Module Handbook

for the

Master Programme "Cyber Security"

at

Rheinischen Friedrich-Wilhelms-Universität Bonn

revised version: September 30, 2024

The curriculum of the master programme comprises a compulsory area, a subject-specific compulsory elective area and optionally a non-subject-specific compulsory elective area. The subject-specific compulsory elective area is subdivided by the subjects cyber security and computer science (further sub-divided into four main focus areas in research of the Bonn Institute of Computer Science).

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 Compulsory Area

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. Cyber Security	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. Cyber Security	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)

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. Cyber Security	Compulsory	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)

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

MA-INF 3244 Cyber Security Seminar

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

Module coordinator	Lecturer(s)
Prof. Dr. Michael Meier	Prof. Dr. Matthew Smith, Prof. Dr. Peter Martini, Prof. Dr. Michael Meier, Dr. Felix Boes, Dr. Matthias Wübbeling, Dr. Christian Tiefenauf, Dr. Matthias Frank

Programme	Mode	Semester
M. Sc. Cyber Security	Compulsory	2. or 3.

Learning goals: technical skills

Ability to study and discuss current research related to Cyber Security. Didactic preparation of a written report and didactic presentation a talk for a selected topic.

Learning goals: soft skills

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

Contents

Recent research topics in cyber security based on cúrrent journal and conference publications.

In addition the seminar group analyses and discusses current societal and political developments related to Cyber Security. Participation of discussion events that are announced in the seminar.

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 Exam

Ungraded coursework (required for admission to the exam)

MA-INF 3245 Cyber Security Lab

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

Module coordinator	Lecturer(s)
Prof. Dr. Michael Meier	Prof. Dr. Michael Meier, Prof. Dr. Matthew Smith, Prof. Dr. Peter Martini, Dr. Felix Boes, Dr. Matthias Wübbeling, Dr. Christian Tiefenau, Dr. Matthias Frank

Programme	Mode	Semester
M. Sc. Cyber Security	Compulsory	2. or 3.

Learning goals: technical skills

Ability to carry out a practical task in the context of Cyber Security. This includes test and documentation of the implemented software/system. Ability to discuss achieved results in the context of the state-of-the-art of the respective area.

Learning goals: soft skills

Contents

Implementation, documentation and presentation of a practical task in the context of Cyber Security.

Participation of discussion events that are announced in the lab.

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)

2 Compulsory Elective Area

2.1 Cyber Security

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. Cyber Security	Optional	1. 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)

The successful completion of a programming project in groups of up to four students, in three phases. First, the students build a piece of software to predefined requirements; second, they test other groups' solutions for weaknesses; third, they eliminate weaknesses in their own solution. To be admitted to the final exam, the software must conform to the predefined minimum requirements, at least two weaknesses must have been found, and a short report has to be submitted upon completion of the three phases.

Literature

Software Security: Building Security In by Gary McGraw

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. Cyber Security	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 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. Cyber Security	Optional	1. 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)

Participation in two achievement tests. In total, at least 50% of the points much be achieved on these tests.

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. Cyber Security	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. Cyber Security	Optional	2. or 3.

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. Cyber Security	Optional	1., 2. or 3.

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 3243 Tutorenpraktikum Cyber Security

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

Module coordinator	Lecturer(s)
Prof. Dr. Michael Meier	Prof. Dr. Matthew Smith, Prof. Dr. Michael Meier, Prof. Dr. Peter Martini, Dr. Felix Boes, Dr. Matthias Wübbeling, Dr. Marc Ohm, Prof. Dr. Michael Meier, Dr. Christian Tiefenau, Dr. Matthias Frank

Programme	Mode	Semester
M. Sc. Cyber Security	Optional	2. or 3.

Learning goals: technical skills

Ability to and experience in

- conveying knowledge to students,
- presenting technica, conceptional and scientific content,
- evaluating and assessing excercise solutions and argumentations,
- development, implementation and application of teach and learning tools.

Learning goals: soft skills

Contents

Varying practical tutoring tasks in the context of cyber security are carried out. This can include tutoring of exercise sessions for a cyber security course (bachelor or master level), correction of homework, evaluation of students' progress, participation in the regular tutor meetings, development of teaching material (e.g. exercise tasks) and demonstrations to illustrate and convey technical as well as scientific correlations.

Prerequisites

none

Course meetings

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	8	1	15 T / 45 S	2
Practical Work	8	5	75 T / 135 S	7

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

Graded exams

Project work

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. Cyber Security	Optional	2. or 3.

Learning goals: technical skills

recognition of vulnerabilities in binary programs, static reverse engineering of binary programs (Ghidra, IDA Free, Linux command line tools), debugging of binary programs with gdb/pwndbg, Python programming with pwntools, application of exploit strategies such as overwriting return addresses/function pointers, return-oriented programming (ROP, SROP, ret2csu), shellcoding, glibc heap exploitation techniques (Use-After-Free, Unlink Exploit, House of Orange), understanding a complex real-world exploit, usage of git/GitLab and Docker for the exercises.

Learning goals: soft skills

Frustration tolerance when working with binary representations and trying to apply taught techniques, focused working on technically challenging problems, simultaneously applying knowledge from different areas of computer science.

Contents

This university course covers various topics related to software security and exploitation techniques. It starts with an introduction to finding vulnerabilities in C programs and binaries. The course then delves into stack-based buffer overflows and the mitigations used to prevent them. Students will also learn about circumventing these mitigations and explore return-oriented programming. The course continues with a focus on manual crafting of shellcode and understanding the internals of the glibc heap. Students will gain knowledge about heap exploitation techniques, including use-after-free exploits, heap unlink exploits, and the house of orange exploit. The course concludes with a complex case study on the Exim RCE exploit, providing students with a practical understanding of real-world vulnerabilities. Additionally, guest lectures will be held to provide further insights into the field of software security.

Please note that basic skills in static and dynamic binary analysis (e. g. read disassembled/decompiled code or debug a binary program with gdb) are required to successfully participate in this lecture.

Prerequisites

Required:
Required: NOT attended former PABE (MA-INF 3322, BA-INF 148)

Recommended:
- Binary Analysis skills (Lecture: “Applied Binary Analysis”)
- 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

2.2 Computer Science – Algorithms

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. Cyber Security	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 a solution to an exercise in the exercise sessions twice.

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. Cyber Security	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)

The completion of regularly provided exercise sheets. The work can be done in groups. A total of 50% of the points must be achieved. Each student must present a solution to an exercise in the exercise sessions twice. At the beginning of each exercise session, all participants mark on a list which (sub)exercises they have completed successfully and for which they wish to receive credit. The tutor then selects, for each (sub)exercise, one participant to present it. For more complex exercises, a written solution is required, which can be uploaded during the presentation.

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. Cyber Security	Optional	2. or 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)

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 once.

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 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. Cyber Security	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 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. Cyber Security	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. Cyber Security	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. Cyber Security	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 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. Cyber Security	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 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. Cyber Security	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 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. Cyber Security	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 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. Cyber Security	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.

2.3 Computer Science – Graphics, Vision, Audio

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. Cyber Security	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)

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. 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. Cyber Security	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

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.

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 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. Cyber Security	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 and Machine Learning

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 two 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. Cyber Security	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

Recommended:
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 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. Cyber Security	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 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. Cyber Security	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

Recommended:
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. Cyber Security	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. Cyber Security	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 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. Cyber Security	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 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	Jun. Prof. Dr. Zorah Lähner

Programme	Mode	Semester
M. Sc. Cyber Security	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. Cyber Security	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 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. Cyber Security	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. Cyber Security	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)

2.4 Computer Science – Security, Information and Communication Management

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. Cyber Security	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. Cyber Security	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. Cyber Security	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. Cyber Security	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 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. Cyber Security	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 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. Cyber Security	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 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. Cyber Security	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)

50% of the possible points for the exercises. The points are acquired by a small programming exercise with a workload of about 15 hours and some theoretical exercises with a workload of 10 hours. The solution has to be submitted individually or in groups of up to three students and will be rated by points.

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. Cyber Security	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. Cyber Security	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. Cyber Security	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. Cyber Security	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. Cyber Security	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 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. Cyber Security	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 3325 Geometric Deep Learning

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

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

Programme	Mode	Semester
M. Sc. Cyber Security	Optional	2-3.

Learning goals: technical skills

• Understanding advanced topics in the design of neural networks using geometric data
• Mathematical modelling of invariances and non-Euclidean domains in deep learning and guarantees that can be derived from these
• Gain an overview of practical applications in which this theory can be applied

Learning goals: soft skills

• Problem solving skills: ability to identify and utilize 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 lecture will cover advanced topics in deep learning focusing on theory related to geometric data and the incorporation of invariances in network architectures. Topics include, among others, permutation invariance, differential geometry, the curse of dimensionality, neural fields and physics-informed neural networks. Students will learn how to process a variety of geometric data structures and implement deep learning algorithms on these related to applications in visual computing, physics and graph processing.

Prerequisites

Recommended:
Students are recommended to have basic knowledge about deep learning and computer vision, for example gained in MA-INF 4111 Principles of Machine Learning or MA-INF 2201 Computer Vision, and proficiency 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

Written exam

Ungraded coursework (required for admission to the exam)

2.5 Computer Science – 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. Cyber Security	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. Cyber Security	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, Prof. Dr. Maren Bennewitz

Programme	Mode	Semester
M. Sc. Cyber Security	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

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

- 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. Cyber Security	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 4201 Artificial Life

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

Module coordinator	Lecturer(s)
Prof. Dr. Sven Behnke	Dr. Nils Goerke

Programme	Mode	Semester
M. Sc. Cyber Security	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 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. Cyber Security	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)

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 twice.

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, Dr. Nils Goerke

Programme	Mode	Semester
M. Sc. Cyber Security	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 one of the following:

MA-INF 2201 - Computer Vision

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. Cyber Security	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. Raphael Memmesheimer

Programme	Mode	Semester
M. Sc. Cyber Security	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. Cyber Security	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. Cyber Security	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. Cyber Security	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)

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

- 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 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. Cyber Security	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. Cyber Security	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. Cyber Security	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. Cyber Security	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 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	Prof. Dr. Rafet Sifa

Programme	Mode	Semester
M. Sc. Cyber Security	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 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. Cyber Security	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, Dr. Raphael Memmesheimer

Programme	Mode	Semester
M. Sc. Cyber Security	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. Cyber Security	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	Prof. Dr. Sven Behnke

Programme	Mode	Semester
M. Sc. Cyber Security	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 2201 - Computer Vision

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. Cyber Security	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 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. Cyber Security	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
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 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. Cyber Security	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
MA-INF 4328 - Spatio-Temporal Data Analytics

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. Cyber Security	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

MA-INF 4328 - Spatio-Temporal Data Analytics

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. Rafet Sifa	Dr. Tiansi Dong

Programme	Mode	Semester
M. Sc. Cyber Security	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 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. Cyber Security	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 4331 Lab Perception and Learning for Robotics

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

Module coordinator	Lecturer(s)
JProf. Dr. Hermann Blum	JProf. Dr. Hermann Blum

Programme	Mode	Semester
M. Sc. Cyber Security	Optional	2-4.

Learning goals: technical skills

Participants learn how to practically approach a robot perception problem. In small groups, they apply their knowledge of robot perception, deep learning, and computer vision to a novel problem. They analyze the problem, read into relevant literature, propose and implement a solution, and empirically test it. They then refine their approach based on an analysis of the experimental outcomes.

Learning goals: soft skills

Participants learn how to communicate in academic settings (how to communicate with their team members and supervisors, how to present their results to peers, how to write a short scientific project report). They also practice self-organization (time management, goal-oriented decision making, work distribution in teams).

Contents

Robot localization, planning, navigation, manipulation; Practical aspects of Deep Learning; Sensor models, calibration, capture, processing. Containerized software deployment.

Prerequisites

Recommended:
Recommended are 2 out of the following:

- MA-INF 2201 Computer Vision
- MA-INF 2213 Advanced Computer Vision
- MA-INF 2218 Video Analytics
- 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, 2005

I. Goodfellow, Y. Bengio and A. Courville: Deep Learning. MIT Press, 2016

Per-project assigned literature