functions, Kalman filter, Unscented Kalman Filter, Extended Kalman Filter, Particle Filter, Multi-Hypothesis-Trackier, Extended Target Tracking, Road Tracking, Interacting Multiple Model Filter, Retrodiction, Smoothing, Maneuver Modeling

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

W. Koch: "Tracking and Sensor Data Fusion: Methodological Framework and Selected Applications", Springer, 2014.

Y. Bar-Shalom: "Estimation with Applications to Tracking and Navigation", Wiley-Interscience, 2001.

MA-INF 3312 Lab Sensor Data Fusion

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Wolfgang Koch	Prof. Dr. Wolfgang Koch

Programme	Mode	Semester
M. Sc. Computer Science	Optional	3.

Learning goals: technical skills

The students will work together on a data fusion project using various sensor hardware. Latest algorithms for fusing information from several nodes will be implemented.

Learning goals: soft skills

The students shall work together in a team. Everyone is responsible for a specific part in the context of a main goal. Results will be exchanged and integrated via software interfaces.

Contents

Varying selected topics on sensor data fusion.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

The relevant literature will be announced at the beginning of the lab.

MA-INF 3317 Seminar Selected Topics in IT Security

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Michael Meier	Prof. Dr. Michael Meier, Prof. Dr. Peter Martini

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current conference and journal papers

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 3319 Lab Usable Security and Privacy

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Matthew Smith	Prof. Dr. Matthew Smith

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of usable security and privacy, including user studies.

Learning goals: soft skills

Ability to create and defend a scientific user study

Contents

Students have a great degree of freedom to chose their own topics within the context of human aspects of security and privacy.

Prerequisites

Required:
Knowledge on how to run and evaluate user studies is required, for example as it is taught in BA-INF 145 - Usable Security and Privacy.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 3320 Lab Security in Distributed Systems

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Matthew Smith	Prof. Dr. Matthew Smith

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of distributed security, including documentation of the implemented software/system.

Strong programming skills required.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Security in distributed systems, including amongst others:

- Secure Messaging
- App Security
- SSL/HTTPS
- API Security
- Machine Learning for Security
- Passwords
- Intrusion Detection Systems
- Anomaly Detection
- Security Visualisation

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 3321 Seminar Usable Security and Privacy

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Matthew Smith	Prof. Dr. Matthew Smith

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current conference and journal papers

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 3322 Applied Binary Exploitation

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Peter Martini	Prof. Dr. Elmar Padilla

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Static and dynamic program analysis, Exploitation (Stack-based Buffer Overflows, Format String Exploits, Heap Exploitation, Use-After-Free Exploits) and Countermeasures (Stack Cookies, NX, ASLR, RELRO)

Learning goals: soft skills

Frustration tolerance when working with binary representations and trying to apply taught techniques, focussed working on technically challenging problems, simultaneously applying knowledge from different areas of computer science

Contents

Our computers run a lot of closed source binary programs meaning that the source code of those programs is not available. Naturally, those programs contain bugs, mistakes that the programmer made during the development. Those bugs could (under certain circumstances) be exploited by attackers and thus may lead to arbitrary code execution. In this lecture we aim to teach you how to find well known exploitable bugs and how to exploit them. After a brief recap of basic binary program analysis such as static and dynamic analysis, we will talk about vulnerability discovery in general, meaning that you will learn how to find exploitable bugs by yourself. Next we move on to basic stack-based buffer overflows and add mitigation techniques (stack cookies, NX, ASLR, RELRO, ...) as we progress and exploit them as well. After we finished the topic of stack-based buffer overflows we move on to more advanced topics such as heap exploitation, use-after-free exploits and others. The lecture ends with an introduction to fuzzing and an analysis of a sophisticated real-world exploit.

Prerequisites

Required:
none

Recommended:
- Binary Analysis skills (Lecture: "Applied Binary Analysis" BA-INF 155)
- Basic knowledge of the Linux operating system
- System Programming skills in C (Lecture: "Systemnahe Programmierung")
- Basic Python programming skills

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral Examination

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to three students. A total of 50% of the points must be achieved. The exercises are divided into group tasks (four per exercise sheet) and tasks to be completed individually (one per exercise sheet) and the points to be achieved apply separately to both categories.

Literature

The relevant literature will be announced at the beginning of the lecture

MA-INF 3323 Lab Fuzzing Bootcamp

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Matthew Smith	Dr. Christian Tiefenau

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of fuzz testing, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 3324 Lab Design of Usable Security Mechanisms

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Matthew Smith	Dr. Emmanuel von Zezschwitz

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of usable security mechanisms, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

4 Intelligent Systems

MA-INF 4111 Principles of Machine Learning

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every 2 years

Module coordinator	Lecturer(s)
Prof. Dr.-Ing. Christian Bauckhage	Prof. Dr.-Ing. Christian Bauckhage

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1.

Learning goals: technical skills

Upon successful completion of this module, students should be able to describe fundamental methods, algorithms, and use cases of machine learning. Students acquire knowledge about supervised and unsupervised learning; based on the knowledge and skills acquired, students should be able to

• Implement, algorithms for optimization and parameter estimation in model training and machine learning tasks.
• Adopt the fundamental methods they learned about to a wide range of problems in automated intelligent data analysis.

Learning goals: soft skills

In the exercises, students can put their knowledge about theoretical concepts, mathematical methods, and algorithmic approaches into practice and realize small projects involving the implementation and evaluation of machine learning algorithms. This requires teamwork; upon successful completion of the module, students should be able to

• draft and implement basic machine learning algorithms for various practical problem settings
• prepare and give oral presentations about their work in front of an audience

Contents

Fundamental machine learning models for classification and clustering, model training via minimization of loss functions, fundamental optimization algorithms, model regularization, kernel methods for supervised and unsupervised learning, probabilistic modeling and inference, dimensionality reduction and latent factor models, the basic theory behind neural networks and neural network training; This course is intended to lay the foundation for more advanced courses on modern deep learning and reinforcement learning.

Prerequisites

Recommended:
Linear algebra, statistics, probability theory, calculus, python programming

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Forms of media

• lecture slides / lecture notes are made available online
• notebooks with programming examples are made available online

Literature

• D.J.C MacKay: Information Theory, Inference and Learning Algorithms, Cambridge University Press, 2003
• C.M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006
• S. Haykin: Neural Networks and Learning Machines, Pearson, 2008

MA-INF 4112 Algorithms for Data Science

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Stefan Wrobel	Dr. Tamas Horvath, Prof. Dr. Stefan Wrobel

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1.

Learning goals: technical skills

In this module the students will learn algorithms for data science as well as implement and practice selected algorithms from this field. The module concentrates on basic algorithms in association rule mining, graph mining, and data streams. At the end of the module, students will be capable of analyzing formal properties of this kind of algorithms and choosing appropriate pattern discovery and data stream algorithms.

Learning goals: soft skills

Communicative skills (oral and written presentation of solutions, discussions in teams), self-competences (ability to accept and formulate criticism, ability to analyse, creativity in the context of an "open end" task), social skills (effective team work and project planning).

Contents

The module is offered every year, each time concentrating on one or more specific issues, such as frequent, closed and maximal frequent itemset mining, frequent subgraph mining algorithms for forests and for other graph classes beyond forests, frequent items and frequency moments in data streams, and graph stream algorithms.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Forms of media

lectures, exercises

Literature

- Avrim Blum, John Hopcroft, Ravindran Kannan: Foundations of Data Science. Cambridge University Press, 2020.
- Jiawei Han, Micheline Kamber, Jian Pei: Data Mining: Concepts and Techniques. Morgan Kaufmann Publishers, 2012.
- David J. Hand, Heikki Mannila and Padhraic Smyth: Principles of Data Mining. The MIT Press, 2001.

MA-INF 4113 Cognitive Robotics

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Prof. Dr. Sven Behnke

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1. or 2.

Learning goals: technical skills

This lecture is one of two introductory lectures of the intelligent systems track. The lecture covers cognitive capabilities of robots, like self-localization, mapping, object perception, and action-planning in complex environments.

This module complements MA-INF 4114 and can be taken before or after that module.

Learning goals: soft skills

Communicative skills (oral and written presentation of solutions, discussions in small teams), self competences (ability to accept and formulate criticism, ability to analyze problems)

Contents

Probabilistic approaches to state estimation (Bayes Filters, Kalman Filter, Particle Filter), motion models, sensor models, self-localization, mapping with known poses, simultaneous mapping and localization (SLAM), iterated closest-point matching, path planning, place- and person recognition, object recognition.

Prerequisites

Required:
MA-INF 4101 - Theory of Sensorimotor Systems has not been passed.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008.
- R. Szeliski: Computer Vision: Algorithms and Applications, Springer 2010.

MA-INF 4114 Robot Learning

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Prof. Dr. Sven Behnke, Dr. Nils Goerke

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1. or 2.

Learning goals: technical skills

This lecture is one of two introductory lectures of the intelligent systems track. Creating autonomous robots that can learn to assist humans in situations of daily life is a fascinating challenge for machine learning. The lecture covers key ingredients for a general robot learning approach to get closer towards human-like performance in robotics, such as reinforcement learning, learning models for control, learning motor primitives, learning from demonstrations and imitation learning, and interactive learning.

This module complements MA-INF 4113 and can be taken before or after that module.

Learning goals: soft skills

Communicative skills (oral and written presentation of solutions, discussions in small teams), self competences (ability to accept and formulate criticism, ability to analyze problems)

Contents

Reinforcement learning, Markov decision processes, dynamic programming, Monte Carlo methods, temporal-difference methods, function approximation, liear quadratic regulation, differential dynamic programming, partially observable MDPs, policy gradient methods, inverse reinforcement learning, imitation learning, learning kinematic models, perceiving and handling of objects.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved.

Literature

- R. Sutton and A. Barto: Reinforcement Learning, MIT-Press, 1998.
- O. Sigaud and J. Peters (Eds.): From Motor Learning to Interaction Learning in Robots. Springer, 2010.

MA-INF 4115 Introduction to Natural Language Processing

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Lucie Flek	Prof. Dr. Lucie Flek

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1. or 2.

Learning goals: technical skills

This class provides a technical perspective on NLP ? methods for building computer software that understands and manipulates human language. Contemporary data-driven approaches are emphasized, focusing on machine learning techniques. The covered applications vary in complexity, including for example Entity Recognition, Argument Mining, or Emotion Analysis.

Learning goals: soft skills

Group work during programming exercises will allow students to work on real-world NLP application projects. The final project offers you the chance to apply your newly acquired skills towards an in-depth application using different frameworks such as PyTorch and spaCy and present it in a poster session.

Contents

Through lectures, exercises, and a final project, you will gain a thorough introduction to cutting-edge research in NLP, from the linguistic basis of computational language methods to recent advances in deep learning and large language models. This course provides:

- An overview of NLP goals, challenges, and applications
- Text representation (Words, sentences, paragraphs, documents), word embeddings, word2vec, BERT, word similarity
- Machine learning / deep learning algorithms for text classification, Transformers
- Basics of neural language modeling
- Basics of computational linguistics

- Transforming words to their base forms (tokenization, stemming, lemmatization)

- Syntactic analysis (part of speech tagging, chunking, and parsing)

- Techniques for extracting meaning from text (semantic analysis), use of lexical resources in NLP

- NLP applications and projects (e.g., Sentiment Analysis, Named Entity Recognition, Question Answering, Summarization, Fake news detection, Plagiarism detection, Abusive language detection, Opinion mining...)

Prerequisites

Recommended:
- Basics of statistics recommended.
- Basic programming knowledge in Python is of advantage.
- Basics of machine learning are of advantage.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		3	45 T / 45 S	3
Exercises		1	15 T / 75 S	3

T = face-to-face teaching
S = independent study

Graded exams

Written exam (60 %); Project work (40 %)

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Forms of media

- Lecture slides
- Exercise slides
- Notebooks with programming examples

Literature

- J. Eisenstein: Introduction to Natural Language Processing
- Jurafsky, Daniel, and James H. Martin. "Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition."
- S. Bird, E. Klein, E. Loper; Natural Language Processing with Python

MA-INF 4116 AI Ethics Seminar

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Lucie Flek	Prof. Dr. Lucie Flek

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1. or 2.

Learning goals: technical skills

The seminar aims to introduce students to the ethical dilemmas of artificial intelligence. Students will develop skills in assessing AI systems, identifying ethical dilemmas and social impacts, reasoning through ethical and social issues, and communicating their reasoning.

Learning goals: soft skills

Students will learn about the design of ethical and socially responsible systems. They will gain practice engaging with multidisciplinary perspectives from behavioral and social science. At the end of the course, students will write a final term essay on one of the course topics.

Contents

We study artificial intelligence and the ethical dilemmas associated with the research, design, deployment, and interaction with AI systems.

Six broad modules structure the seminar:

- Foundations of AI and AI ethics
- Bias & fairness
- Privacy & data privacy
- Social networks & civility of communication
- Politics & policy
- AI for "social good"

A typical lecture will consist of 2-3 student presentations that focus on a research article and the broad context of its topic.

Following each presentation, we discuss the work with a focus on assessing relevant ethical issues and potential approaches for ethical design and engineering.

Prerequisites

Required:
No previous knowledge is required.

Recommended:
Previously attended classes in machine learning, robotics, data mining, or related, can be useful for understanding the topics but are not a must.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

MA-INF 4201 Artificial Life

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Nils Goerke	Dr. Nils Goerke

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1-3.

Learning goals: technical skills

Detailed understanding of the most important approaches and principles of artificial life. Knowledge and understanding of the current state of research in the field of artificial life

Learning goals: soft skills

Capability to identify the state of the art in artificial life, and to present and defend the found solutions within the exercises in front of a group of students. Critical discussion of the results of the homework.

Contents

Foundations of artificial life, cellular automata, Conway's "Game of Life"; mechanisms for structural development; foundations of nonlinear dynamical systems, Lindenmeyer-systems, evolutionary methods and genetic algorithms, reinforcement learning, artificial immune systems, adaptive behaviour, self-organising criticality, multi-agent systems, and swarm intelligence, particle swarm optimization.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions twice.

Forms of media

Pencil and paper work, explain solutions in front of the exercise group, implementation of small programs, use of simple simulation tools.

Literature

- Christoph Adami: Introduction to Artificial Life, The Electronic Library of Science, TELOS, Springer-Verlag
- Eric Bonabeau, Marco Dorigo, Guy Theraulaz: Swarm Intelligence: From Natural to Artificial Systems, Oxford University Press, Santa Fe Institute Studies in the Science of Complexity.
- Andrzej Osyczka: Evolutionary Algorithms for Single and Multicriteria Design Optimization, Studies in Fuzzyness and Soft Computing, Physica-Verlag, A Springer-Verlag Company, Heidelberg

MA-INF 4203 Autonomous Mobile Systems

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Dr. Dirk Schulz, Prof. Dr. Sven Behnke

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Profound knowledge of development and test regarding structure and function of learning, autonomous, mobile systems; Knowledge of the computational, mathematical, and technical requirements for the design of autonomous systems for specific applications and for specific functional environments

Learning goals: soft skills

The students will be capable to assess applications for autonomous mobile systems. They will be capable to identify what part of the applications might be improved by using state of the art developments. The student will learn how to plan and implement a software project in small working groups.

Contents

Requirements for the implementation of autonomous mobile systems, e.g. for: map making, dead reckoning, localisation, SLAM-methods, various principles of robot path planning; methods for action planning. Comparison of different learning paradigms for specific applications.

Prerequisites

Recommended:
any of the following:

MA-INF 4101 – Theory of Sensorimotor Systems

MA-INF 4113 – Cognitive Robotics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

- J. Buchli: Mobile Robots: Moving Intelligence, Published by Advanced Robotic Systems and Pro Literatur Verlag
- Sebastian Thrun, Wolfram Burgard, Dieter Fox: Probabilistic Robotics, MIT Press, 2005
- Howie Choset et al.: Principles of Robot Motion, MIT-Press, 2005

MA-INF 4204 Technical Neural Nets

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Nils Goerke	Dr. Nils Goerke

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1-3.

Learning goals: technical skills

Detailed knowledge of the most important neural network approaches and learning algorithms and its fields of application. Knowledge and understanding of technical neural networks as Non-Von Neumann computer architectures similar to concepts of brain functions at different stages of development

Learning goals: soft skills

The students will be capable to propose several paradigms from neural networks that are capable to solve a given task. They can discuss the pro and cons with respect to efficency and risk. The will be capable to plan and implement a small project with state of the art neural network solutions.

Contents

Multi-layer perceptron, radial-basis function nets, Hopfield nets, self organizing maps (Kohonen), adaptive resonance theory, learning vector quantization, recurrent networks, back-propagation of error, reinforcement learning, Q-learning, support vector machines, pulse processing neural networks. Exemplary applications of neural nets: function approximation, prediction, quality control, image processing, speech processing, action planning, control of technical processes and robots. Implementation of neural networks in hardware and software: tools, simulators, analog and digital neural hardware.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Forms of media

Pencil and paper work, explaining solutions in front of the exercise group, implementation of small programs, use of simple simulation tools

Literature

- Christopher M. Bishop: Neural Networks for Pattern Recognition, Oxford University Press, ISBN-10: 0198538642, ISBN-13: 978-0198538646
- Ian T. Nabney: NETLAB. Algorithms for Pattern Recognition, Springer, ISBN-10: 1852334401, ISBN-13: 978-1852334406
- David Kriesel: A brief Introduction on Neural Networks, http://www.dkriesel.com/en/science/neural_networks
- David Kriesel: Ein kleiner Überblick über Neuronale Netze, http://www.dkriesel.com/science/neural_networks
- Simon Haykin: Neural Networks, and Learning Machines, 3rd Edition,

Prentice Hall International Editions.

MA-INF 4208 Seminar Vision Systems

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Prof. Dr. Sven Behnke, Prof. Dr. Joachim K. Anlauf, Dr. Nils Goerke

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

• Knowledge in advanced topics in the area of technical vision systems, such as image segmentation, feature extraction, and object recognition.
• Ability to understand new research results presented in original scientific papers and to present them in a research talk as well as in a seminar report.

Learning goals: soft skills

Self-competences (time management, literature search, self-study), communication skills (preparation and clear didactic presentation of research talk, scientific discussion, structured writing of seminar report), social skills (ability to formulate and accept criticism, critical examination of research results).

Contents

Current research papers from conferences and journals in the field of vision systems covering fundamental techniques and applications.

Prerequisites

Recommended:
At least 1 of the following:

MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning

MA-INF 4204 – Technical Neural Nets

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

• R. Szeliski: Computer Vision: Algorithms and Applications, Springer 2010.
• C. M. Bishop: Pattern Recognition and Machine Learning, Springer 2006.
• D. A. Forsyth and J. Ponce: Computer Vision: A Modern Approach, Prentice Hall, 2003.

MA-INF 4209 Seminar Principles of Data Mining and Learning Algorithms

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Stefan Wrobel	Prof. Dr. Stefan Wrobel

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Enhanced and in-depth knowledge in specialized topics in the area of machine learning and data mining, acquiring the competence to independently study scientific literature, present it to others and discuss it with a knowledgeable scientific auditorium. Learn how to scientifically present prior work by others, in writing and in presentations.

Learning goals: soft skills

Communicative skills (preparing and presenting talks, written presentation of contents in a longer document), self competences (time management with long-ranging deadlines, ability to accept and formulate criticism, ability to analyse, creativity).

Contents

Theoretical, statistical and algorithmical principles of data mining and learning algorithms. Search and optimization algorithms. Specialized learning algorithms from the frontier of research. Fundamental results from neighbouring areas.

Prerequisites

Recommended:
At least 1 of the following:

MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning

MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Forms of media

Scientific papers and websites, interactive presentations.

Literature

The relevant literature will be announced towards the end of the previous semester.

MA-INF 4211 Seminar Cognitive Robotics

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Prof. Dr. Sven Behnke, Dr. Nils Goerke

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Knowledge in advanced topics in the area of cognitive robotics, such as robot perception, action planning, and robot learning.

Ability to understand new research results presented in original scientific papers and to present them in a research talk as well as in a seminar report.

Learning goals: soft skills

Self-competences (time management, literature search, self-study), communication skills (preparation and clear didactic presentation of research talk, scientific discussion, structured writing of seminar report), social skills (ability to formulate and accept criticism, critical examination of research results).

Contents

Current research papers from conferences and journals in the field of cognitive robotics covering fundamental techniques and applications.

Prerequisites

Recommended:
At least 1 of the following:

MA-INF 4113 – Cognitive Robotics

MA-INF 4114 – Robot Learning

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008.
- Selected papers.

MA-INF 4213 Seminar Humanoid Robots

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Maren Bennewitz	Prof. Dr. Maren Bennewitz

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Knowledge in advanced topics in the area of humanoid robotics, such as environment perception, state estimation, navigation, or motion planning. Ability to understand new research results of scientific papers and to present them in a talk as well as in a self-written summary.

Learning goals: soft skills

Self-competences (time management, literature search, self-study), communication skills (preparation of the talk, clear didactic presentation of techniques and experimental results, scientific discussion, structured writing of summary), social skills (ability to formulate and accept criticism, critical examination of algorithms and experimental results).

Contents

Current research papers from conferences and journals in the field of humanoid robotics covering fundamental techniques and applications.

Prerequisites

Recommended:
At least 1 of the following:

MA-INF 4215 – Humanoid Robotics

MA-INF 4113 – Cognitive Robotics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics
- K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer
- Selected papers.

MA-INF 4214 Lab Humanoid Robots

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Maren Bennewitz	Prof. Dr. Maren Bennewitz

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Practical experience and in-depth knowledge in the design and implementation of perception, state estimation, environment representation, navigation, and motion planning techniques for humanoid robots. In small groups, the participants analyze a problem, realize a solution, and perform an experimental evaluation.

Learning goals: soft skills

Self-competences (time management, goal-oriented work, ability to analyze problems theoretically and to find practical solutions), communication skills (collaboration in small teams, oral and written presentation of solutions, critical examination of implementations).

Contents

Robot middleware, perception, state estimation, environment representations, navigation, and motion planning for humanoid robots.

Prerequisites

Recommended:
At least 1 of the following:

MA-INF 4215 – Humanoid Robotics

MA-INF 4113 – Cognitive Robotics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics
- K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer
- Selected papers.

MA-INF 4215 Humanoid Robotics

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Maren Bennewitz	Prof. Dr. Maren Bennewitz

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2-3.

Learning goals: technical skills

This lecture covers techniques for humanoid robots such as perception, navigation, and motion planning.

Learning goals: soft skills

Communicative skills (oral and written presentation of solutions, discussions in small teams), ability to analyze problems.

Contents

Self-calibration with least squares, 3D environment representations, self-localization with particle filters, footstep planning, inverse kinematics, whole-body motion planning with rapidly exploring random trees, statistical testing.

Prerequisites

Recommended:
MA-INF 4113 – Cognitive Robotics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Literature

- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics
- K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer
- Selected research papers.

MA-INF 4216 Biomedical Data Science \&{} AI

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Holger Fröhlich	Dr. Holger Fröhlich

Programme	Mode	Semester
M. Sc. Computer Science	Optional	3.

Learning goals: technical skills

- understanding and knowledge of fundamental data mining and machine learning methods
- understanding of their application in bioinformatics

Learning goals: soft skills

- communication: oral and written presentation of solutions to exercises
- self-competences: ability to analyze application problems and to formulate possible solutions
- practical skills: ability to practically implement solutions
- social skills: working in a small team with other students

Contents

This lecture gives a broad overview about frequently used statistical techniques as well as data mining and machine learning algorithms. The use of the respective methods to solve problems in bioinformatics is explained. The goal is to understand the explained methods, being able to apply them correctly and partially implement them. More detailed, the following topics are covered in the context of their application in bioinformatics:

- Short introduction to Bioinformatics and Biomedicine
- Statistical Basics: Probability distributions and Bayesian inference, statistical hypothesis testing, linear models, logistic regression, Principal Component Analysis
- Clustering
- Hidden Markov Models
- Principles of Supervised Machine Learning
- Elastic Net
- Basics of deep learning

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

(i) The completion of regularly provided exercise sheets. The work can be done in groups of up to three students. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions once. (ii) Participation in an achievement test. On the test, at least 50% of the points much be achieved.

Literature

T. Hastie, R. Tibshirani, J. Friedman, The Elements of Statistical Learning, Springer, 2008

S.Boslaugh, P. Watters, Statistics in a Nutshell, O'Reilly, 2008

N. Jones, P. Pevzner, An Introduction to Bioinformatics Algorithms, MIT Press, 2004

MA-INF 4217 Seminar Machine Learning Methods in the Life Sciences

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Holger Fröhlich	Dr. Holger Fröhlich

Programme	Mode	Semester
M. Sc. Computer Science	Optional	4.

Learning goals: technical skills

- understanding and knowledge of machine learning methods and their application in modern life sciences, e.g. biomedicine

Learning goals: soft skills

- communication: oral scientific presentation of a defined topic
- self-competences: ability to identify relevant literature for a given topic; ability to read, understand and analyze scientific publications
- social skills: ability to discuss a scientific topic with other students and the staff

Contents

Machine learning techniques play a crucial role in modern life sciences, including biomedicine. The goal of this seminar is to discuss a variety of machine learning techniques in the context of their application to solve real-world problems in biomedicine.

Topics will be selected from the following areas:

- Ensemble learning
- Survival and disease progression models
- Bayesian Networks
- Stochastic processes, e.g. Gaussian Proceses, Dirichlet Process Mixture Models
- MCMC methods
- Deep learning methods, e.g. DNNs, CNNs, Deep Belief Networks
- feature selection and non-linear embedding methods
- multi-modal data fusion techniques

Attendees will be asked to perform research about their topic in a self-responsible manner.

Prerequisites

Recommended:
MA-INF 4216 – Data Mining and Machine Learning Methods in Bioinformatics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Forms of media

powerpoint

Literature

selected journal and conference papers

MA-INF 4226 Lab Parallel Computing for Mobile Robotics

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Maren Bennewitz	Prof. Dr. Maren Bennewitz

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Students will make practical experience with the design and implementation of parallelized algorithms in the context of motion planning and navigation.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Parallel programming on the GPU, CUDA, shortest path planning, collision checking, visibility graph, A* algorithm

Prerequisites

Recommended:
C++, Linux.

Since the exercises revolve around path planning, one of those courses might be helpful:

MA-INF 4203: Autonomous Mobile Systems

MA-INF 4113: Cognitive Robotics

MA-INF 4310: Lab Mobile Robots

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 4228 Foundations of Data Science

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Michael Nüsken	Dr. Michael Nüsken

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Knowledge: Peculiarities of high dimensional spaces in geometry and probabilities. Singular vector decomposition. Basics in machine learning and clustering.

Skills: Understanding of mathematical tools.

Learning goals: soft skills

Competences: Application to data science problems and ability to assess similar methods.

Contents

Data science aims at making sense of big data. To that end, various tools have to be understood for helping in analyzing the arising structures.

Often data comes as a collection of vectors with a large number of components. To understand their common structure is the first main objective of understanding the data. The geometry and the linear algebra behind them becomes relevant and enlightning. Yet, the intuition from low-dimensional space turns out to be often misleading. We need to be aware of the particular properties of high-dimensional spaces when working with such data. Fruitful methods for the analysis include singular vector decomposition from linear algebra and supervised and unsupervised machine learning. If time permits, we also consider random graphs, which are the second most used model for real world phenomena.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions twice.

Literature

Avrim Blum, John Hopcroft, and Ravindran Kannan (2018+). Foundations of Data Science.

MA-INF 4230 Advanced Methods of Information Retrieval

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Elena Demidova	Prof. Dr. Elena Demidova

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

This module introduces the students to the advanced methods, data structures, and algorithms of information retrieval for structured and semi-structured data (including, for example, knowledge graphs, relational data, and tabular data).

At the end of the module, the students will be capable of choosing appropriate data structures and retrieval algorithms for specific applications and correctly apply relevant statistical and machine learning-based information retrieval procedures.

Learning goals: soft skills

Communication skills: oral and written presentation and discussion of solutions.

Self-competences: ability to analyse and solve problems.

Contents

The module topics include data structures, ranking methods, and efficient algorithms that enable end-users to effectively obtain the most relevant search results from structured, heterogeneous, and distributed data sources. Furthermore, we will study the corresponding evaluation techniques as well as novel applications.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to three, four or five students, depending on the total number of students taking the course. A total of 50% of the points must be achieved. For 80% of the exercise sheets, 40% of the points must be achieved for each sheet. Each student must present a solution to an exercise in the exercise sessions once.

Literature

Selected chapters from:

• Christopher D. Manning, Prabhakar Raghavan and Hinrich Schütze, Introduction to Information Retrieval, Cambridge University Press. 2008.
• Bhaskar Mitra and Nick Craswell (2018), "An Introduction to Neural Information Retrieval ", Foundations and Trendső in Information Retrieval: Vol. 13: No. 1, pp 1-126.

- Ridho Reinanda, Edgar Meij and Maarten de Rijke (2020), "Knowledge Graphs: An Information Retrieval Perspective", Foundations and Trendső in Information Retrieval: Vol. 14: No. 4, pp 289-444.

- Jeffrey Xu Yu, Lu Qin, Lijun Chang. Keyword Search in Databases. Synthesis Lectures on Data Management. Morgan & Claypool Publishers. 2009.

Further references to relevant material will be provided during the lecture.

MA-INF 4231 Seminar Advanced Topics in Information Retrieval

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Elena Demidova	Prof. Dr. Elena Demidova

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

This module concentrates on specialized topics in information retrieval. The students obtain skills in the independent, in-depth study of state-of-the-art scientific literature on specific topics, discussion with their peers and presentation to the scientific audience.

Learning goals: soft skills

Communication skills: oral and written presentation of scientific content. Self-competences: the ability to analyze problems, time management, creativity.

Contents

Statistical and machine learning-based information retrieval methods, including typical steps of the information retrieval process: data collection, feature extraction, indexing, retrieval, ranking, and evaluation. Specialized data representation and retrieval methods for selected data types and applications in specific domains.

Prerequisites

Recommended:
MA-INF 4230 - Advanced Methods of Information Retrieval

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

None

Literature

Selected chapters from:

- Christopher D. Manning, Prabhakar Raghavan and Hinrich Schütze, Introduction to Information Retrieval, Cambridge University Press. 2008.
- Bhaskar Mitra and Nick Craswell (2018), "An Introduction to Neural Information Retrieval ", Foundations and Trendső in Information Retrieval: Vol. 13: No. 1, pp 1-126.

Further relevant literature will be announced at the beginning of the seminar.

MA-INF 4232 Lab Information Retrieval in Practice

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Elena Demidova	Prof. Dr. Elena Demidova

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

This module concentrates on practical experience in information retrieval. Participants acquire basic knowledge and practical experience in designing and implementing information retrieval systems for specific data types and applications.

Learning goals: soft skills

Communication skills: the ability to work in teams.

Self-competences: the ability to analyse problems and find practical solutions. Time management, creativity, presentation of results.

Contents

Practical application of information retrieval methods to solve retrieval problems on real-world data and evaluate proposed solutions.

Prerequisites

Recommended:
MA-INF 4230 - Advanced Methods of Information Retrieval

MA-INF 4231 - Seminar Advanced Topics in Information Retrieval

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

None

Literature

Selected chapters from:

- Christopher D. Manning, Prabhakar Raghavan and Hinrich Schütze, Introduction to Information Retrieval, Cambridge University Press. 2008.
- Bhaskar Mitra and Nick Craswell (2018), "An Introduction to Neural Information Retrieval ", Foundations and Trendső in Information Retrieval: Vol. 13: No. 1, pp 1-126.

Further references to relevant material will be provided during the lab.

MA-INF 4235 Reinforcement Learning

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every 2 years

Module coordinator	Lecturer(s)
Prof. Dr.-Ing. Christian Bauckhage	Prof. Dr.-Ing. Christian Bauckhage

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2-3.

Learning goals: technical skills

Upon successful completion of this module, students should be able to describe fundamental methods, algorithms, and use cases of reinforcement learning. Students acquire knowledge about underlying mathematical models and corresponding algorithms; based on the knowledge and skills acquired, students should be able to:

- implement algorithms for reinforcement learning problems;
- adopt the fundamental methods they learned about to a wide

range of problems in policy optimization.

Learning goals: soft skills

In the exercises, students can put their knowledge about theoretical concepts, mathematical methods, and algorithmic approaches into practice and realize small projects involving the implementation and evaluation of search- and policy learning algorithms. This requires teamwork; upon successful completion of the module, students should be

able to:

- draft and implement basic reward functions and policy learning algorithms for various practical problem settings;
- prepare and give oral presentations about their work in front of an audience.

Contents

State space models, tree search algorithms, Monte Carlo tree search,

Markov chain models, Markov decision processes, value functions,

reward functions, Bellman equations, policy learning, TD learning Q

learning, deep Q learning

Prerequisites

Required:
Linear algebra, statistics, probability theory, python programming

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to four students. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions once.

Forms of media

- lecture slides / lecture notes are made available online
- notebooks with programming examples are made available online

Literature

R.S. Sutton and A.G. Barto: Reinforcement Learning, 2nd ed., MIT Press,

2018

MA-INF 4236 Advanced Methods for Text Mining

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Rafet Sifa	

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2-4.

Learning goals: technical skills

Knowledge: Students will learn about the basic as well as the advanced methods for processing textual data, including necessary preprocessing steps such as stemming and lemmatization. They will also learn about representation learning methods, such as TF-IDF, Latent Semantic Indexing, Global Vectors, Recurrent Neural Networks, Transformer Networks, as well as the variants of the last such as Generative Pre-trained Transformers and Bidirectional Encoder Representations from Transformers, to extract meaningful embeddings for downstream tasks. The students will gain knowledge on how to build predictive and prescriptive methods for a variety of objectives, including text classification, outlier detection, and recommender systems. Additionally, they will learn how to categorize these methods based on their complexities and their applicability to different text mining problems, such as sentiment analysis, natural language inference, computational argumentation, information extraction, named entity recognition, text summarization, opinion mining, text segmentation, event detection, and more.

Skill: Students should be able to analyze, design as well as reason about existing and new data mining algorithms, theoretically compare algorithms, strengthen their analytical thinking to solve difficult modelling problems, have acquired the necessary mathematical as well as programming/IT skills to systematically plan, design and implement text and data mining projects.

Competences: Based on the knowledge and skills acquired in this module, the students will be able to assess certain characteristics of the already existing text mining methods as well as build new solutions to emerging problems. Additionally, the students will be able to transfer their knowledge to other data science areas involving modelling data with sequential dependencies.

Learning goals: soft skills

Contents

Neural Networks, Text Mining Pipelines, Stemming, Lemmatization, TF-IDF, Latent Semantic Indexing, Global Vectors, Recurrent Neural Networks, Transformer Networks, Generative Pre-trained Transformers, Bidirectional Encoder Representations, Prompt Analysis, Sentiment Analysis, Natural Language Inference, Computational Argumentation, Information Extraction, Named Entity Recognition, Text Summarization, Opinion Mining, Text Segmentation, Event Detection, Representation Learning and Applications

Prerequisites

Recommended:
Basic knowledge of AI, data science, machine learning, and pattern recognition; programming skills; good working knowledge in statistics, linear algebra, and optimization.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		1	15 T / 30 S	1.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation (written homework as well as the given programming assignments)

Literature

- Introduction to Information Retrieval, Christopher D. Manning, Prabhakar Raghavan and Heinrich Schütze
- Aggarwal, C. C. (2018). Machine learning for text (Vol. 848). Cham: Springer.
- Lecture notes of the instructors

MA-INF 4237 Natural Language Processing Lab

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Lucie Flek	Prof. Dr. Lucie Flek

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2-3.

Learning goals: technical skills

The Natural Language Processing (NLP) Lab course provides students with a detailed look at the recent advancements in NLP, covering various aspects such as large language models (LLMs), conversational systems, and computational social science. The course emphasizes a practical approach and offers you the opportunity to gain hands-on experience in developing NLP-based systems, allowing you to deepen your understanding of NLP technologies and apply theoretical knowledge to real-world scenarios.

Learning goals: soft skills

Through tutorials and a final project, you will gain practical skills in NLP techniques and have this chance to apply this knowledge to a various interesting project. Students will collaborate in small teams (a group of two students) and implement NLP applications over the course of the term. Each team is advised by one researcher of the CAISA Lab.

Contents

The course emphasizes a practical approach and offers you the opportunity to gain hands-on experience in developing NLP-based systems, allowing you to deepen your understanding of NLP technologies and apply theoretical knowledge to real-world scenarios.

Prerequisites

Required:
MA-INF 4115: Introduction to Natural Language Processing

Recommended:
- Basic programming knowledge in Python and Machine Learning
- Basics of Machine Learning
- Basic knowledge of Python Libraries for ML (NumPy, Scikit-Learn, Pandas)
- Basics of Probability, Linear Algebra and Statistics

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Successful exercise participation

MA-INF 4302 Advanced Learning Systems

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every 2 years

Module coordinator	Lecturer(s)
Prof. Dr. Stefan Wrobel	Prof. Dr. Stefan Wrobel

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Participants specialize and require in-depth knowledge of one particular class of learning algorithms, they acquire the necessary knowledge to improve existing algorithms and construct their own within the given class, all the way up to the research frontier on the topic.

Learning goals: soft skills

In group work, students acquire the necessary social and communication skills for effective team work and project planning, and learn how to present software projects to others.

Contents

The module each time concentrates on one or more specific algorithm classes, e.g.

- kernel machines
- neural networks
- probabilistic and statistical learning approaches
- logic-based learning approaches
- reinforcement learning

Prerequisites

Recommended:
all of the following:

MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning

MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Forms of media

lectures, exercises, software systems

Literature

- B. Schoelkopf, A.J. Smola, Learning with Kernels, The MIT Press, 2002, Cambridge, MA
- John Shawe-Taylor, Nello Christianini, Kernel Methods for Pattern Analysis, CUP, 2004
- Christopher Bishop, Pattern Recognition and Machine Learning, The University of Edinburgh, 2006
- David MacKay, Information Theory, Inference, and Learning Algorithms, 2003
- Richard Duda, Peter Hart, David Stork, Pattern Classification, John Wiley and Sons, 2001

MA-INF 4303 Learning from Non-Standard Data

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Stefan Wrobel	Prof. Dr. Stefan Wrobel, Dr. Tamas Horvath

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Participants deepen their knowledge of learning systems with respect to one particular non-standard data type, i.e., non-tabular data, as they are becoming increasingly important in many applications. Each type of data not only requires specialized algorithms but also knowledge of the surrounding pre- and postprocessing operations which is acquired by the participants in the module. In group work, students acquire the necessary social and communication skills for effective team work and project planning, and learn how to present software projects to others.

Learning goals: soft skills

Communicative skills (oral and written presentation of solutions, discussions in teams), self-competences (ability to accept and formulate criticism, ability to analyse, creativity in the context of an "open end" task)

Contents

The module will offered every year, concentrating on one particular non-standard data type each time, including: Text Mining, Multimedia Mining, Graph Mining. Learning from structured data, Spatial Data Mining

Prerequisites

Recommended:
all of the following:

MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning

MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Forms of media

lectures, exercises, software systems.

Literature

- Gennady Andrienko, Natalia Andrienko, Exploratory Analysis of Spatial and Temporal Data, Springer, 2006
- Diane J. Cook, Lawrence B. Holder, Mining Graph Data, Wiley & Sons, 2006
- Saso Dzeroski, Nada Lavrac, Relational Data Mining, Springer, 2001
- Sholom M. Weiss, Nitin Indurkhya, Tong Zhang, Fred J. Damerau, Text Mining. Predictive Methods for Analyzing Unstructured Information, Springer, 2004

MA-INF 4304 Lab Cognitive Robotics

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Prof. Dr. Sven Behnke

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Participants acquire practical experience and in-depth knowledge in the design and implementation of perception and control algorithms for complex robotic systems. In a small group, they analyze a problem, realize a state-of-the-art solution, and evaluate its performance.

Learning goals: soft skills

Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions), communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of implementations)

Contents

Robot middleware (ROS), simultaneous localization and mapping (SLAM), 3D representations of objects and environments, object detection and recognition, person detection and tracking, action recognition, action planning and control, mobile manipulation, human-robot interaction.

Prerequisites

Recommended:
At least 1 of the following:
MA-INF 4113 – Cognitive Robotics
MA-INF 4114 – Robot Learning

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008.
- Selected research papers.

MA-INF 4306 Lab Development and Application of Data Mining and Learning Systems

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Stefan Wrobel	Prof. Dr. Stefan Wrobel

Programme	Mode	Semester
M. Sc. Computer Science	Optional	3.

Learning goals: technical skills

Students will acquire in-depth knowledge in the construction and development of intelligent learning systems for machine learning and data mining. They learn how to work with existing state-of-the-art systems and apply them to application problems, usually extending them for the requirements of their particular task.

Learning goals: soft skills

Communicative skills (appropriate oral presentation and written documentation of project results), social skills (ability to work in teams), self-competences (time management, aiming at long-range goals under limited ressources, ability to work under pressure, ability to accept/formulate ciriticsm)

Contents

Data storage and process models of data analysis. Common open source frameworks for the construction of data analysis systems, specialized statistical packages. Pre-processing tools. Mathematical libraries for numerical computation. Search and optimization methods. User interfaces and visualization for analysis systems. Data analysis algorithms for embedded and distributed systems. Ubiquitous discovery systems.

Prerequisites

Recommended:
At least 1 of the following:

MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning

MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Forms of media

Computer Software, Documentation, Research Papers.

Literature

The relevant literature will be announced towards the end of the previous semester.

MA-INF 4308 Lab Vision Systems

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every semester

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Dr. Nils Goerke

Programme	Mode	Semester
M. Sc. Computer Science	Optional	3.

Learning goals: technical skills

Students will acquire knowledge of the design and implementation of parallel algorithms on GPUs. They will apply these techniques to accelerate standard machine learning algorithms for data-intensive computer vision tasks.

Learning goals: soft skills

Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions), communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of implementations)

Contents

Basic matrix and vector computations with GPUs (CUDA). Classification algorithms, such as multi-layer perceptrons, support-vector machines, k-nearest neighbors, linear-discriminant analysis. Image preprocessing and data handling. Quantitative performance evaluation of learning algorithms for segmentation and categorization.

Prerequisites

Recommended:
At least 1 of the following:

MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning

MA-INF 4204 – Technical Neural Nets

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

- R. Szeliski: Computer Vision: Algorithms and Applications, Springer 2010.
- C. M. Bishop: Pattern Recognition and Machine Learning, Springer 2006.
- NVidia CUDA Programming Guide, Version 4.0, 2011.

MA-INF 4309 Lab Sensor Data Interpretation

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
PD. Dr. Volker Steinhage	PD. Dr. Volker Steinhage

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Competence to implement algorithms for sensor data interpretation, efficient handling and testing, documentation.

Learning goals: soft skills

Efficient implementation of complex algorithms, abstract thinking, documentation of source code.

Contents

Varying selected up-to-date topics on sensor data interpretation

Prerequisites

Required:
MA-INF 2201 – Computer Vision

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

Relevant literature will be announced at start of the lab.

MA-INF 4310 Lab Mobile Robots

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	at least every year

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Prof. Dr. Sven Behnke, Dr. Nils Goerke

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Participants acquire basic knowledge and practical experience in the design and implementation of control algorithms for simple structured robotic systems using real mobile robots. Fundamental paradigms for mobile robots will be identified and implemented in 2 person groups.

Learning goals: soft skills

Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions), communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of implementations)

Contents

Robot middleware (e.g. ROS), robot simulation tools, basic capabilities for mobile robots: reactive control, SMPA architecture, navigation, path planning, localisation, simultaneous localization and mapping (SLAM), visual based object detection, learning robot control.

Prerequisites

Recommended:
At least 1 of the following:

BA-INF 132 – Grundlagen der Robotik

BA-INF 131 – Intelligente Sehsysteme

MA-INF 1314 – Online Motion Planning

MA-INF 2201 – Computer Vision

MA-INF 4113 – Cognitive Robotics

MA-INF 4114 – Robot Learning

MA-INF 4203 – Autonomous Mobile Systems

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Forms of media

Robots simulation environments, robot control middleware, computer vision libraries, programming, demonstration of robot capabilities (real robotic systems), presentation and written report of approach and results.

Literature

- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.
- J. Buchli: Mobile Robots: Moving Intelligence, Published by Advanced Robotic Systems and Pro Literatur Verlag
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008.
- Additional State-of-the-art publications.

MA-INF 4312 Semantic Data Web Technologies

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Jens Lehmann	Prof. Dr. Jens Lehmann, Dr. Christoph Lange, Dr. Maria Maleschkova

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1.

Learning goals: technical skills

The goal of this lecture is to impart knowledge on the fundamentals, technologies and applications of the Semantic Web and information retrieval. As part of the lecture the basic concepts and standards for semantic technologies are explained.

Learning goals: soft skills

Contents

As part of the W3C Semantic Web initiative standards and technologies have been developed for machine-readable exchange of data, information and knowledge on the Web. These standards and technologies are increasingly being used in applications and have already led to a number of exciting projects (e.g. DBpedia, semantic wiki or commercial applications such as schema.org, OpenCalais, or Google's Freebase). The module provides a theoretically grounded and practically oriented introduction to this area. The topics discussed within the lecture include:

- RDF syntax and data model
- RDF Schema and formal semantics of RDF (S)
- ontologies in OWL and formal semantics of OWL
- RDF databases, triple and knowledge stores, query languages
- Linked Data Web and Semantic Web applications
- Semantic text analysis and information retrieval systems

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

MA-INF 4313 Seminar Semantic Data Web Technologies

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	at least every year

Module coordinator	Lecturer(s)
Prof. Dr. Jens Lehmann	Dr. Christoph Lange, Dr. Maria Maleshkova

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

Through the seminar, students will learn to work with tools and technologies of the Semantic Web as well as assess their capabilities for given problems. They will gain the ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss technologies and research results in the framework of Semantic Web technologies.

Contents

- technologies such as triple stores, link discovery frameworks, NLP pipelines.
- recent conference and journal papers

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 4314 Lab Semantic Data Web Technologies

Workload	**Credit points**	**Duration**	**Frequency**
270 h	9 CP	1 semester	every year

Module coordinator	**Lecturer(s)**
Prof. Dr. Jens Lehmann	Prof. Dr. Jens Lehmann, Dr. Maria Maleschkova

Programme	**Mode**	**Semester**
M. Sc. Computer Science	Optional	2.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of Semantic Web technologies, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify own results with regard to the state-of-the-art

Contents

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 4316 Graph Representation Learning

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	at least every 2 years

Module coordinator	Lecturer(s)
Dr. Pascal Welke	Dr. Pascal Welke

Programme	Mode	Semester
M. Sc. Computer Science	Optional	1.

Learning goals: technical skills

• Deep understanding of the trade-off between expressiveness of graph representation and computational complexity, as well as practical runtime of algorithms in the context of machine learning applications.

- Ability to implement, practically apply, and theoretically analyze graph representation, graph kernels, and graph mining algorithms.

Learning goals: soft skills

• Social, methodological, and analytical competences via communication, own development, and presentation of problem formulations, algorithms, and solutions.
• Learning to solve project tasks in a group.
• Learning to evaluate the trade-offs and limitations of existing methods.

Contents

We will discuss general approaches for machine learning (ML) on graph structured data. In particular, computational methods for graph representation learning such as graph neural networks (GNNs), graph

kernels, as well as graph mining techniques will be discussed, analyzed, and applied. Regarding GNNs and graph kernels, we will discuss the expressive power and how these concepts are related, as well as several specific examples. In the area of graph mining, we will likely investigate fast (approximate) algorithms to count small patterns, such as triangles, or trees.

If time permits, we might venture into the realm of ranking on large-scale graphs, with applications such as recommender systems. The exercises will focus on practical implementations and the application of these methods to real world examples.

Prerequisites

Recommended:
Helpful: one or more of the following

• MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning
• MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery
• MA-INF 4212 – Data Science and Big Data
• MA-INF 1105 - Algorithms for Data Analysis
• MA-INF 1102 - Combinatorial Optimization

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Oral exam or written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

Forms of media

• Lecture slides
• Jupyter notebooks

Literature

• William L. Hamilton: Graph Representation Learning, Synthesis Lectures on Artificial Intelligence and Machine Learning, Morgan and Claypool.
• Nils M. Kriege, Fredrik D. Johansson, Christopher Morris: A survey on graph kernels, Applied Network Science 5(1):6.
• Karsten M. Borgwardt, M. Elisabetta Ghisu et al.: Graph Kernels: State-of-the-Art and Future Challenges, Foundations and Trends in Machine Learning 13(5-6).

MA-INF 4318 Seminar Representation Learning for Big Data Analytics

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Emmanuel Müller	Prof. Dr. Emmanuel Müller

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Smart representations (such as embeddings, kernels, and dimensionality reduction methods) are useful models that allow the abstraction of data within a well-defined mathematical formalism. The representations we aim at are conceptual abstractions of real world phenomena (such as social interactions, chemical reactions and biological processes) into the world of statistics and discrete mathematics in such a way that the powerful tools developed in those areas are available for complex analyses in a simple and elegant manner.

The focus will be the understanding and comparison of smart representations and their explicit/implicit data transformation models. We will study limitations and advantages of different techniques, and how the data representation changes the problem setup, reduces complexity, introduces robustness, or other valuable properties for big data analytics.

Prerequisites

Recommended:
Open-minded for new problem settings, Programming in different languages (C++, Python, Java), Critical approach to existing solutions, Research curiosity

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature

[1] Sergey Ivanov, Evgeny Burnaev. "Anonymous Walk Embeddings" ICML, 2018.

[2] Tsitsulin, Anton, Davide Mottin, Panagiotis Karras, and Emmanuel Müller "VERSE: Versatile Graph Embeddings from Similarity Measures." WWW, 2018.

[3] Yanardag, Pinar, and S. V. N. Vishwanathan. "Deep graph kernels." KDD, 2015.

[4] Holger Dell, Martin Grohe, Gaurav Rattan "Lovász Meets Weisfeiler and Leman". ICALP, 2018

[5] Anton Tsitsulin, Davide Mottin, Panagiotis Karras, Alexander M. Bronstein, Emmanuel Müller "NetLSD: Hearing the Shape of a Graph". KDD, 2018

[6] Nino Shervashidze, Pascal Schweitzer, Erik Jan van Leeuwen, Kurt Mehlhorn, Karsten M. Borgwardt "Weisfeiler-Lehman Graph Kernels". JMLR, 2011

[7] Haochen Chen, Bryan Perozzi, Yifan Hu, Steven Skiena "HARP: Hierarchical Representation Learning for Networks". AAAI, 2018.

MA-INF 4322 Lab Machine Learning on Encrypted Data

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Michael Nüsken	Dr. Michael Nüsken

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of Cryptography, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend

design decisions, to prepare readable documentation of software;

skills in constructively collaborating with others in small teams

over a longer period of time; ability to classify ones own results

into the state-of-the-art of the resp. area

Contents

With the rise of more and more mechanisms and installations of data science methodology to automatically analyze large amounts of possibly privacy infringing data we have to carefully understand how to protect our data. Also more and more fake data shows up and we have to find ways to distinguish faked from trustable data. At the same time we want to allow insightful research and life-easing analyzes to be possible. This seeming contradiction has lead to various efforts for unifying both: protecting data and allowing analyzes, at least to some extent and possibly under some restrictions. See Munn et al. (2019) for a review on challenges and options.

The target of the lab is to understand how computations on encrypted data may work in one particular application that we are chosing together. Ideally, we can come up with a novel solution for performing an unconsidered algorithm. We study the tasks and tools, select algorithms, find a protocol, prototype an implemention, perform a security analysis, present an evaluation, ...

Prerequisites

Recommended:
Basic knowledge in cryptography is highly recommended, eg. by MA-INF 1103 - Cryptography, MA-INF 1223 - PETs, MA-INF 1209 - Seminar Advanced Topics in Cryptography.

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

Successful exercise participation

MA-INF 4324 Seminar Advanced Topics in Data Science

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Elena Demidova	Prof. Dr. Elena Demidova

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

This module concentrates on specialized topics in data science. The students obtain skills in the independent, in-depth study of state-of-the-art scientific literature on specific topics, discussion with their peers and presentation to the scientific audience.

Learning goals: soft skills

- Communication skills: oral and written presentation of scientific content.
- Self-competences: the ability to analyze problems, time management, creativity.

Contents

Statistical and machine learning-based methods of data analytics, including typical steps of the data science process: data generation, integration, cleaning, exploration, modelling and evaluation. Specialized data representation and analytics methods for selected data types and applications in specific domains.

Prerequisites

Recommended:
BA-INF 150 - Einführung in die Data Science

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

None

Literature

Relevant literature will be announced at the beginning of the seminar

MA-INF 4325 Lab Data Science in Practice

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Elena Demidova	Prof. Dr. Elena Demidova

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

This module concentrates on practical experience in data analytics. Participants acquire basic knowledge and practical experience in the design and implementation of data science workflows for specific data types and applications.

Learning goals: soft skills

• Communication skills: the ability to work in teams.
• Self-competences: the ability to analyse problems and find practical solutions. Time management, creativity, presentation of results.

Contents

Practical application of statistical and machine learning-based methods to solve data analytics problems on real-world datasets and evaluate proposed solutions.

Prerequisites

Recommended:
BA-INF 150 - Einführung in die Data Science
MA-INF 4230 - Advanced Methods of Information Retrieval

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

None

MA-INF 4326 Explainable AI and Applications

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Dr. Tiansi Dong	Dr. Tiansi Dong

Programme	Mode	Semester
M. Sc. Computer Science	Optional	3.

Learning goals: technical skills

• Know the dual-model functioning of the human mind, and two main AI paradigms
• Develop white-box neural AI systems
• Understand the problems and limitations of Blackbox Deep-Learning systems, and Know the state-of-the-art Methods for Interpreting Deep-Learning systems (XAI)

Learning goals: soft skills

• Know System 1 and 2 of the mind, prons and cons of symbolic AI and connectionist AI
• Develop neural-geometric systems that have both good features of symbolic AI and connectionist AI
• Know the limitation of famous Deep-Learning systems, such as GPT3, self-driving. Know standard methods to explore the explainability of Deep-Learning systems

Contents

1. Introduction: fates of large Deep-Learning systems, e.g. Watson, GPT, self-driving cars
2. Dual-system theories (System 1 and 2), nine laws of cognition, criteria of semantic models
3. The target and the state-of-art methods of XAI
4. Neural-symbolic AI
5. Cognitive maps, Collages, Mental Spatial Representation, Events
6. Qualitative Spatial Representation and Reasoning
7. Rotating Sphere Embedding: A New Wheel for Neural-Symbolic Unification
8. Neural Syllogistic Reasoning
9. Recognizing Variable Environments
10. Humor Understanding
11. Rotating Spheres as building-block semantic components for Language, Vision, and Action

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to four students. A total of 50% of the points must be achieved.

Literature

• Kahneman, D. (2011). Thinking fast and slow. Farrar, Straus and Giroux.
• Gaedenfors, P. (2017). The Geometry of Meaning. MIT Press.
• Attardo, Hempelmann, Maio (2003). Script Oppositions and Logical Mechanisms: Modeling Incongruities and their Resolutions, HUMOR 15(1)3–46
• Tversky, B. (2019). Mind in Motion. Basic Books, New York.
• Dong, et al. (2020). Learning Syllogism with Euler Neural-Networks. arXiv:2007.07320
• Dong, T. (2021). A Geometric Approach to the Unification of Symbolic Structure and Neural Networks. Springer.
• Knauff and Spohn (2021). Handbook of Rationality. MIT Press, Cambridge, MA, USA.
• Samek et.al. (2019), Explainable AI: Interpreting, Explaining and Visualizing Deep Learning. Springer.
• Greg Dean (2019). Step by Step to Stand-Up Comedy (Revised Edition). ISBN: 978-0-9897351-7-9

MA-INF 4327 Lab Biomedical Data Science

Workload	Credit points	Duration	Frequency
270 h	9 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Holger Fröhlich	Prof. Dr. Holger Fröhlich

Programme	Mode	Semester
M. Sc. Computer Science	Optional	3.

Learning goals: technical skills

The students will carry out a practical task (project) in the context of biomedical data science, including test and documentation of the implemented software/system.

Learning goals: soft skills

Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area

Contents

Varying selected topics close to current research in the area of biomedical data science.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

MA-INF 4328 Spatio-Temporal Data Analytics

Workload	Credit points	Duration	Frequency
180 h	6 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Elena Demidova	Prof. Dr. Elena Demidova

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

This module introduces the students to the advanced methods, data structures, and data analytics algorithms for spatio-temporal data. At the end of the module, the students will be capable of choosing appropriate data representations, data structures and algorithms for specific applications and correctly applying relevant statistical and machine learning-based data analytics procedures.

Learning goals: soft skills

Communication skills: oral and written presentation and discussion of solutions. Self-competences: the ability to analyze and solve problems.

Contents

The module topics include data structures, data representation and analysis methods, and algorithms that enable analyzing spatio-temporal data and building predictive models effectively and effectively. Furthermore, we will study the corresponding evaluation techniques and novel applications.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching
S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

The completion of regularly provided exercise sheets. The work can be done in groups of up to three, four or five students, depending on the total number of students taking the course. A total of 50% of the points must be achieved. For 80% of the exercise sheets, 40% of the points must be achieved for each sheet. Each student must present a solution to an exercise in the exercise sessions once.

MA-INF 4329 Seminar Biological Intelligence

Workload	Credit points	Duration	Frequency
120 h	4 CP	1 semester	every year

Module coordinator	Lecturer(s)
Prof. Dr. Dr. Dominik Bach	Prof. Dr. Dr. Dominik Bach

Programme	Mode	Semester
M. Sc. Computer Science	Optional	2. or 3.

Learning goals: technical skills

Ability to understand new research results presented in original scientific papers.

Learning goals: soft skills

Ability to present and to critically discuss these results in the framework of the corresponding area.

Contents

Current conference and journal papers.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation, written report

Ungraded coursework (required for admission to the exam)

5 Master Thesis

MA-INF 0401 Master Thesis

Workload	Credit points	Duration	Frequency
900 h	30 CP	1 semester	every semester

Module coordinator	Lecturer(s)
	All lecturers of computer science

Programme	Mode	Semester
M. Sc. Computer Science	Compulsory	4.

Learning goals: technical skills

Ability to solve a well-defined, significant research problem under supervision, but in principle independently

Learning goals: soft skills

Ability to write a scientific documentation of considerable length according to established scientific principles of form and style, in particular reflecting solid knowledge about the state-of-the-art in the field

Contents

Topics of the thesis may be chosen from any of the areas of computer science represented in the curriculum

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Independent preparation of a scientific thesis with individual coaching		0	900 S	30

T = face-to-face teaching
S = independent study

Graded exams

Master Thesis

Ungraded coursework (required for admission to the exam)

Literature

Individual bibliographic research required for identifying relevant literature (depending on the topic of the thesis)

MA-INF 0402 Master Seminar

Workload	Credit points	Duration	Frequency
60 h	2 CP	1 semester	every semester

Module coordinator	Lecturer(s)
	All lecturers of computer science

Programme	Mode	Semester
M. Sc. Computer Science	Compulsory	4.

Learning goals: technical skills

Ability to document and defend the results of the thesis work in a scientifically appropriate style, taking into consideration the state-of-the-art in research in the resp. area

Learning goals: soft skills

Contents

Topic, scientific context, and results of the master thesis

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar		2	30 T / 30 S	2

T = face-to-face teaching
S = independent study

Graded exams

Oral presentation of final results

Ungraded coursework (required for admission to the exam)

Literature

Individual bibliographic research required for identifying relevant literature (depending on the topic of the thesis)