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

2 Compulsory Elective Area

2.1 Cyber Security

2.2 Computer Science – Algorithms

2.3 Computer Science – Graphics, Vision, Audio

2.4 Computer Science – Security, Information and Communication Management

2.5 Computer Science – Intelligent Systems
## 1 Compulsory Area

<table>
<thead>
<tr>
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<tr>
<td>MA-INF 0401</td>
<td>30 CP</td>
<td>Master Thesis</td>
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<tr>
<td>MA-INF 0402</td>
<td>2 CP</td>
<td>Master Seminar</td>
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<tr>
<td>MA-INF 3236</td>
<td>L2E2 6 CP</td>
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<td>MA-INF 3244</td>
<td>Sem2 4 CP</td>
<td>Cyber Security Seminar</td>
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<tr>
<td>MA-INF 3245</td>
<td>Lab4 9 CP</td>
<td>Cyber Security Lab</td>
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MA-INF 0401 Master Thesis

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<th>Module coordinator</th>
<th>Lecturer(s)</th>
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<td>All lecturers of computer science</td>
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<tr>
<td>M. Sc. Cyber Security</td>
<td>Compulsory</td>
<td>4</td>
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</table>

**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**

<table>
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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

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Module coordinator

Lecturer(s)
All lecturers of computer science

Programme

M. Sc. Cyber Security

Mode

Compulsory

Semester

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          |

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

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#### Module coordinator
Prof. Dr. Michael Meier

#### Lecturer(s)
Prof. Dr. Michael Meier

#### Programme
M. Sc. Cyber Security

#### Mode
Compulsory

#### Semester
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, transferring 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

<table>
<thead>
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<th>Teaching format</th>
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#### Graded exams
Written exam

**Ungraded coursework (required for admission to the exam)**
Successful exercise participation
## MA-INF 3244  Cyber Security Seminar

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### Module coordinator
- Prof. Dr. Michael Meier

### Lecturer(s)
- 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
- M. Sc. Cyber Security

### Mode
- Compulsory

### Semester
- 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 current 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

<table>
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### Graded exams
- Oral Exam

### Ungraded coursework (required for admission to the exam)
### MA-INF 3245  Cyber Security Lab

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**Module coordinator**
Prof. Dr. Michael Meier

**Lecturer(s)**
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**
M. Sc. Cyber Security

**Mode**
Compulsory

**Semester**
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**

<table>
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<tr>
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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

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<thead>
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<th>Semester</th>
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<td>L2E2</td>
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<td>MA-INF 3140</td>
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<td>Advanced Computer Forensics</td>
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<td>MA-INF 3202</td>
<td>L2E2</td>
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<td>MA-INF 3238</td>
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<td>MA-INF 3239</td>
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<td>Malware Analysis</td>
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<td>MA-INF 3241</td>
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<td>Practical Challenges in Human Factors of Security and Privacy</td>
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MA-INF 3108  Secure Software Engineering

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<td>every year</td>
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Module coordinator: Dr. Christian Tiefenau
Lecturer(s): Dr. Christian Tiefenau, Mischa Meier

Programme: M. Sc. Cyber Security
Mode: Optional
Semester: 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

<table>
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T = face-to-face teaching
S = independent study

Graded exams
Written exam

Ungraded coursework (required for admission to the exam)
Successful exercise participation

Literature
Software Security: Building Security In by Gary McGraw
### MA-INF 3140  Advanced Computer Forensics

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#### Module coordinator
Dr. Christian Tiefenau

#### Lecturer(s)
Dr. Christian Tiefenau

#### Programme
M. Sc. Cyber Security

#### Mode
Optional

#### Semester
1. or 3.

#### Learning goals: technical skills
The course covers advanced research topics in computer forensics and secure software engineering.

#### Learning goals: soft skills

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

#### Prerequisites
none

#### Course meetings

<table>
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<th>Workload[h]</th>
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#### Graded exams
Written exam

**Ungraded coursework (required for admission to the exam)**

Successful exercise participation
MA-INF 3202  Mobile Communication

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<td>1 semester</td>
<td>every year</td>
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**Module coordinator**

Prof. Dr. Peter Martini

**Lecturer(s)**

Prof. Dr. Peter Martini, Dr. Matthias Frank

**Programme**

M. Sc. Cyber Security

**Mode**

Optional

**Semester**

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**

<table>
<thead>
<tr>
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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
- Further up-to-date literature will be announced in due course before the beginning of the lecture
MA-INF 3238  Side Channel Attacks

<table>
<thead>
<tr>
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**Module coordinator**
Dr. Felix Boes

**Lecturer(s)**
Dr. Felix Boes

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

<table>
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<td>S = independent study</td>
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**Graded exams**
Written Exam

**Ungraded coursework (required for admission to the exam)**
Successful exercise participation
MA-INF 3239  Malware Analysis

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
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**Module coordinator**

Prof. Dr. Peter Martini

**Lecturer(s)**

Prof. Dr. Elmar Padilla

**Programme**

M. Sc. Cyber Security

**Mode**

Optional

**Semester**

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**

<table>
<thead>
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<td>30 T / 75 S</td>
<td>3.5</td>
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</table>

**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

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<td>every year</td>
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**Module coordinator**
Prof. Dr. Matthew Smith

**Lecturer(s)**
Prof. Dr. Matthew Smith

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
2. or 3.

**Learning goals: technical skills**
After completing the unit students will be able to conduct related work searches 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**

<table>
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<th>h/week</th>
<th>Workload[h]</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>1</td>
<td>15 T / 45 S</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Exercises</td>
<td>3</td>
<td>45 T / 75 S</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
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</tr>
</thead>
<tbody>
<tr>
<td>180 h</td>
<td>6 CP</td>
<td>1 semester</td>
<td>every year</td>
</tr>
</tbody>
</table>

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

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

Learning goals: technical skills
Ability to understand and analyse theoretical and practical cyber security challenges of distributed and resource-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

<table>
<thead>
<tr>
<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
<th>Workload[h]</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>2</td>
<td>30 T / 45 S</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Exercises</td>
<td>2</td>
<td>30 T / 75 S</td>
<td>3.5</td>
<td></td>
</tr>
</tbody>
</table>

Graded exams
Written exam

Ungraded coursework (required for admission to the exam)
Successful exercise participation
MA-INF 3243  Tutorenpraktikum Cyber Security

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>every year</td>
</tr>
</tbody>
</table>

**Module coordinator**

Prof. Dr. Michael Meier

**Lecturer(s)**

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**

M. Sc. Cyber Security

**Mode**

Optional

**Semester**

2. or 3.

**Learning goals: technical skills**

Ability to and experience in
- conveying knowledge to students,
- presenting technical, conceptional and scientific content,
- evaluating and assessing exercise solutions and argumentations,
- development, implementation and application of teaching 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**

<table>
<thead>
<tr>
<th>Teaching format</th>
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<th>h/week</th>
<th>Workload[h]</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seminar</td>
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<td>1</td>
<td>15 T / 45 S</td>
<td>2</td>
</tr>
<tr>
<td>Practical Work</td>
<td>8</td>
<td>5</td>
<td>75 T / 135 S</td>
<td>7</td>
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</table>

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

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 h</td>
<td>6 CP</td>
<td>1 semester</td>
<td>every year</td>
</tr>
</tbody>
</table>

**Module coordinator**
Prof. Dr. Peter Martini

**Lecturer(s)**
Prof. Dr. Elmar Padilla

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
2. or 3.

**Learning goals: technical skills**
Static and dynamic program analysis, Exploitation (Stack-based Buffer Overflows, Format String Exploits, Heap Exploitation, Use-After-Free Exploits) and Countermeasures (Stack Cookies, NX, ASLR, RELRO)

**Learning goals: soft skills**
Frustration tolerance when working with binary representations and trying to apply taught techniques, focussed working on technically challenging problems, simultaneously applying knowledge from different areas of computer science

**Contents**
Our computers run a lot of closed source binary programs meaning that the source code of those programs is not available. Naturally, those programs contain bugs, mistakes that the programmer made during the development. Those bugs could (under certain circumstances) be exploited by attackers and thus may lead to arbitrary code execution. In this lecture we aim to teach you how to find well known exploitable bugs and how to exploit them. After a brief recap of basic binary program analysis such as static and dynamic analysis, we will talk about vulnerability discovery in general, meaning that you will learn how to find exploitable bugs by yourself. Next we move on to basic stack-based buffer overflows and add mitigation techniques (stack cookies, NX, ASLR, RELRO, ...) as we progress and exploit them as well. After we finished the topic of stack-based buffer overflows we move on to more advanced topics such as heap exploitation, use-after-free exploits and others. The lecture ends with an introduction to fuzzing and an analysis of a sophisticated real-world exploit.

**Prerequisites**
Required: none

Recommended:
- Binary Analysis skills (Lecture: “Applied Binary Analysis” BA-INF 155)
- Basic knowledge of the Linux operating system
- System Programming skills in C (Lecture: “Systemnahe Programmierung”)
- Basic Python programming skills

**Course meetings**

<table>
<thead>
<tr>
<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
<th>Workload[h]</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>2</td>
<td>30 T / 45 S</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Exercises</td>
<td>2</td>
<td>30 T / 75 S</td>
<td>3.5</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>CP</th>
<th>Title</th>
</tr>
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<tbody>
<tr>
<td>MA-INF 1103</td>
<td>L4E2</td>
<td>9 CP</td>
<td>Cryptography</td>
</tr>
<tr>
<td>MA-INF 1105</td>
<td>L2E2</td>
<td>6 CP</td>
<td>Algorithms for Data Analysis</td>
</tr>
<tr>
<td>MA-INF 1108</td>
<td>L2E2</td>
<td>6 CP</td>
<td>Introduction to High Performance Computing: Architecture Features and Practical Parallel Programming</td>
</tr>
<tr>
<td>MA-INF 1209</td>
<td>Sem2</td>
<td>4 CP</td>
<td>Seminar Advanced Topics in Cryptography</td>
</tr>
<tr>
<td>MA-INF 1221</td>
<td>Lab4</td>
<td>9 CP</td>
<td>Lab Computational Analytics</td>
</tr>
<tr>
<td>MA-INF 1222</td>
<td>Lab4</td>
<td>9 CP</td>
<td>Lab High Performance Optimization</td>
</tr>
<tr>
<td>MA-INF 1223</td>
<td>L4E2</td>
<td>9 CP</td>
<td>Privacy Enhancing Technologies</td>
</tr>
<tr>
<td>MA-INF 1225</td>
<td>Lab4</td>
<td>9 CP</td>
<td>Lab Exploring HPC technologies</td>
</tr>
<tr>
<td>MA-INF 1309</td>
<td>Lab4</td>
<td>9 CP</td>
<td>Lab Efficient Algorithms: Design, Analysis and Implementation</td>
</tr>
<tr>
<td>MA-INF 1316</td>
<td>Lab4</td>
<td>9 CP</td>
<td>Lab Cryptography</td>
</tr>
<tr>
<td>MA-INF 1322</td>
<td>Sem2</td>
<td>4 CP</td>
<td>Seminar Focus Topics in High Performance Computing</td>
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MA-INF 1103 Cryptography

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>every year</td>
</tr>
</tbody>
</table>

Module coordinator: Dr. Michael Nüsken

Lecturer(s): Dr. Michael Nüsken

Programme: M. Sc. Cyber Security

Mode: Optional

Semester: 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

<table>
<thead>
<tr>
<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
<th>Workload[h]</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
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<td>60 T / 105 S</td>
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<tr>
<td>Exercises</td>
<td>2</td>
<td>30 T / 75 S</td>
<td>3.5</td>
<td></td>
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</table>

T = face-to-face teaching

S = independent study

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)

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

Literature

- Course notes
MA-INF 1105  Algorithms for Data Analysis

<table>
<thead>
<tr>
<th>Workload</th>
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<th>Duration</th>
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</thead>
<tbody>
<tr>
<td>180 h</td>
<td>6 CP</td>
<td>1 semester</td>
<td>at least every 2 years</td>
</tr>
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</table>

**Module coordinator**
Prof. Dr. Petra Mutzel

**Lecturer(s)**
Prof. Dr. Petra Mutzel

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

<table>
<thead>
<tr>
<th>Teaching format</th>
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<th>h/week</th>
<th>Workload[h]</th>
<th>CP</th>
</tr>
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<tbody>
<tr>
<td>Lecture</td>
<td>2</td>
<td>2</td>
<td>30 T / 45 S</td>
<td>2.5</td>
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<tr>
<td>Exercises</td>
<td>2</td>
<td>2</td>
<td>30 T / 75 S</td>
<td>3.5</td>
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</table>

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

**Graded exams**

Oral exam

**Ungraded coursework (required for admission to the exam)**
Successful exercise participation
MA-INF 1108  Introduction to High Performance Computing: Architecture Features and Practical Parallel Programming

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 h</td>
<td>6 CP</td>
<td>1 semester</td>
<td>every year</td>
</tr>
</tbody>
</table>

Module coordinator
Prof. Dr. Estela Suarez

Lecturer(s)
Prof. Dr. Estela Suarez

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
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

<table>
<thead>
<tr>
<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
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<th>CP</th>
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<tbody>
<tr>
<td>Lecture</td>
<td>2</td>
<td>30 T / 45 S</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Exercises</td>
<td>2</td>
<td>30 T / 75 S</td>
<td>3.5</td>
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</table>

Graded exams
Written exam

Ungraded coursework (required for admission to the exam)
Successful participation in the exercises

Forms of media
Laptop and projector
<table>
<thead>
<tr>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Message Passing Interface Forum: MPI: A Message-Passing Interface Standard, Version 3.1</td>
</tr>
<tr>
<td>• OpenMP Application Programming Interface, Version 4.5, November 2015</td>
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</table>
MA-INF 1209  Seminar Advanced Topics in Cryptography

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
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</thead>
<tbody>
<tr>
<td>120 h</td>
<td>4 CP</td>
<td>1 semester</td>
<td>every semester</td>
</tr>
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</table>

**Module coordinator**
Dr. Michael Nüsken

**Lecturer(s)**
Dr. Michael Nüsken

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

<table>
<thead>
<tr>
<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
<th>Workload[h]</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seminar</td>
<td>10</td>
<td>2</td>
<td>30 T / 90 S</td>
<td>4</td>
</tr>
</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
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</thead>
<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>every year</td>
</tr>
</tbody>
</table>

**Module coordinator**
Prof. Dr. Petra Mutzel

**Lecturer(s)**
Prof. Dr. Petra Mutzel

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

<table>
<thead>
<tr>
<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
<th>Workload[h]</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab</td>
<td>8</td>
<td>4</td>
<td>60 T / 210 S</td>
<td>9</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>every year</td>
</tr>
</tbody>
</table>

#### Module coordinator
Prof. Dr. Petra Mutzel

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

#### Programme
M. Sc. Cyber Security

#### Mode
Optional

#### Semester
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

<table>
<thead>
<tr>
<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
<th>Workload</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab</td>
<td>8</td>
<td>4</td>
<td>60 T / 210 S</td>
<td>9</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
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</thead>
<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>every year</td>
</tr>
</tbody>
</table>

Module coordinator  
Dr. Michael Nüsken

Lecturer(s)  
Dr. Michael Nüsken

Programme  
M. Sc. Cyber Security

Mode  
Optional

Semester  
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

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

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>every year</td>
</tr>
</tbody>
</table>

Module coordinator
Prof. Dr. Estela Suarez

Lecturer(s)
Prof. Dr. Estela Suarez

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
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**

<table>
<thead>
<tr>
<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
<th>Workload</th>
<th>h</th>
<th>CP</th>
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<td>Lab</td>
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<td>60 T/210 S</td>
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</table>

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

- OpenMP Application Programming Interface, Version 4.5, November 2015
MA-INF 1309  Lab Efficient Algorithms: Design, Analysis and Implementation

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<th>Workload</th>
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<td>270 h</td>
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<td>1 semester</td>
<td>at least every year</td>
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**Module coordinator**
Prof. Dr. Heiko Röglin

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

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

<table>
<thead>
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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

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**Module coordinator**
Dr. Michael Nüsken

**Lecturer(s)**
Dr. Michael Nüsken

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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 one’s 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**

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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

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**Module coordinator**
Prof. Dr. Estela Suarez

**Lecturer(s)**
Prof. Dr. Estela Suarez

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

<table>
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<th>Teaching format</th>
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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

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<th>Course Code</th>
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<tr>
<td>MA-INF 2202</td>
<td>L4E2</td>
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<td>Computer Animation</td>
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<tr>
<td>MA-INF 2212</td>
<td>L2E2</td>
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<td>MA-INF 2213</td>
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<td>MA-INF 2308</td>
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<tr>
<td>MA-INF 2309</td>
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MA-INF 2201  Computer Vision

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Module coordinator
Prof. Dr. Jürgen Gall

Lecturer(s)
Prof. Dr. Jürgen Gall

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
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

<table>
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<tr>
<th>Teaching format</th>
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T = face-to-face teaching
S = independent study

Graded exams
Written exam

Ungraded coursework (required for admission to the exam)
Successful exercise participation

Literature
• R. Hartley, A. Zisserman: Multiple View Geometry in Computer Vision
• R. Szeliski: Computer Vision: Algorithms and Applications
• S. Prince: Computer Vision: Models, Learning, and Inference
MA-INF 2202  Computer Animation

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<th>Lecturer(s)</th>
<th>Programme</th>
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<tr>
<td>Prof. Dr. Björn Krüger</td>
<td>Prof. Dr. Björn Krüger</td>
<td>M. Sc. Cyber Security</td>
<td>Optional</td>
<td>2.</td>
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</table>

**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**

<table>
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<tr>
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<td>2</td>
<td>30 T / 75 S</td>
<td>3.5</td>
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T = face-to-face teaching  
S = independent study

**Graded exams**

Written exam

**Ungraded coursework (required for admission to the exam)**

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

**Literature**

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

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<td>apl. Prof. Dr. Frank Kurth</td>
<td>apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen</td>
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<tbody>
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<td>Optional</td>
<td>2</td>
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</table>

**Learning goals: technical skills**
- Introduction into selected topics of digital signal processing;
- Applications in the field of Audio Signal Processing;
- Methods of Automatic Pattern Recognition

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

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

**Prerequisites**
none

**Course meetings**

<table>
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T = face-to-face teaching  
S = independent study

**Graded exams**
Written exam

**Ungraded coursework (required for admission to the exam)**
The completion of regularly provided exercise sheets. The work can be done in groups of up to four students. A total of 50% of the points must be achieved.

**Forms of media**
Slides, Blackboard, Whiteboard
MA-INF 2213 Advanced Computer Vision

<table>
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<tr>
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Module coordinator
Prof. Dr. Jürgen Gall
Lecturer(s)
Prof. Dr. Jürgen Gall

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

Learning goals: technical skills
Students will learn about various learning methods and their applications to computer vision problems.

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

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

Prerequisites
Required:
MA-INF 2201 – Computer Vision

Course meetings

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<td>15 T / 75 S</td>
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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

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<th>Workload</th>
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**Module coordinator**
Prof. Dr. Florian Bernard

**Lecturer(s)**
Prof. Dr. Florian Bernard

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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 one’s 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**

<table>
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<tr>
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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

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<td>180 h</td>
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Module coordinator
Prof. Dr. Jürgen Gall

Lecturer(s)
Prof. Dr. Jürgen Gall

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
2-3.

Learning goals: technical skills
Students will learn advanced techniques for analyzing video data.

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

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

Prerequisites
Required:
MA-INF 2201 – Computer Vision

Course meetings
<table>
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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

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**Module coordinator**

Prof. Dr. Thomas Schultz

**Lecturer(s)**

Prof. Dr. Thomas Schultz

**Programme**

M. Sc. Cyber Security

**Mode**

Optional

**Semester**

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**

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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

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**Module coordinator**
Prof. Dr. Thomas Schultz

**Lecturer(s)**
Prof. Dr. Thomas Schultz

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

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<td>8</td>
<td>4</td>
<td>60 T / 210 S</td>
<td>9</td>
</tr>
</tbody>
</table>

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

**Graded exams**
Oral presentation, written report

**Ungraded coursework (required for admission to the exam)**
# MA-INF 2226  Lab Geometry Processing

<table>
<thead>
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<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>at least every 2 years</td>
</tr>
</tbody>
</table>

**Module coordinator**

Lecturer(s)

Jun. Prof. Dr. Zorah Lähner

**Programme**

M. Sc. Cyber Security

**Mode**

Optional

**Semester**

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**

<table>
<thead>
<tr>
<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
<th>Workload[h]</th>
<th>CP</th>
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<tbody>
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<td>60 T / 210 S</td>
<td>9</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
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</thead>
<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>every semester</td>
</tr>
</tbody>
</table>

**Module coordinator**
Prof. Dr. Ina Prinz

**Lecturer(s)**
Prof. Dr. Ina Prinz

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

<table>
<thead>
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</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
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</thead>
<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>every semester</td>
</tr>
</tbody>
</table>

**Module coordinator**
Prof. Dr. Reinhard Klein

**Lecturer(s)**
Prof. Dr. Reinhard Klein

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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

<table>
<thead>
<tr>
<th>Teaching format</th>
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</tr>
</tbody>
</table>

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

<table>
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<th>Workload</th>
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<th>Duration</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>every year</td>
</tr>
</tbody>
</table>

Module coordinator
apl. Prof. Dr. Frank Kurth

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

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
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

<table>
<thead>
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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

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Type</th>
<th>Credits</th>
<th>Title and Description</th>
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<tr>
<td>MA-INF 3209</td>
<td>Sem2</td>
<td>4 CP</td>
<td>Seminar Selected Topics in Communication Management</td>
</tr>
<tr>
<td>MA-INF 3216</td>
<td>Sem2</td>
<td>4 CP</td>
<td>Seminar Sensor Data Fusion</td>
</tr>
<tr>
<td>MA-INF 3229</td>
<td>Lab4</td>
<td>9 CP</td>
<td>Lab IT-Security</td>
</tr>
<tr>
<td>MA-INF 3233</td>
<td>L2E2</td>
<td>6 CP</td>
<td>Advanced Sensor Data Fusion in Distributed Systems</td>
</tr>
<tr>
<td>MA-INF 3237</td>
<td>L2E2</td>
<td>6 CP</td>
<td>Array Signal and Multi-channel Processing</td>
</tr>
<tr>
<td>MA-INF 3204</td>
<td>Lab4</td>
<td>9 CP</td>
<td>Lab Communication and Communicating Devices</td>
</tr>
<tr>
<td>MA-INF 3305</td>
<td>Lab4</td>
<td>9 CP</td>
<td>Lab Information Systems</td>
</tr>
<tr>
<td>MA-INF 3310</td>
<td>L2E2</td>
<td>6 CP</td>
<td>Introduction to Sensor Data Fusion - Methods and Applications</td>
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<tr>
<td>MA-INF 3312</td>
<td>Lab4</td>
<td>9 CP</td>
<td>Lab Sensor Data Fusion</td>
</tr>
<tr>
<td>MA-INF 3317</td>
<td>Sem2</td>
<td>4 CP</td>
<td>Seminar Selected Topics in IT Security</td>
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<tr>
<td>MA-INF 3319</td>
<td>Lab4</td>
<td>9 CP</td>
<td>Lab Usable Security and Privacy</td>
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<tr>
<td>MA-INF 3320</td>
<td>Lab4</td>
<td>9 CP</td>
<td>Lab Security in Distributed Systems</td>
</tr>
<tr>
<td>MA-INF 3321</td>
<td>Sem2</td>
<td>4 CP</td>
<td>Seminar Usable Security and Privacy</td>
</tr>
<tr>
<td>MA-INF 3323</td>
<td>Lab4</td>
<td>9 CP</td>
<td>Lab Fuzzing Bootcamp</td>
</tr>
<tr>
<td>MA-INF 3324</td>
<td>Lab4</td>
<td>9 CP</td>
<td>Lab Design of Usable Security Mechanisms</td>
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</table>
MA-INF 3209  Seminar Selected Topics in Communication Management

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>120 h</td>
<td>4 CP</td>
<td>1 semester</td>
<td>at least every year</td>
</tr>
</tbody>
</table>

**Module coordinator**
Prof. Dr. Peter Martini

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

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

<table>
<thead>
<tr>
<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
<th>Workload[h]</th>
<th>CP</th>
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<td>Seminar</td>
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<td>2</td>
<td>30 T / 90 S</td>
<td>4</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 h</td>
<td>4 CP</td>
<td>1 semester</td>
<td>every year</td>
</tr>
</tbody>
</table>

**Module coordinator**
P.D. Dr. Wolfgang Koch

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

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

<table>
<thead>
<tr>
<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
<th>Workload[h]</th>
<th>CP</th>
<th>T = face-to-face teaching</th>
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<tbody>
<tr>
<td>Seminar</td>
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<td>2</td>
<td>30 T / 90 S</td>
<td>4</td>
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</table>

**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
Prof. Dr. Michael Meier

Lecturer(s)
Prof. Dr. Michael Meier

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
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 one's own results into the state-of-the-art of the resp. area

Contents

Prerequisites
none

Course meetings

<table>
<thead>
<tr>
<th>Teaching format</th>
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<tbody>
<tr>
<td>Lab</td>
<td>8</td>
<td>4</td>
<td>60 T / 210 S</td>
<td>9</td>
</tr>
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</table>

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

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 h</td>
<td>6 CP</td>
<td>1 semester</td>
<td>every year</td>
</tr>
</tbody>
</table>

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

Programme
M. Sc. Cyber Security
Mode
Optional
Semester
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 received at a fusion center (FC), the tracks then are fused to reconstruct a global estimate. In this lecture, methodologies to 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, Decorlated 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

<table>
<thead>
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<th>Teaching format</th>
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<th>h/week</th>
<th>Workload[h]</th>
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<tr>
<td>Exercises</td>
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<td>30 T / 75 S</td>
<td>3.5</td>
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</table>

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
### MA-INF 3237  Array Signal and Multi-channel Processing

<table>
<thead>
<tr>
<th>Workload</th>
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</tbody>
</table>

**Module coordinator**

Prof. Dr. Wolfgang Koch

**Lecturer(s)**

Dr. Marc Oispuu

**Programme**

M. Sc. Cyber Security

**Mode**

Optional

**Semester**

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:


**Course meetings**

<table>
<thead>
<tr>
<th>Teaching format</th>
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<tr>
<td>Exercises</td>
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<td>30 T / 75 S</td>
<td>3.5</td>
<td></td>
</tr>
</tbody>
</table>

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**

MA-INF 3304  Lab Communication and Communicating Devices

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>every semester</td>
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</table>

**Module coordinator**
Prof. Dr. Peter Martini

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

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

<table>
<thead>
<tr>
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<td>9</td>
</tr>
</tbody>
</table>

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

**Graded exams**
Oral presentation, written report

**Ungraded coursework (required for admission to the exam)**

**Literature**
The relevant literature will be announced towards the end of the previous semester.
MA-INF 3305  Lab Information Systems

<table>
<thead>
<tr>
<th>Workload</th>
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<th>Frequency</th>
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<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
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</tr>
</tbody>
</table>

Module coordinator
Dr. Thomas Bode

Lecturer(s)
Dr. Thomas Bode

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
2. or 3.

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

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

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

Prerequisites
none

Course meetings

<table>
<thead>
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</table>

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

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<thead>
<tr>
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</table>

Module coordinator
Prof. Dr. Wolfgang Koch

Lecturer(s)
Prof. Dr. Wolfgang Koch

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
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

<table>
<thead>
<tr>
<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
<th>Workload[h]</th>
<th>CP</th>
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<tbody>
<tr>
<td>Lecture</td>
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<td>30 T / 45 S</td>
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<tr>
<td>Exercises</td>
<td>2</td>
<td>30 T / 75 S</td>
<td>3.5</td>
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</tr>
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</table>

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

Graded exams
Written exam

Ungraded coursework (required for admission to the exam)
Successful exercise participation

Literature
MA-INF 3312  Lab Sensor Data Fusion

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
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<th>Frequency</th>
</tr>
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<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>every year</td>
</tr>
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</table>

Module coordinator
Prof. Dr. Wolfgang Koch

Lecturer(s)
Prof. Dr. Wolfgang Koch

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
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

<table>
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</tr>
</tbody>
</table>

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

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<th>Workload</th>
<th>Credit points</th>
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Module coordinator
Prof. Dr. Michael Meier

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

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
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

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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

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<td>every year</td>
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</table>

Module coordinator
Prof. Dr. Matthew Smith

Lecturer(s)
Prof. Dr. Matthew Smith

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
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 choose 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

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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

<table>
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**Module coordinator**

Prof. Dr. Matthew Smith

**Lecturer(s)**

Prof. Dr. Matthew Smith

**Programme**

M. Sc. Cyber Security

**Mode**

Optional

**Semester**

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 |
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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

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**Module coordinator**

Prof. Dr. Matthew Smith

**Lecturer(s)**

Prof. Dr. Matthew Smith

**Programme**

M. Sc. Cyber Security

**Mode**

Optional

**Semester**

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**

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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

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<tr>
<td>Prof. Dr. Matthew Smith</td>
<td>Dr. Christian Tiefenau</td>
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<th>Semester</th>
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<td>Optional</td>
<td>2. or 3.</td>
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**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 one's own results into the state-of-the-art of the resp. area.

**Contents**

**Prerequisites**

none

**Course meetings**

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S = independent study

**Graded exams**

Oral presentation, written report

**Ungraded coursework (required for admission to the exam)**
MA-INF 3324  Lab Design of Usable Security Mechanisms

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**Module coordinator**
Prof. Dr. Matthew Smith

**Lecturer(s)**
Dr. Emmanuel von Zezschwitz

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
2. or 3.

**Learning goals: technical skills**
The students will carry out a practical task (project) in the context of usable security mechanisms, including test and documentation of the implemented software/system.

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

**Contents**

**Prerequisites**
none

**Course meetings**

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**Graded exams**
Oral presentation, written report

**Ungraded coursework (required for admission to the exam)**
2.5 Computer Science – Intelligent Systems

MA-INF 4111 L2E2 6 CP Principles of Machine Learning ........................................ 63
MA-INF 4112 L2E2 6 CP Algorithms for Data Science ............................................... 64
MA-INF 4113 L2E2 6 CP Cognitive Robotics ........................................................... 65
MA-INF 4114 L2E2 6 CP Robot Learning ................................................................. 66
MA-INF 4201 L2E2 6 CP Artificial Life .................................................................... 67
MA-INF 4204 L2E2 6 CP Technical Neural Nets ...................................................... 68
MA-INF 4208 Sem2 4 CP Seminar Vision Systems .................................................... 69
MA-INF 4209 Sem2 4 CP Seminar Principles of Data Mining and Learning Algorithms ... 70
MA-INF 4211 Sem2 4 CP Seminar Cognitive Robotics .............................................. 71
MA-INF 4213 Sem2 4 CP Seminar Humanoid Robots .............................................. 72
MA-INF 4214 Lab4 9 CP Lab Humanoid Robots ...................................................... 73
MA-INF 4215 L2E2 6 CP Humanoid Robotics ............................................................ 74
MA-INF 4228 L4E2 9 CP Foundations of Data Science .............................................. 75
MA-INF 4230 L2E2 6 CP Advanced Methods of Information Retrieval ..................... 76
MA-INF 4231 Sem2 4 CP Seminar Advanced Topics in Information Retrieval ............... 77
MA-INF 4232 Lab4 9 CP Lab Information Retrieval in Practice ................................ 78
MA-INF 4236 L2E2 4 CP Advanced Methods for Text Mining .................................... 79
MA-INF 4302 L2E2 6 CP Advanced Learning Systems ............................................. 81
MA-INF 4303 L2E2 6 CP Learning from Non-Standard Data .................................... 82
MA-INF 4304 Lab4 9 CP Lab Cognitive Robotics .................................................... 83
MA-INF 4306 Lab4 9 CP Lab Development and Application of Data Mining and Learning Systems 84
MA-INF 4308 Lab4 9 CP Lab Vision Systems ........................................................... 85
MA-INF 4309 Lab4 9 CP Lab Sensor Data Interpretation .......................................... 86
MA-INF 4310 Lab4 9 CP Lab Mobile Robots ............................................................. 87
MA-INF 4316 L2E2 6 CP Graph Representation Learning .......................................... 88
MA-INF 4322 L4E2 9 CP Lab Machine Learning on Encrypted Data ......................... 90
MA-INF 4324 Sem2 4 CP Seminar Advanced Topics in Data Science ....................... 91
MA-INF 4325 Lab4 9 CP Lab Data Science in Practice ............................................. 92
MA-INF 4326 L2E2 6 CP Explainable AI and Applications ....................................... 93
MA-INF 4328 L2E2 6 CP Spatio-Temporal Data Analytics ........................................ 95
### MA-INF 4111 Principles of Machine Learning

<table>
<thead>
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<td>180 h</td>
<td>6 CP</td>
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<td>every 2 years</td>
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</table>

#### Module coordinator
Prof. Dr.-Ing. Christian Bauckhage

#### Lecturer(s)
Prof. Dr.-Ing. Christian Bauckhage

#### Programme
M. Sc. Cyber Security

#### Mode
Optional

#### Semester
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

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<td>30 T / 75 S</td>
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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
- 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

<table>
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Module coordinator
Prof. Dr. Stefan Wrobel

Lecturer(s)
Dr. Tamas Horvath, Prof. Dr. Stefan Wrobel

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
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

Teaching format

<table>
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Graded exams
Written exam

Ungraded coursework (required for admission to the exam)
Successful exercise participation

Forms of media
lectures, exercises

Literature
• Jiawei Han, Micheline Kamber, Jian Pei: Data Mining: Concepts and Techniques. Morgan Kaufmann Publishers, 2012.
# MA-INF 4113 Cognitive Robotics

<table>
<thead>
<tr>
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**Module coordinator**
Prof. Dr. Sven Behnke

**Lecturer(s)**
Prof. Dr. Sven Behnke

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
1. or 2.

## Learning goals: technical skills
This lecture is one of two introductory lectures of the intelligent systems track. The lecture covers cognitive capabilities of robots, like self-localization, mapping, object perception, and action-planning in complex environments.

This module complements MA-INF 4114 and can be taken before or after that module.

## Learning goals: soft skills
Communicative skills (oral and written presentation of solutions, discussions in small teams), self competences (ability to accept and formulate criticism, ability to analyze problems)

## Contents
Probabilistic approaches to state estimation (Bayes Filters, Kalman Filter, Particle Filter), motion models, sensor models, self-localization, mapping with known poses, simultaneous mapping and localization (SLAM), iterated closest-point matching, path planning, place- and person recognition, object recognition.

## Prerequisites
**Required:**
MA-INF 4101 - Theory of Sensorimotor Systems has not been passed.

## Course meetings

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## Graded exams
- Written exam

## Ungraded coursework (required for admission to the exam)
Successful exercise participation

## Literature
MA-INF 4114  Robot Learning

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Module coordinator
Prof. Dr. Sven Behnke

Lecturer(s)
Prof. Dr. Sven Behnke, Dr. Nils Goerke

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
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, linear 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

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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
MA-INF 4201  Artificial Life

<table>
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Module coordinator
Dr. Nils Goerke

Lecturer(s)
Dr. Nils Goerke

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
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

<table>
<thead>
<tr>
<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
<th>Workload[h]</th>
<th>CP</th>
</tr>
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<td>Lecture</td>
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<td>30 T / 45 S</td>
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<tr>
<td>Exercises</td>
<td>2</td>
<td>30 T / 75 S</td>
<td>3.5</td>
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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
MA-INF 4204  Technical Neural Nets

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

Module coordinator
Dr. Nils Goerke
Lecturer(s)
Dr. Nils Goerke

Programme
M. Sc. Cyber Security
Mode
Optional
Semester
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 efficacy 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

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</table>

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

Graded exams

Written exam

Ungraded coursework (required for admission to the exam)
Successful exercise participation

Forms of media
Pencil and paper work, explaining solutions in front of the exercise group, implementation of small programs, use of simple simulation tools

Literature
MA-INF 4208 Seminar Vision Systems

<table>
<thead>
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<th>Workload</th>
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<tbody>
<tr>
<td>120 h</td>
<td>4 CP</td>
<td>1 semester</td>
<td>every semester</td>
</tr>
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</table>

**Module coordinator**
Prof. Dr. Sven Behnke

**Lecturer(s)**
Prof. Dr. Sven Behnke, Prof. Dr. Joachim K. Anlauf, Dr. Nils Goerke

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
2. or 3.

**Learning goals: technical skills**
- Knowledge in advanced topics in the area of technical vision systems, such as image segmentation, feature extraction, and object recognition.
- Ability to understand new research results presented in original scientific papers and to present them in a research talk as well as in a seminar report.

**Learning goals: soft skills**
Self-competences (time management, literature search, self-study), communication skills (preparation and clear didactic presentation of research talk, scientific discussion, structured writing of seminar report), social skills (ability to formulate and accept criticism, critical examination of research results).

**Contents**
Current research papers from conferences and journals in the field of vision systems covering fundamental techniques and applications.

**Prerequisites**
Recommended:
At least 1 of the following:
MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning
MA-INF 4204 – Technical Neural Nets

**Course meetings**

<table>
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<tr>
<td>Seminar</td>
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<td>2</td>
<td>30 T / 90 S</td>
<td>4</td>
</tr>
</tbody>
</table>

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

**Graded exams**
Oral presentation, written report

**Ungraded coursework (required for admission to the exam)**

**Literature**
MA-INF 4209  Seminar Principles of Data Mining and Learning Algorithms

<table>
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</table>

**Module coordinator**
Prof. Dr. Stefan Wrobel

**Lecturer(s)**
Prof. Dr. Stefan Wrobel

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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

<table>
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</table>

**Module coordinator**

Prof. Dr. Sven Behnke

**Lecturer(s)**

Prof. Dr. Sven Behnke, Dr. Nils Goerke

**Programme**

M. Sc. Cyber Security

**Mode**

Optional

**Semester**

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**

<table>
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T = face-to-face teaching

S = independent study

**Graded exams**

Oral presentation, written report

**Ungraded coursework (required for admission to the exam)**

**Literature**

- Selected papers.
MA-INF 4213  Seminar Humanoid Robots

<table>
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<td>1 semester</td>
<td>every semester</td>
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**Module coordinator**
Prof. Dr. Maren Bennewitz

**Lecturer(s)**
Prof. Dr. Maren Bennewitz

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

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

**Graded exams**
Oral presentation, written report

**Ungraded coursework (required for admission to the exam)**

**Literature**
- 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

<table>
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<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>every semester</td>
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</tbody>
</table>

Module coordinator
Prof. Dr. Maren Bennewitz

Lecturer(s)
Prof. Dr. Maren Bennewitz

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
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

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<td>4</td>
<td>60 T / 210 S</td>
<td>9</td>
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</table>

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

Graded exams
Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature
- 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

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<td>180 h</td>
<td>6 CP</td>
<td>1 semester</td>
<td>at least every 2 years</td>
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**Module coordinator**
Prof. Dr. Maren Bennewitz
Lecturer(s)
Prof. Dr. Maren Bennewitz

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

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<td>Lecture</td>
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<td>2</td>
<td>30 T / 45 S</td>
<td>2.5</td>
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<td>Exercises</td>
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<td>2</td>
<td>30 T / 75 S</td>
<td>3.5</td>
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</table>

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

**Graded exams**
Oral exam

**Ungraded coursework (required for admission to the exam)**
Successful exercise participation

**Literature**
- B. 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

<table>
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<th>Workload</th>
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<th>Frequency</th>
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<tbody>
<tr>
<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>every year</td>
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### Module coordinator
Dr. Michael Nüsken

### Lecturer(s)
Dr. Michael Nüsken

### Programme
M. Sc. Cyber Security

### Mode
Optional

### Semester
2. or 3.

### Learning goals: technical skills
- 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 enlightening. 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

<table>
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</table>

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
**MA-INF 4230  Advanced Methods of Information Retrieval**

<table>
<thead>
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<th><strong>Workload</strong></th>
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<th><strong>Frequency</strong></th>
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<td>6 CP</td>
<td>1 semester</td>
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**Module coordinator**
Prof. Dr. Elena Demidova

**Lecturer(s)**
Prof. Dr. Elena Demidova

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

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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:

Further references to relevant material will be provided during the lecture.
MA-INF 4231  Seminar Advanced Topics in Information Retrieval

<table>
<thead>
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<td>4 CP</td>
<td>1 semester</td>
<td>every year</td>
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</table>

Module coordinator: Prof. Dr. Elena Demidova
Lecturer(s): Prof. Dr. Elena Demidova

Programme: M. Sc. Cyber Security
Mode: Optional
Semester: 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

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<td>Seminar</td>
<td>10</td>
<td>2</td>
<td>30 T / 90 S</td>
<td>4</td>
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</table>

Graded exams
Oral presentation, written report

Ungraded coursework (required for admission to the exam)
None

Literature
Selected chapters from:

Further relevant literature will be announced at the beginning of the seminar.
MA-INF 4232 Lab Information Retrieval in Practice

<table>
<thead>
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<th>Workload</th>
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<th>Duration</th>
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<td>9 CP</td>
<td>1 semester</td>
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**Module coordinator**
Prof. Dr. Elena Demidova

**Lecturer(s)**
Prof. Dr. Elena Demidova

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

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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:

Further references to relevant material will be provided during the lab.
MA-INF 4236  Advanced Methods for Text Mining

<table>
<thead>
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Module coordinator: Prof. Dr. Rafet Sifa

Programme: M. Sc. Cyber Security

Mode: Optional

Semester: 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

<table>
<thead>
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<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
<th>Workload[h]</th>
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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
- Lecture notes of the instructors
MA-INF 4302  Advanced Learning Systems

<table>
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<th>Workload</th>
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<td>180 h</td>
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<td>every 2 years</td>
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Module coordinator
Prof. Dr. Stefan Wrobel

Lecturer(s)
Prof. Dr. Stefan Wrobel

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
2. or 3.

Learning goals: technical skills
Participants specialize and require in-depth knowledge of one particular class of learning algorithms, they acquire the necessary knowledge to improve existing algorithms and construct their own within the given class, all the way up to the research frontier on the topic.

Learning goals: soft skills
In group work, students acquire the necessary social and communication skills for effective team work and project planning, and learn how to present software projects to others.

Contents
The module each time concentrates on one or more specific algorithm classes, e.g.
- kernel machines
- neural networks
- probabilistic and statistical learning approaches
- logic-based learning approaches
- reinforcement learning

Prerequisites
Recommended:
all of the following:
MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning
MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery

Course meetings

<table>
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<tr>
<th>Teaching format</th>
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</table>

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
- John Shawe-Taylor, Nello Christianini, Kernel Methods for Pattern Analysis, CUP, 2004
- Christopher Bishop, Pattern Recognition and Machine Learning, The University of Edinburgh, 2006
- Richard Duda, Peter Hart, David Stork, Pattern Classification, John Wiley and Sons, 2001
MA-INF 4303 Learning from Non-Standard Data

<table>
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<th>Workload</th>
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<tbody>
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Module coordinator
Prof. Dr. Stefan Wrobel
Lecturer(s)
Prof. Dr. Stefan Wrobel, Dr. Tamas Horvath

Programme
M. Sc. Cyber Security
Mode
Optional
Semester
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
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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
- Diane J. Cook, Lawrence B. Holder, Mining Graph Data, Wiley & Sons, 2006
- Saso Dzeroski, Nada Lavrac, Relational Data Mining, Springer, 2001
MA-INF 4304  Lab Cognitive Robotics

<table>
<thead>
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<th>Workload</th>
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Module coordinator
Prof. Dr. Sven Behnke

Lecturer(s)
Prof. Dr. Sven Behnke

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
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

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<td>9</td>
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T = face-to-face teaching
S = independent study

Graded exams
Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature
- Selected research papers.
MA-INF 4306  Lab Development and Application of Data Mining and Learning Systems

<table>
<thead>
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**Module coordinator**
Prof. Dr. Stefan Wrobel

**Lecturer(s)**
Prof. Dr. Stefan Wrobel

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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 resources, ability to work under pressure, ability to accept/formulate criticism)

**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**

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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

<table>
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</table>

Module coordinator
Prof. Dr. Sven Behnke

Lecturer(s)
Dr. Nils Goerke

Programme
M. Sc. Cyber Security

Mode
Optional
Semester
3.

Learning goals: technical skills
Students will acquire knowledge of the design and implementation of parallel algorithms on GPUs. They will apply these techniques to accelerate standard machine learning algorithms for data-intensive computer vision tasks.

Learning goals: soft skills
Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions), communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of implementations)

Contents
Basic matrix and vector computations with GPUs (CUDA). Classification algorithms, such as multi-layer perceptrons, support-vector machines, k-nearest neighbors, linear-discriminant analysis. Image preprocessing and data handling. Quantitative performance evaluation of learning algorithms for segmentation and categorization.

Prerequisites
Recommended:
At least 1 of the following:
MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning
MA-INF 4204 – Technical Neural Nets

Course meetings
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Graded exams
Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Literature
MA-INF 4309  Lab Sensor Data Interpretation

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<th>Workload</th>
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**Module coordinator**
PD. Dr. Volker Steinhage

**Lecturer(s)**
PD. Dr. Volker Steinhage

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

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**Graded exams**
Oral presentation, written report

**Ungraded coursework (required for admission to the exam)**

**Literature**
Relevant literature will be announced at start of the lab.
MA-INF 4310  Lab Mobile Robots

<table>
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<tbody>
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<td>9 CP</td>
<td>1 semester</td>
<td>at least every year</td>
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Module coordinator
Prof. Dr. Sven Behnke

Lecturer(s)
Prof. Dr. Sven Behnke, Dr. Nils Goerke

Programme
M. Sc. Cyber Security

Mode
Optional

Semester
2. or 3.

Learning goals: technical skills
Participants acquire basic knowledge and practical experience in the design and implementation of control algorithms for simple structured robotic systems using real mobile robots. Fundamental paradigms for mobile robots will be identified and implemented in 2 person groups.

Learning goals: soft skills
Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions), communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of implementations)

Contents
Robot middleware (e.g. ROS), robot simulation tools, basic capabilities for mobile robots: reactive control, SMPA architecture, navigation, path planning, localisation, simultaneous localization and mapping (SLAM), visual based object detection, learning robot control.

Prerequisites
Recommended:
At least 1 of the following:
BA-INF 132 – Grundlagen der Robotik
BA-INF 131 – Intelligente Sehsysteme
MA-INF 1314 – Online Motion Planning
MA-INF 2201 – Computer Vision
MA-INF 4113 – Cognitive Robotics
MA-INF 4114 – Robot Learning
MA-INF 4203 – Autonomous Mobile Systems

Course meetings

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

Graded exams
Oral presentation, written report

Ungraded coursework (required for admission to the exam)

Forms of media
Robots simulation environments, robot control middleware, computer vision libraries, programming, demonstration of robot capabilities (real robotic systems), presentation and written report of approach and results.

Literature
- J. Buchli: Mobile Robots: Moving Intelligence, Published by Advanced Robotic Systems and Pro Literatur Verlag
- Additional State-of-the-art publications.
MA-INF 4316  Graph Representation Learning

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<td>180 h</td>
<td>6 CP</td>
<td>1 semester</td>
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</table>

Module coordinator: Dr. Pascal Welke
Lecturer(s): Dr. Pascal Welke

Programme: M. Sc. Cyber Security
Mode: Optional

Learning goals: technical skills
- Deep understanding of the trade-off between expressiveness of graph representation and computational complexity, as well as practical runtime of algorithms in the context of machine learning applications.
- Ability to implement, practically apply, and theoretically analyze graph representation, graph kernels, and graph mining algorithms.

Learning goals: soft skills
- Social, methodological, and analytical competences via communication, own development, and presentation of problem formulations, algorithms, and solutions.
- Learning to solve project tasks in a group.
- Learning to evaluate the trade-offs and limitations of existing methods.

Contents
We will discuss general approaches for machine learning (ML) on graph structured data. In particular, computational methods for graph representation learning such as graph neural networks (GNNs), graph kernels, as well as graph mining techniques will be discussed, analyzed, and applied. Regarding GNNs and graph kernels, we will discuss the expressive power and how these concepts are related, as well as several specific examples. In the area of graph mining, we will likely investigate fast (approximate) algorithms to count small patterns, such as triangles, or trees.

If time permits, we might venture into the realm of ranking on large-scale graphs, with applications such as recommender systems. The exercises will focus on practical implementations and the application of these methods to real world examples.

Prerequisites
Recommended:
Helpful: one or more of the following
- MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning
- MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery
- MA-INF 4212 – Data Science and Big Data
- MA-INF 1105 - Algorithms for Data Analysis
- MA-INF 1102 - Combinatorial Optimization

Course meetings

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

Graded exams
Oral exam or written exam

Ungraded coursework (required for admission to the exam)
Successful exercise participation

Forms of media
- Lecture slides
- Jupyter notebooks
Literature

- William L. Hamilton: Graph Representation Learning, Synthesis Lectures on Artificial Intelligence and Machine Learning, Morgan and Claypool.
MA-INF 4322 Lab Machine Learning on Encrypted Data

<table>
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<th>Workload</th>
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<tbody>
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<td>270 h</td>
<td>9 CP</td>
<td>1 semester</td>
<td>every year</td>
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</table>

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

Programme
M. Sc. Cyber Security
Mode
Optional
Semester
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 choosing 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 implementation, 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
<table>
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T = face-to-face teaching
S = independent study

Graded exams
Written exam

Ungraded coursework (required for admission to the exam)
Successful exercise participation
MA-INF 4324  Seminar Advanced Topics in Data Science

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**Module coordinator**

Prof. Dr. Elena Demidova

**Lecturer(s)**

Prof. Dr. Elena Demidova

**Programme**

M. Sc. Cyber Security

**Mode**

Optional

**Semester**

2. or 3.

**Learning goals: technical skills**

This module concentrates on specialized topics in data science. The students obtain skills in the independent, in-depth study of state-of-the-art scientific literature on specific topics, discussion with their peers and presentation to the scientific audience.

**Learning goals: soft skills**

- Communication skills: oral and written presentation of scientific content.
- Self-competences: the ability to analyze problems, time management, creativity.

**Contents**

Statistical and machine learning-based methods of data analytics, including typical steps of the data science process: data generation, integration, cleaning, exploration, modelling and evaluation. Specialized data representation and analytics methods for selected data types and applications in specific domains.

**Prerequisites**

Recommended:

BA-INF 150 - Einführung in die Data Science

**Course meetings**

Teaching format | Group size | h/week | Workload[h] | CP  | T = face-to-face teaching | S = independent study
Seminar          | 10         | 2      | 30 T / 90 S | 4   |

**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

<table>
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**Module coordinator**
Prof. Dr. Elena Demidova

**Lecturer(s)**
Prof. Dr. Elena Demidova

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
2. or 3.

**Learning goals: technical skills**
This module concentrates on practical experience in data analytics. Participants acquire basic knowledge and practical experience in the design and implementation of data science workflows for specific data types and applications.

**Learning goals: soft skills**
- Communication skills: the ability to work in teams.
- Self-competences: the ability to analyse problems and find practical solutions. Time management, creativity, presentation of results.

**Contents**
Practical application of statistical and machine learning-based methods to solve data analytics problems on real-world datasets and evaluate proposed solutions.

**Prerequisites**
Recommended:
BA-INF 150 - Einführung in die Data Science
MA-INF 4230 - Advanced Methods of Information Retrieval

**Course meetings**

<table>
<thead>
<tr>
<th>Teaching format</th>
<th>Group size</th>
<th>h/week</th>
<th>Workload[h]</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab</td>
<td>8</td>
<td>4</td>
<td>60 T / 210 S</td>
<td>9</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit points</th>
<th>Duration</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 h</td>
<td>6 CP</td>
<td>1 semester</td>
<td>every year</td>
</tr>
</tbody>
</table>

**Module coordinator**
Dr. Tiansi Dong

**Lecturer(s)**
Dr. Tiansi Dong

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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 limitition 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 Sylogistic 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**

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<tbody>
<tr>
<td>Lecture</td>
<td></td>
<td>2</td>
<td>30 T / 45 S</td>
<td>2.5</td>
</tr>
<tr>
<td>Exercises</td>
<td></td>
<td>2</td>
<td>30 T / 75 S</td>
<td>3.5</td>
</tr>
</tbody>
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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

MA-INF 4328  Spatio-Temporal Data Analytics

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**Module coordinator**
Prof. Dr. Elena Demidova

**Lecturer(s)**
Prof. Dr. Elena Demidova

**Programme**
M. Sc. Cyber Security

**Mode**
Optional

**Semester**
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**

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**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.