Module handbook

Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach
(Examination regulations version 2020)
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Prolog
This module handbook is based on the current version of the examination regulations for the Master of Science degree program in the 2020 version, subject-specific provisions for the major in Informatik / Computer Science. These provisions define the course content structured in the modules and the curriculum structured in terms of semesters and areas.

Modules consist of different elements: Courses (e.g. lectures, exercises, seminars, etc.) and coursework (pass/fail assessments) or examinations (graded assessments). The module descriptions explain in more detail both the course elements and the required coursework and examinations to demonstrate the acquisition of competencies.

In each case, the regular course and examination assessments are described; should it become necessary to deviate from the described assessments at short notice due to unforeseen circumstances, the substitute assessments will be announced in the first week of the lecture period at the latest.

For successfully completed modules, credit points are awarded, the so-called ECTS credit points according to the "European Credit Transfer and Accumulation System". These credits indicate the weighting of a course in a module as well as the workload associated with the course. One credit point corresponds to an effort of approx. 30 working hours per semester for an average student. A student should collect approx. 30 ECTS credits per semester.

The standard period of study is four semesters. A total of 120 ECTS points must be acquired in the Master of Science Informatik / Computer Science.

Regulations regarding attendance:
Attendance is not mandatory in lectures.
Seminars and lab courses require regular attendance as part of the Studienleistung (pass/fail assessment) because it is essential for reaching the learning targets of these courses. Exercises may require regular attendance as well, in which case this fact will be stated in the description of the specific module.

While there are generally no admission requirements for examinations within a module, in the case of elective modules, it happens in very rare cases that two modules build directly on each other in terms of content and the corresponding advanced module can therefore only be completed if the introductory module has been successfully completed beforehand. This is indicated accordingly in the module descriptions.

Further information on the program (e.g. the examination regulations, the model study plan, entry requirements, etc.) can be found at https://www.tf.uni-freiburg.de/en/study-programs/computer-science/m-sc-computer-science

B. Overview of Study program and teaching unit

<table>
<thead>
<tr>
<th>Subject</th>
<th>Informatik / Computer Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree</td>
<td>Master of Science (M.Sc.)</td>
</tr>
<tr>
<td>Scope of ECTS credit points</td>
<td>120</td>
</tr>
<tr>
<td>Study duration</td>
<td>4 Semesters / 2 years</td>
</tr>
</tbody>
</table>
### Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Study format</th>
<th>Full-time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of study program</td>
<td>Consecutive and research oriented</td>
</tr>
<tr>
<td>Regular study duration</td>
<td>4 Semesters</td>
</tr>
<tr>
<td>University</td>
<td>Albert-Ludwigs-Universität Freiburg / University of Freiburg</td>
</tr>
<tr>
<td>Faculty</td>
<td>Faculty of Engineering</td>
</tr>
<tr>
<td>Department</td>
<td>Department of Computer Science</td>
</tr>
<tr>
<td>Homepage</td>
<td><a href="https://www.tf.uni-freiburg.de/en/study-programs/computer-science">https://www.tf.uni-freiburg.de/en/study-programs/computer-science</a></td>
</tr>
</tbody>
</table>

#### Short profile

The Master of Science Informatik / Computer Science program is versatile with a very flexible curriculum. Students acquire in-depth knowledge in various self-chosen IT areas by participating in different courses: Advanced and specialization lectures (accompanied by exercises), seminars, a lab course, a study project and the Master's thesis form a personal competency profile in the field of computer science. The Customized Course Selection area allows a look outside the box by taking some courses in subjects other than Computer Science. In the last semester, students work on their master's thesis. They are expected to tackle an actual research question in close cooperation with a professor of the Department of Computer Science as their supervisor, writing the Thesis and presenting the results for the supervisors. Students can opt to either choose their courses with a broad thematic orientation, combining various topics from all areas of Computer Science, or specialize in either artificial intelligence or cyber-physical systems, with the additional qualification "Specialization in Artificial Intelligence" resp. "Specialization in Cyber-Physical Systems" mentioned on the transcript.

#### Educational Goals / Qualification

The Master degree program in Computer Science offers a study program based on the mathematical and methodological foundations of computer science, which deepens methodological knowledge and strengthens application knowledge in computer science, and verifies the student’s independent problem solving skills. Students can choose between a broad thematic focus covering
various areas of computer science or a specialization in either Artificial Intelligence or Cyber-Physical Systems. The degree program prepares students for a career in academic research or in data-processing companies.

<table>
<thead>
<tr>
<th>Language(s)</th>
<th>English (some elective courses in application areas in German)</th>
</tr>
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</table>
| Admission requirements | ■ Bachelor's degree in computer science, math, or in a closely related field with 180 ECTS and a duration of at least 3 years or equivalent  
|                       | ■ Average grade of 2.9 or better in German grading system  
|                       | ■ English language proficiency level C1 or German C1 plus English B2 |
| Intake               | can be started either in the winter semester or the summer semester |
| Date/Version         | As of March 2024 / exam regulations 2020 |

C. Profile of the degree program with qualification goals (technical and interdisciplinary)

The Master of Science degree program in Informatik / Computer Science is a two-year program open to highly qualified international and German graduate students with a Bachelor of Science degree in Computer Science or a similar subject. Building on the knowledge and skills from the basic course in the previous undergraduate Bachelor's degree, this graduate degree program conveys in-depth technical, methodological and subject related practical content. Students also acquire research skills and interdisciplinary skills.

The program has a total scope of 120 ECTS credits with a regular study duration of 4 semesters and can be started either in the winter semester or in the summer semester. With its flexible and versatile curriculum students acquire in-depth knowledge in various self-chosen IT areas by participating in different courses, structured in modules:

- **advanced and specialization lectures**, most of them accompanied by exercises (42 ECTS credits)
- **seminars** (6 ECTS credits)
- a **lab course** (6 ECTS credits)
- a **study project** (18 ECTS credits)

Completing these modules, students form a personal competency profile in the field of computer science.

The **Customized Course Selection area** (18 ECTS credits) allows a look outside the box by taking some courses in subjects other than Computer Science (like mathematics, microsystems engineering, economical sciences, applied bioinformatics, sustainable systems, neuroscience, physics, medicine or cognitive science).
In the last semester, students work on their Master’s thesis (30 ECTS credits), tackling an actual research question in close cooperation with a supervising professor (of the Department of Computer Science) and their staff, writing the Thesis and presenting the results.

Students can opt to either choose their courses with a broad thematic orientation, combining various topics from all areas of Computer Science, or specialize in either the area of artificial intelligence or cyber-physical systems, with the additional qualification "Specialization Artificial Intelligence" resp. "Specialization Cyber-Physical Systems" mentioned on the final graduation documents and certificates.

The academic degree “Master of Science” (M.Sc.) awarded after successfully completing the study program forms the second professional qualification and enables students to pursue an academic career by applying for a PhD and working towards a doctorate; or they can enter a career in industry, research and development.

C.1 Qualification goals of graduates of the program Master of Science Informatik / Computer Science

Computer science has become an integral part of our lives; it permeates all levels of everyday life, research areas and fields of work. So, as an expert in computer science possible occupational fields are divers and numerous. It depends on the distinct focus set during education in which area graduates will start out there career, and it is common that computer scientists change their focus more than once. Lifelong learning is a necessary concept in a subject as fast moving as computer science.

The Master of Science program in Informatik / Computer Science offers a study program based on the mathematical and methodological foundations of computer science that deepens methodological knowledge in computer science, and strengthens and verifies the student’s independent problem solving skills. Students can choose between a broad thematic focus covering various areas of computer science or a specialization in either Artificial Intelligence or Cyber-Physical Systems. The degree program prepares students for a career in academic research or in data-processing companies.

Graduates specialized in AI are highly sought after, for example in work or research fields connected to autonomous driving, image recognition, medical- or biotechnology and neuroscience and many more innovative areas. For graduates choosing to refrain from specializing in favor of building a broader set of skills, some of these areas might be equally interesting, maybe from a slightly different point of view. They can also go into a completely different direction, for instance by working in the media industry or application development. Companies in the sustainable energy industry or transportation industry will benefit from the expertise in safety and security graduates specialized in Cyber-Physical Systems can provide, but so can research areas in biomedical technology.

Some common qualification goals exist for all graduates, no matter the individual specialization or focus during their studies. Those are mentioned next, sorted by technical qualifications and general or interdisciplinary qualifications.

C2. Technical qualification goals

Graduates from the Master of Science Informatik / Computer Science program
- have professional methodological competence in various fields of computer science (advanced proficiency in their chosen specialization area) and can transfer the concepts into practical
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- know about and can apply the usual procedures in computer science from engineering approaches (such as analyzing and construction) to mathematical methods for gaining knowledge (such as formalizing and proving) to empirical methods (such as experimentation and simulation)
- can grasp and structure complex problems and solve them using the usual methods of computer science
- are able to plan, carry out, document and present an IT task independently using scientific methods
- are proficient in using the usual IT tools, like programming, software development, system design, optimization procedures, testing etc.
- are aware of current requirements regarding safety and security aspects in computer science and can analyze potential threats and issues in new developments and applications
- are able to transfer their subject-related problem solving skills to other subjects and work with experts from that area to develop new applications and systems
- are aware of the social relevance of computer science and are able to grasp IT facts in various application and factual contexts; they can evaluate new concepts critically with regard to technical, societal and ethical aspects

C3. General and interdisciplinary qualification goals

Graduates also
- have general, interdisciplinary problem-solving skills
- can assess themselves and their performance to the point, that they are capable of planning and implementing a wide variety of projects
- have the ability to work in a team and can take responsibility for themselves and others
- know the rules of good scientific practice and have the skills for problem-oriented scientific research as well as the ability to critically assess research results
- can document technical contexts and present information in a suitable written or oral form
- have analysis and decision-making skills in respect to technical, social and ethical aspects
- are able to continue learning independently in the field of computer science
- can adapt to new technologies and transfer their knowledge to future developments

D. Special features of the program (regarding stays abroad and internships)

While neither stays abroad nor internships are compulsory for the Master program in Informatik / Computer Science, students are welcome to participate in either one or both on a voluntary base. Students who would like to broaden their cultural horizons by spending a semester abroad will find information and support from various offices, such as the University's International Office and the Faculty's Erasmus coordinator for planning and coordination, and from the student advisor for useful adjustments to the individual personal study plan.

Students who want to gain practical experience through an internship will be supported in their project in an advisory capacity by the study coordinator and general advisor of the Faculty of Engineering.

E. Module descriptions and model study plan

E.1 Course structure
There is no predetermined curriculum for all the students in this Master program in Informatik / Computer Science. The exam regulations just provide the framework, which students fill with individually chosen lectures, seminars and other courses. As there are no mandatory courses, students in this versatile and individually adaptable program have to build and organize their own study plan following the regulations. They compose their individual portfolio of courses and determine the semester when to take them (observing the frequency of the offered courses as per the course catalog). Therefore, each student follows their own personalized study plan and course schedule.

The overall structure of the curriculum is shown in a diagram in the Curriculum section under https://www.tf.uni-freiburg.de/en/study-programs/computer-science/m-sc-computer-science

Students can choose to either expand the range of the computer science expertise even more by one more lecture, or to complete all the available courses in this area in subjects other than computer science and so pursue interdisciplinary knowledge and skills on a slightly larger scale.

If so desired, students can choose to focus in one of the two specialization areas:

- Cyber-Physical Systems
- Artificial Intelligence

To specialize, students have to take the following courses from the respective areas:

- at least 4 Specialization courses or Advanced lectures (24 ECTS credit points)
- the Study project (18 ECTS credit points)
- the Thesis (30 ECTS credit points)

The affiliation of a course with one of the specialization areas is mentioned in the module description. An overview of the lectures and courses that are assigned to the respective area, from which the courses with at least 24 ECTS credits can be put together, is provided as an overview via PDF documents in the Curriculum section on the program website mentioned above.

On the program website, students can also find an overview with the list of subjects and the respective individual modules and courses offered in other departments that are generally open for students in the Master program of Informatik / Computer Science in the Customized Course Selection area: https://www.tf.uni-freiburg.de/bilder/studium_lehre/studienplaene/liste-fach-fremder-wahlmodule-msc-informatik-po-2020

For detailed descriptions for all these modules and courses from the available subjects students are referred to the according module handbooks at the various departments, as it would go beyond the scope of the module handbook for Master Informatik / Computer Science to include them all. A language course can replace one of the courses in other subjects; especially international students are encouraged to use this possibility to develop some language proficiency in German.

The contributions of the individual modules to the Master program structure are stated in the Epilog.

**E.2 Example for study plan**

Since all of the modules in this study program are compulsory elective modules with a large selection of courses to select from, or individual work without a fixed reference to the lecture period, presenting a study schedule is only useful to a limited extent, as the specific plan is different for each student. An exemplary study plan/curriculum for M.Sc. Informatik / Computer Science in the Curriculum section of the program website offers more detailed information about the program structure (sorted by modules with mentions of the semesters the courses could be taken in).
F. Teaching and Learning Methods

Lectures and related exercises make up the majority of the different courses in the Master program. Lectures convey fundamental and advanced subject-relevant knowledge on specific topics as well as methodological knowledge in a coherent manner. Lectures are an integral part of teaching in technical subjects, as they summarize facts, structures and interdependencies of a subject area and convey general knowledge.

In accompanying exercises, the acquired technical and methodological knowledge as well as scientific working techniques are applied and practiced independently. Usually, exercises are held as follows: in a first part, students work on subject-specific questions methodically and independently. In a second part, the work results are discussed under the guidance of a tutor. The students improve their problem-solving skills through qualified feedback on their own performance and discovering common sources of error.

A seminar as a type of course introduces and develops the ability to independent scientific work - alone and in groups - and intensive discussion in regards to a given topic. In seminars, content on a specific subject area is not prepared and presented by the lecturers alone; instead, the students work through provided literature largely independently and present the acquired knowledge to their fellow students. Following the presentations, there is generally a discussion between the supervising lecturer and the participating students, which offers room for reflection and constructive criticism. In addition, a written version of the results in the form of a scientific poster or a term paper, is often expected as part of the coursework. The interdisciplinary skills usually learned in seminars - e.g. B. analyzing, reflecting, discussing and presenting – are achieved in a group with a supervised setting. Therefore, a group-related compulsory attendance is required in these events.

Lab courses and practical exercises provide subject-related practical and methodical skills. Students are required to work largely independently and often in a special setting, e.g. in appropriately equipped laboratories or (possibly in small groups) with special tool kits provided. Accordingly, compulsory attendance can be required here. In most cases, the performance for lab courses is assessed through written reports, exercise sheets, supervised experiments and / or a presentation.

In projects, students learn to critically analyze complex problems in groups or alone and to work out solutions. In line this work, theoretical knowledge and methodological skills are applied in practical settings. A self-chosen or specified task from a real-life situation is tackled alone or in a team. Problem-solving skills relevant to the specific topic of the task are developed and professional qualifications like communication, team work and self-management skills are deepened. Projects are usually evaluated on the basis of a written draft, a demonstrator and / or a presentation.

The university library (especially with the faculty's own branch) provides literature necessary for self-study that supplements the lectures and for background research required for project work.

G. Explanation of the examination system

Evaluation of the successful achievement of the qualification goals is done during the study program at the end of the module in each semester. Most modules in this program (11 out of 13 in total) are completed with a graded assessment (“Prüfungsleistung”); details depend on the chosen courses. Courses can include additional coursework, depending on the qualification goals. Details are given in the examination regulations and in the individual module descriptions. Lecturer provide further specifications at the beginning of the respective course.
Courses from subjects outside of computer science, that are taken in the Customized Course Selection, are completed with pass/fail assessments. For these courses, the regulations and deadlines of the respective offering faculty/department apply. The list of available subjects and courses can be found in the module handbook and on the program website. The organization of these courses regarding booking and registration procedures in the Campus Management System (HISinOne) is subject to constant further development, and it requires students to actively inform themselves. For questions the program coordinator or the study advisor can be contacted.

The Master program is completed by writing a Master thesis and presenting it during the Master colloquium. With the thesis students show, that they are able to work on a computer science topic independently within a given period of time using scientific methods and to present the results appropriately. If the specialization Artificial Intelligence or Cyber-Physical Systems is chosen, the topic of the master thesis must be chosen from within that specialization area.

G.1 Graded assessments / Exams („Prüfungsleistungen“)

Usually, modules are completed with a graded examination. The type and scope of the examinations are specified in the subject-specific examination regulations as well as in the module handbook and are also announced to the students at the beginning of the respective course.

Written course-based graded assessments include supervised written examinations (Klausuren) and written term papers or essays. Graded assessments can also be administered orally, in the form of oral examinations (exam interviews) and presentations. Practical examinations include conducting experiments and creating and demonstrating software or demonstrators. Examinations (as well as pass/fail assessments) can also be taken as online exams, in accordance with the current examination regulations and framework regulations of the University of Freiburg.

The duration of written exams lies between a minimum of 60 and a maximum of 240 minutes. Students will be notified about the dates for exams and information about permitted aids in a suitable manner in good time. The duration of an oral examination (which can be carried out as an individual or as a group examination) is at least 10 and a maximum of 30 minutes (per examinee); if the oral exam is a final module exam, the maximum duration per examinee is 45 minutes. Presentations usually have a duration of 10-20 minutes (depending on the topic and purpose; details are announced by the lecturers in the respective course. The scope (number of pages) of homework/papers varies depending on the topic and format and is therefore specified by the lecturer in the course.

Timely registration for exams via the HISinOne administration system is required for course-related examinations. The exact dates and information about the procedure can be found on the homepage of the examination office of the Faculty of Engineering (https://www.tf.uni-freiburg.de/en/studies-and-teaching/a-to-z-study-faq/examinations). It is important to note that for elective modules and courses from other subjects, the regulations of the respective offering faculty/department apply.

Unless otherwise specified in the examination regulations or in the module descriptions, the grade for the module is calculated purely from the stated graded assessment. The overall grade is calculated as the arithmetic average of the module grades weighted by ECTS points. More details are given in the examination regulations.

G.2 Pass/fail assessments / Coursework („Studienleistungen“)
Pass/fail assessments or coursework are individual written, oral or practical achievements that are provided by students in connection with courses, but which only have to be passed. These assessments can be repeated as often as necessary until they are passed. They can be graded, but do not have to be, and are not included in the respective final grade (i.e. the final grade of the module as well as the final grade of the course). The scope and type of them are specified in the module descriptions and are announced to the students at the beginning of the respective course.

Coursework may consist, for example, of

- regular attendance in a course
- written tests or examinations (i.e. written supervisory work, possibly also online, or as an open-book exam)
- written elaborations such as reports, case studies, wikis, websites or posters
- oral tests or exams
- the completion of exercises or worksheets
- presentations
- doing experiments
- the creation and presentation of software or demonstrators

Examination prerequisites (i.e. admission requirements for examinations within a module) do not exist in the Master of Science Computer Science / Informatik program, as these could have the adverse effect of extending the study duration considerably. If a module requires the completion of coursework as well as graded examination, these can, if necessary, be completed independently of each other. This means that completion of the coursework is not a mandatory requirement for participation in the graded examination, although in most cases it makes more sense from a didactic point of view to complete the coursework before taking the exam.

Since for the calculation of the final grade all relevant module grades (i.e. from modules completed by a graded assessment) are weighted by ECTS credits, this is not specifically mentioned in each individual module description. Please refer to the examination regulations.
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### Name of module

Mastermodul

### Number of module

11LE13K-T-8000-MSc-679-2020

### Responsible

Prof. Dr. Hannah Bast

### Faculty

Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
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<tbody>
<tr>
<td>Workload</td>
<td>900 Stunden</td>
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<td>Recommended semester</td>
<td>4</td>
</tr>
<tr>
<td>Duration</td>
<td>1 semester / 6 months</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Pflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>in jedem Semester</td>
</tr>
</tbody>
</table>

### Compulsory requirement


<table>
<thead>
<tr>
<th>Recommended requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertiefte Kenntnisse in mathematischen Grundlagen, in praktischen und theoretischen Informatikbereichen und insbesondere im Themenbereich, in dem die Arbeit erstellt wird</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assigned Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contents</th>
</tr>
</thead>
</table>


Bei Wahl der Spezialisierung Künstliche Intelligenz oder Cyber-Physical Systems ist das Thema der Masterarbeit aus dem Bereich der betreffenden Spezialisierung zu wählen.

The topic of the master thesis is given by a professor from the Department of Computer Science in consultation with the student. The topic may originate outside of the Faculty of Engineering, as long as one of the
professors at the Department of Computer Science agrees to the assessment and evaluation of the work as the official supervisor. The student is assigned a supervisor with a university-level qualification. The technical content is task-specific and is predominantly acquired in self-study through independent research.

If the specialization Artificial Intelligence or Cyber-Physical Systems is chosen, the topic of the master thesis must be chosen from within the relevant specialization.

Qualification


In the master thesis, the students work independently on a computer science topic. For the given questions, they carry out background research in literature for scientific sources. The students select suitable scientific procedures and methods and apply them on their topic, adapt them or develop them. The results obtained are critically compared with the current state of research and evaluated. The students present their results clearly and in an academically appropriate form in their written thesis, as well in its presentation during the colloquium. They are able to discuss their work on a suitable academic level.

Examination achievement

Schriftliche Masterarbeit in deutscher oder englischer Sprache, anzufertigen innerhalb von 6 Monaten


Written Master thesis in German or English, must be completed within six months

The master thesis is supplemented by an approximately 60-minute master colloquium, which may be held in German or English at the student’s choice. The master colloquium is usually led and evaluated by the supervisor of the master thesis and consists of an approximately 20-minute presentation by the student on the results of the master thesis and a subsequent discussion. Admission to the master colloquium is granted only if the master thesis has been submitted. The master colloquium counts for 3 ECTS points and is usually open to the university public.

Course achievement

Regelmäßige Teilnahme an Besprechungen mit dem Betreuer/der Betreuerin, Selbstorganisation der gestellten Aufgaben, Durchführung von Hintergrundrecherchen

Regular attendance in meetings with the supervisor, self-organizing the given tasks, doing background research

Literature

Abhängig vom Thema | Depending on topic
<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compulsory Module for students of the study program</td>
</tr>
<tr>
<td>M.Sc. in Informatik / Computer Science (PO 2020)</td>
</tr>
</tbody>
</table>
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
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<th>Number of node</th>
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</thead>
<tbody>
<tr>
<td>Weiterführende Vorlesung</td>
<td>11LE13KT-Weiterf Vorlesung</td>
</tr>
<tr>
<td>Faculty</td>
<td></td>
</tr>
<tr>
<td>Technische Fakultät</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pflicht/Wahlpflicht (P/WP)</th>
<th>Pflicht</th>
</tr>
</thead>
</table>

**Comment**

Students have to take at least 1 Advanced Lecture and are allowed at most 2 Advanced Lectures (depending on number of Specialization Courses - together it must be 7 courses).

Please note:
If you choose to take an additional Computer Science lecture in the Customized Course Selection, that one will be counted as an 8th lecture, overall.
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algorithms Theory</td>
<td>11LE13MO-2010_PO 2020</td>
</tr>
</tbody>
</table>

**Responsible**

Prof. Dr. Hannah Bast  
Prof. Dr. Fabian Kuhn

**Organizer**

Institut für Informatik Algorithmen und Komplexität

**Faculty**

Technische Fakultät

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<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
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<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>1</td>
</tr>
<tr>
<td>Duration</td>
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<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>nur im Wintersemester</td>
</tr>
</tbody>
</table>

**Compulsory requirement**

keine | none

**Recommended requirement**

Basic algorithms and data structures knowledge, comparable to what is done in Algorithms and Datastructures, is assumed.

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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</thead>
<tbody>
<tr>
<td>Algorithms Theory</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>3.0</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Algorithms Theory</td>
<td>Übung</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Qualification**

The design and analysis of algorithms is fundamental to computer science. Students know important algorithmic techniques, are able to apply them and, if necessary, adapt them for new situations. Students have mastered the basic principles of algorithm design and are able to use complex data structures to implement algorithms. They can assess the power of algorithmic design principles, such as randomization and dynamic programming, and are able to apply sophisticated approaches for the analysis of methods designed according to such principles.

**Examination achievement**

Written exam (usually 90 to 180 minutes).
Course achievement

Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have 50% of all exercise points.

Recommendation

Exercises should be done in groups of 2 students. Please team up with a colleague and send an email (including name and matriculation number of both students) to the lecturer.

Usability

Compulsory elective module for students of the study program

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
This course teaches fundamental algorithms and data structures, and a variety of fundamental techniques for their design and analysis. The focus is on material not already covered in the basic undergraduate course on algorithms and data structures, or on the enhancement of that material. Example techniques are: divide and conquer, randomization, amortized analysis, greedy algorithms, dynamic programming. Example algorithms and data structures are: fast Fourier transformation, randomized quicksort, Fibonacci heaps, minimum spanning trees, longest common subsequence, network flows.

The design and analysis of algorithms is fundamental to computer science. In this course, we will study efficient algorithms for a variety of basic problems and, more generally, investigate advanced design and analysis techniques. Central topics are algorithms and data structures that go beyond what has been considered in the undergraduate course Informatik II. Basic algorithms and data structures knowledge, comparable to what is done in Informatik II, or, is therefore assumed. The topics of the course include (but are not limited to):

- Divide and conquer: geometrical divide and conquer, fast fourier transformation
- Randomization: median, randomized quicksort, probabilistic primality testing, etc.
- Amortized analysis: binomial queues, Fibonacci heaps, union-find data structures
- Greedy algorithms: minimum spanning trees, bin packing problem, scheduling
- Dynamic programming: matrix chain product problem, edit distance, longest common subsequence problem
- Graph algorithms: network flows, combinatorial optimization problems on graphs

Examination achievement

Siehe Modulebene | See module level

Course achievement

Siehe Modulebene | See module level
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

### Literature

- Jon Kleinberg and Éva Tardos: Algorithm Design, Addison Wesley
- Thomas Ottmann and Peter Widmayer: Algorithmen und Datenstrukturen, Spektrum Akademischer Verlag

### Compulsory requirement

keine | none

### Recommended requirement

Grundkenntnisse in Algorithmen und Datenstrukturen |
Basic algorithms and data structures knowledge
### Name of module

<table>
<thead>
<tr>
<th></th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algorithms Theory</td>
<td>11LE13MO-2010_PO 2020</td>
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### Veranstaltung

<table>
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<tr>
<td>Event type</td>
<td>Übung</td>
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<td>Organizer</td>
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<tr>
<td>Institut für Informatik Algorithmen u. Datenstrukturen</td>
<td></td>
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<tr>
<td>Institut für Informatik Algorithmen und Komplexität</td>
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### ECTS-Points

<table>
<thead>
<tr>
<th></th>
<th>Attendance</th>
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<tbody>
<tr>
<td></td>
<td>15 Stunden</td>
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<table>
<thead>
<tr>
<th></th>
<th>Hours of week</th>
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<tr>
<td></td>
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<table>
<thead>
<tr>
<th></th>
<th>Recommended semester</th>
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<tbody>
<tr>
<td></td>
<td>nur im Wintersemester</td>
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<tr>
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<th>Frequency</th>
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### Pflicht/Wahlpflicht (P/WP)

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### Contents

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### Examination achievement

<table>
<thead>
<tr>
<th></th>
<th>Siehe Modulebene</th>
<th>See module level</th>
</tr>
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</table>

### Course achievement

<table>
<thead>
<tr>
<th></th>
<th>Siehe Modulebene</th>
<th>See module level</th>
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</table>

### Compulsory requirement

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### Recommendation

We might be able to offer German exercise tutorials (there will definitely be English tutorials). In case you’d prefer to have the exercise tutorials in German, please indicate this via email to the lecturer.
**Name of module**

Datenbanken und Informationssysteme / Data Bases and Information Systems

**Number of module**

11LE13MO-2060_PO 2020

**Responsible**

Prof. Dr. Hannah Bast  
Dr. Fang Wei-Kleiner

**Organizer**

Institut für Informatik Algorithmen u. Datenstrukturen  
Institut für Informatik Datenbanken u. Informationssysteme

**Faculty**

Technische Fakultät

**ECTS-Points**

6.0

**Workload**

180 Stunden | hours

**Recommended semester**

1

**Duration**

1 Semester

**Pflicht/Wahlpflicht (P/WP)**

Wahlpflicht

**Frequency**

nur im Wintersemester

**Compulsory requirement**

keine | none

**Recommended requirement**

Grundkenntnisse in praktischer Informatik, zu Algorithmen und Datenstrukturen sowie grundlegende Programmierkenntnisse;  
Grundkenntnisse über Betriebssysteme und deren Einsatz, über Netzwerk und Protokolle  
|  
Basic knowledge of practical computer science, algorithms and data structures as well as basic programming skills;  
Basic knowledge of operating systems and their use, fundamental knowledge about networks and protocols

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Datenbanken und Informationssysteme / Data Bases and Information Systems</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>2.0</td>
<td>180 Stunden</td>
<td>hours</td>
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<tr>
<td>Datenbanken und Informationssysteme / Data Bases and Information Systems</td>
<td>Übung</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Qualification**

Students understand the basic concepts of databases. They are able to think on different levels of abstraction and have methodical skills in designing a database. They know essential concepts of the SQL standard.  
Students gained practical experience in using a declarative, set-oriented language for databases.
They are able to estimate the processing effort of a request and are able to deal with access rights.

**Examination achievement**

Written exam (usually 90 to 180 minutes)

**Course achievement**

The exercise sheets will be assessed. To pass the course, at least 50% of the points you can get by working on the exercise sheets must be achieved.

**Recommendation**

The exercises deepen the subject matter dealt with in the lecture in theory and practice. The exercise sheets also contain tasks to be solved on the computer. Familiarization with the required software is required for this.

While the course is usually offered in German, there are English recordings available; at least one exercise group will be held in English. You are allowed to do the coursework and the written exam in English.

**Usability**

Compulsory elective module for students of the study program

- M.Sc. Informatik / Computer Science (PO 2020) in Weiterführende Vorlesung | Advanced Lectures
- M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Essential Lectures in Computer Science

Pflichtmodul für Studierende des Studiengangs

- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)

Wahlpflichtmodul für Studierende des Studiengangs

- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
Name of module | Number of module
--- | ---
Datenbanken und Informationssysteme / Data Bases and Information Systems | 11LE13MO-2060_PO 2020

**Veranstaltung**

Datenbanken und Informationssysteme / Data Bases and Information Systems

**Event type**

Vorlesung 11LE13V-2060

**Organizer**

Institut für Informatik Algorithmen u. Datenstrukturen
Institut für Informatik Datenbanken u. Informationssysteme

| ECTS-Points | 6.0 |
| Workload | 180 Stunden | hours |
| Attendance | 32 Stunden | hours |
| Independent study | 118 Stunden | hours |
| Hours of week | 2.0 |
| Recommended semester | |
| Frequency | nur im Wintersemester |

**Contents**

The function of databases is to manage large, permanent data sets in such a way that a large number of users can process this data independently, efficiently, comfortably and securely.

The material of the lecture is concretized in theoretical and practical exercises using various database systems.

The following aspects are dealt with in detail:

- Introduction to databases
- Database design and data models
- Data manipulation languages
- Design theory
- Data integrity
- Transaction management
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

- Physical data organization and current developments.

### Examination achievement

Siehe Modulebene | See module level

### Course achievement

Siehe Modulebene | See module level

### Literature


### Compulsory requirement

keine | none

### Recommended requirement

Grundkenntnisse in praktischer Informatik, zu Algorithmen und Datenstrukturen sowie grundlegende Programmierkenntnisse;
Grundkenntnisse über Betriebssysteme und deren Einsatz, über Netzwerk und Protokolle

Basic knowledge of practical computer science, algorithms and data structures as well as basic programming skills;
Basic knowledge of operating systems and their use, fundamental knowledge about networks and protocols
### Name of module

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Datenbanken und Informationssysteme / Data Bases and Information Systems</td>
<td>11LE13MO-2060_PO 2020</td>
</tr>
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### Veranstaltung

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Datenbanken und Informationssysteme / Data Bases and Information Systems</td>
<td></td>
</tr>
</tbody>
</table>

### Event type

| Übung                          | 11LE13Ü-2060 |

### Organizer

- Institut für Informatik Datenbanken u. Informationssysteme

### ECTS-Points

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance</td>
<td>30 Stunden</td>
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<tr>
<td>Hours of week</td>
<td>2.0</td>
</tr>
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</table>

### Recommended semester

- nur im Wintersemester

### Frequency

- nur im Wintersemester

### Pflicht/Wahlpflicht (P/WP)

### Contents

The exercises deepen the subject matter dealt with in the lecture in theory and practice. The exercise sheets also contain practical tasks to be solved on the computer. Familiarization with the required software is required for this.
### Name of module

**Foundations of Artificial Intelligence**

### Number of module

11LE13MO-2040_PO 2020

### Responsible

Prof. Dr. Joschka Bödecker  
Prof. Dr. Frank Roman Hutter

### Organizer

Institut für Informatik Grundl.d.künstl.Intelligenz  
Institut für Informatik Autonome intelligente Systeme  
Institut für Informatik Neurorobotik  
Institut für Informatik Maschinelles Lernen

### Faculty

Technische Fakultät

### ECTS-Points

6.0

### Workload

180 Stunden | hours

### Recommended semester

1

### Duration

1 Semester

### Pflicht/Wahlpflicht (P/WP)

Wahlpflicht

### Frequency

nur im Sommersemester

### Compulsory requirement

keine | none

### Recommended requirement

keine | none

Grundlagenkenntnisse in mathematischer Logik können hilfreich sein  
|  
|asic knowledge about formal logic can be helpful

### Qualification

Students have basic knowledge of the various techniques of artificial intelligence. They understand the basic principles of artificial intelligence and apply the technical terms in the correct context. Students are able to interpret tasks in the area of problem solving and searching, and can apply the learned algorithms to new situations. Students know the usual types of knowledge representation and are able to analyze the techniques presented and evaluate their use in new situations.

### Examination achievement

Written exam (usually 90 to 180 minutes)
### Course achievement

none

### Recommendation

Working on the exercise sheets is voluntary, but strongly recommended. The exam will contain similar tasks.

### Usability

Compulsory elective module for students of the study program

Part of the specialization Artificial Intelligence in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
### Name of module | Number of module
--- | ---
Foundations of Artificial Intelligence | 11LE13MO-2040_PO 2020

### Veranstaltung

**Foundations of Artificial Intelligence**

**Event type** | **Number**
--- | ---
Vorlesung | 11LE13V-2040

**Organizer**
Institut für Informatik Grundl.d.künstl.Intelligenz  
Institut für Informatik Autonome intelligente Systeme  
Institut für Informatik Neurorobotik  
Institut für Informatik Maschinelles Lernen

### ECTS-Points
6.0

### Workload
180 Stunden | hours

### Attendance
41 Stunden | hours

### Independent study
126 Stunden | hours

### Hours of week
3.0

### Recommended semester

### Frequency
nur im Sommersemester

### Pflicht/Wahlpflicht (P/WP)

### Contents
This course will introduce the basic concepts and techniques used within the field of Artificial Intelligence. The following topics will be covered:

- Introduction to Artificial Intelligence, including a short history of Artificial Intelligence
- agents
- problem solving and search
- logic and knowledge representation
- action planning
- representation of and reasoning with uncertainty
- machine learning

### Examination achievement
Siehe Modulebene | See module level

### Course achievement
Siehe Modulebene | See module level

### Literature

- Artificial Intelligence: A modern approach, Stuart Russel and Peter Norvig, Prentice Hall, 2009

### Compulsory requirement
keine | none
<table>
<thead>
<tr>
<th>Recommended requirement</th>
</tr>
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<tbody>
<tr>
<td>keine</td>
</tr>
<tr>
<td>Grundlagen Kenntnisse in mathematischer Logik können hilfreich sein</td>
</tr>
</tbody>
</table>
### Name of module
Foundations of Artificial Intelligence

### Number of module
11LE13MO-2040_PO 2020

### Veranstaltung
Foundations of Artificial Intelligence

### Event type
Übung

### Number
11LE13Ü-2040

### Organizer
Institut für Informatik Grundl.d.künstl.Intelligenz
Institut für Informatik Autonome intelligente Systeme
Institut für Informatik Neurorobotik
Institut für Informatik Maschinelles Lernen

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<th>ECTS-Points</th>
<th>Attendance: 13 Stunden</th>
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<td>Hours of week</td>
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</tr>
<tr>
<td>Recommended semester</td>
<td>nur im Sommersemester</td>
<td></td>
</tr>
</tbody>
</table>

### Contents
The exercises are intended to give students a better understanding of the most important techniques they learn during lectures by applying the principles and formal methods to real life tasks.

### Examination achievement
Siehe Modulebene | See module level

### Course achievement
Siehe Modulebene | See module level

### Compulsory requirement
↑
### Name of module

| Image Processing and Computer Graphics |

### Number of module

| 11LE13MO-2050_PO 2020 |

### Responsible

Prof. Dr. Thomas Brox  
Prof. Dr.-Ing. Matthias Teschner

### Organizer

Institut für Informatik Graphische Datenverarbeitung  
Institut für Informatik Mustererkennung u. Bildverarbeitung

### Faculty

Technische Fakultät

### ECTS-Points

| 6.0 |

### Workload

180 Stunden | hours

### Recommended semester

1

### Duration

1 Semester

### Pflicht/Wahlpflicht (P/WP)

Wahlpflicht

### Frequency

nur im Sommersemester

### Compulsory requirement

keine | none

### Recommended requirement

Fundamental mathematical knowledge and programming skills in C/C++

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tbody>
<tr>
<td>Image Processing and Computer Graphics</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>3.0</td>
<td>180 Stunden</td>
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<tr>
<td>Image Processing and Computer Graphics</td>
<td>Übung</td>
<td></td>
<td>1.0</td>
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</tr>
</tbody>
</table>

### Qualification

Students have basic knowledge of the tasks and procedures in image processing and computer graphics. They are able to classify typical image processing problems and questions of generative computer graphics and to understand the main features of current related literature.

### Examination achievement

Written exam (usually 90 to 180 minutes)

### Course achievement

none
### Recommendation

Participation in exercises is recommended to be prepared for the exam.

### Usability

Compulsory elective module for students of the study program

Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
**Name of module**  
Image Processing and Computer Graphics  

**Number of module**  
11LE13MO-2050_PO 2020

### Veranstaltung

**Image Processing and Computer Graphics**

**Event type**  
Vorlesung  

**Number**  
11LE13V-2050

**Organizer**  
Institut für Informatik Graphische Datenverarbeitung  
Institut für Informatik Mustererkennung u. Bildverarbeitung

### ECTS-Points

6.0

### Workload

180 Stunden | hours

### Attendance

41 Stunden | hours

### Independent study

126 Stunden | hours

### Hours of week

3.0

### Recommended semester

nur im Sommersemester

### Frequency

**Pflicht/Wahlpflicht (P/WP)**

Siehe Modulebene |  
See module level

### Contents

The lecture provides an introduction of basic approaches and illustrates the state-of-the-art in image processing and computer graphics. The curriculum covers image generation, point operations on images, linear and non-linear filters, image segmentation, optical flow and techniques such as calculus of variations and energy minimization. In the context of computer graphics, rasterization-based image generation, i.e. the rendering pipeline of modern graphics cards, is covered. Here, homogeneous coordinates, transforms, color spaces, rasterization, visibility, local illumination models and textures are addressed.

### Examination achievement

Siehe Modulebene |  
See module level

### Course achievement

Siehe Modulebene |  
See module level

### Literature

Will be announced in each lesson.

### Compulsory requirement

keine | none

### Recommended requirement

Fundamental mathematical knowledge and programming skills in C/C++
Image Processing and Computer Graphics

Veranstaltung

Image Processing and Computer Graphics

Event type

Übung

Organizer

Institut für Informatik Graphische Datenverarbeitung
Institut für Informatik Mustererkennung u. Bildverarbeitung

ECTS-Points

Attendance

13 Stunden | hours

Hours of week

1.0

Recommended semester

Frequency

nur im Sommersemester

Pflicht/Wahlpflicht (P/WP)

Contents

The exercises are intended to give students a better understanding of the most important techniques they learn during lectures. They are expected to implement some selected methods in C/C++ and develop an intuition of their usage.

Examination achievement

Siehe Modulebene | See module level

Course achievement

Siehe Modulebene | See module level

Compulsory requirement
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

Name of module | Number of module
--- | ---
Machine Learning | 11LE13MO-1153_PO 2020

Responsible
Prof. Dr. Joschka Bödecker
Prof. Dr. Frank Roman Hutter

Organizer
Institut für Informatik Neurorobotik
Institut für Informatik Maschinelles Lernen

Faculty
Technische Fakultät

ECTS-Points | 6.0
--- | ---
Workload | 180 Stunden | hours
Recommended semester | 1
Duration | 1 Semester
Pflicht/Wahlpflicht (P/WP) | Wahlpflicht
Frequency | nur im Wintersemester

Compulsory requirement
keine | none

Recommended requirement
We have to rely on a solid background in basic math, specifically linear algebra (an eigenvalue decomposition, matrix operations, covariance matrices etc. should be very familiar concepts), calculus and probability theory.

We use the Python programming language for most of our assignments. If you do not yet have Python experience, you must ramp up at least basic knowledge thereof.

We recommend basic knowledge of optimization and of the scikit-learn Python library.

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine Learning</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>3.0</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Machine Learning</td>
<td>Übung</td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

Qualification
This course provides you with a good theoretical understanding and practical experience about the basic concepts of machine learning. You shall be enabled to implement a number of basic algorithms, understand advantages and drawbacks of single methods and know typical application domains thereof. Furthermore, you should be able to use (Python) software libraries in order to work on novel data analysis problems.
The course will prepare you to dive deeper into advanced methods of ML, e.g. deep learning, recurrent networks, reinforcement learning, hyperparameter optimization, and into specific application domains such as image analysis, brain signal analysis, robot learning, bioinformatics etc., for which specialized courses are available.

<table>
<thead>
<tr>
<th>Examination achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usually a written exam (duration of 90 to 180 minutes)</td>
</tr>
<tr>
<td>If the number of participants is small, an oral examination (with a duration of 35 minutes) may be held instead. The students will be informed in good time.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>To prepare for the exam, there can be a mock exam (written or oral).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wahlpflichtmodul für Studierende des Studiengangs</td>
</tr>
<tr>
<td>B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik</td>
</tr>
<tr>
<td>B.Sc. in Informatik (PO 2018)</td>
</tr>
<tr>
<td>polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)</td>
</tr>
<tr>
<td>M.Ed. Informatik (PO 2018)</td>
</tr>
<tr>
<td>Master of Education Erweiterungsfach Informatik (PO 2021)</td>
</tr>
<tr>
<td>Compulsory elective module for students of the study program</td>
</tr>
<tr>
<td>M.Sc. Embedded Systems Engineering (ESE) (2021) in Essential Lectures in Computer Science</td>
</tr>
<tr>
<td>Students of the M.Sc. programs Microsystems Engg. and Mikrosystemtechnik (PO 2021) can select this module in the concentration area Biomedical Engineering (Biomedizinische Technik).</td>
</tr>
</tbody>
</table>

| Teil der Spezialisierung Künstliche Intelligenz im Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering| |
| Part of the specialization Artificial Intelligence in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering |
Name of module | Number of module
--- | ---
Machine Learning | 11LE13MO-1153_PO 2020

**Veranstaltung**

Machine Learning

Event type | Number
--- | ---
Vorlesung | 11LE13V-1153

Organizer

Institut für Informatik Maschinelles Lernen

ECTS-Points | 6.0
--- | ---
Workload | 180 Stunden | hours
Attendance | 45 Stunden | hours
Independent study | 120 Stunden | hours
Hours of week | 3.0
Recommended semester

Frequency | nur im Wintersemester

Pflicht/Wahlpflicht (P/WP)

Contents

- Applications / typical problems dealt with by machine learning
- basic data analysis pipeline (from data recording to output shaping)
- software libraries
- linear methods (e.g. LDA, logistic regression, ICA, PCA, OLSR) for dimensionality reduction, classification, regression and blind source separation
- non-linear methods (e.g. support vector machines, kernel PCA, decision trees / random forests, neural networks) for classification and regression
- unsupervised clustering (e.g. k-means, DBSCAN)
- algorithm independent principles in machine learning (z.b. bias-variance trade-off, model complexity, regularization, validation strategies, interpretation of trained machine learning models, basic optimization approaches, feature selection, data visualization)

Examination achievement

Siehe Modulebene | See module level

Course achievement

Siehe Modulebene | See module level

Literature

Duda, Hart and Stork: Pattern Classification
Christopher Bishop: Pattern Recognition and Machine Learning
Hastie, Tibshirani and Friedman: The Elements of Statistical Learning
Mitchell: Machine Learning
Murphy: Machine Learning – a Probabilistic Perspective
Criminisi et. al: Decision Forests for Computer Vision and Medical Image Analysis
Schölkopf & Smola: Learning with Kernels
**Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)**

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goodfellow, Bengio and Courville: Deep Learning</td>
<td></td>
</tr>
<tr>
<td>Michael Nielsen: Neural Networks and Deep Learning</td>
<td></td>
</tr>
</tbody>
</table>

In addition, literature for every section of the course is announced during these sections.

<table>
<thead>
<tr>
<th>Requirement</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Compulsory requirement</td>
<td>keine</td>
</tr>
<tr>
<td>Recommended requirement</td>
<td>We have to rely on a solid background in basic math, specifically linear algebra (an eigenvalue decomposition, matrix operations, covariance matrices etc. should be very familiar concepts), calculus and probability theory. We use the Python programming language for most of our assignments. If you do not yet have Python experience, you must ramp up at least basic knowledge thereof. We recommend basic knowledge of optimization and of the scikit-learn Python library.</td>
</tr>
</tbody>
</table>

**Teaching method**

<table>
<thead>
<tr>
<th>For in-class lectures:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Despite the large lecture rooms, a teacher-centered style shall be enriched as much as possible by measures like:</td>
</tr>
<tr>
<td>■ interactive question and answer rounds</td>
</tr>
<tr>
<td>■ discussions in sub-groups, reporting to the large group</td>
</tr>
<tr>
<td>■ cross-teaching</td>
</tr>
<tr>
<td>■ problem-oriented teaching e.g. via data analysis competition</td>
</tr>
<tr>
<td>■ repetition of important concepts in slightly altered contexts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>For virtual lectures:</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ flipped classroom teaching with videos provided</td>
</tr>
<tr>
<td>■ Q&amp;A sessions to discuss the videos' content</td>
</tr>
<tr>
<td>■ Cross-teaching via Ilias forum</td>
</tr>
<tr>
<td>■ problem-oriented teaching e.g. via data analysis competition</td>
</tr>
<tr>
<td>■ repetition of important concepts in slightly altered contexts</td>
</tr>
</tbody>
</table>
Name of module | Number of module
--- | ---
Machine Learning | 11LE13MO-1153_PO 2020

Veranstaltung

Machine Learning

Event type | Number
--- | ---
Übung | 11LE13Ü-1153

Organizer

Institut für Informatik Maschinelles Lernen

ECTS-Points

Attendance | 15 Stunden | hours
--- | --- | ---
Hours of week | 1.0
Recommended semester
Recommended requirement
none

Frequency | nur im Wintersemester

Pflicht/Wahlpflicht (P/WP)

Contents

The exercises are intended to give students a better understanding of the most important techniques they learn during lectures. They are expected to implement some selected methods to gain experience in practical applications.

Examination achievement

Siehe Modulebene | See module level

Course achievement

Siehe Modulebene | See module level

Compulsory requirement

none

Recommended requirement

none
Name of module: Rechnerarchitektur / Computer Architecture

Number of module: 11LE13MO-2020_PO 2020

Responsible:
Prof. Dr. Armin Biere
Prof. Dr. Christoph Scholl

Organizer:
Institut für Informatik Rechnerarchitektur
Institut für Informatik Betriebssysteme

Faculty:
Technische Fakultät

ECTS-Points: 6.0
Workload: 180 Stunden | hours
Recommended semester: 1
Duration: 1 Semester
Pflicht/Wahlpflicht (P/WP): Wahlpflicht
Frequency: nur im Wintersemester

Compulsory requirement:
keine | none

Recommended requirement:
Grundlegendes Wissen und Kenntnisse aus dem Bereich der technischen Informatik (analog zum Modul Technische Informatik), Grundlagen binärer Mathematik; Grundlagen zu digitalen Schaltkreisen;
Programmierkenntnisse in C / C ++

Basic knowledge and in the area of technical informatics (analogous to the module Technische Informatik),
fundamentals of binary mathematics; basic knowledge of digital circuits;
programming skills in C / C ++

Assigned Courses:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rechnerarchitektur / Computer Architecture</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>3.0</td>
<td>180 Stunden</td>
<td>hours</td>
</tr>
<tr>
<td>Rechnerarchitektur / Computer Architecture</td>
<td>Übung</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Qualification:

Students will be introduced to methods of designing computers, which will cover the topics of testing and verification of digital circuits, processor data and control paths, pipelining and parallelism. They will learn about the RISC-V instruction set and related CPUs. Students will learn to maximize the performance of computing machinery and how to guarantee the correctness of circuits. Finally, they understand how the restrictions resulting from digital technology and the specific computer architectures affect higher levels of abstraction, especially those of software technology.
<table>
<thead>
<tr>
<th>Examination achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written exam (usually 90 to 180 minutes)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Course achievement</th>
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</thead>
<tbody>
<tr>
<td>Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of points per exercise sheet.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compulsory elective module for students of the study program</td>
</tr>
</tbody>
</table>

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

<table>
<thead>
<tr>
<th>Wahlpflichtmodul für Studierende des Studiengangs</th>
</tr>
</thead>
<tbody>
<tr>
<td>- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik</td>
</tr>
<tr>
<td>- B.Sc. in Informatik (PO 2018)</td>
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<tr>
<td>- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)</td>
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<tr>
<td>- M.Ed. Informatik (PO 2018)</td>
</tr>
<tr>
<td>- Master of Education Erweiterungsfach Informatik (PO 2021)</td>
</tr>
</tbody>
</table>
## Name of module
Rechnerarchitektur / Computer Architecture

## Number of module
11LE13MO-2020_PO 2020

### Veranstaltung

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE13V-2020</td>
</tr>
</tbody>
</table>

### Organizer
Institut für Informatik Rechnerarchitektur
Institut für Informatik Betriebssysteme

### ECTS-Points
6.0

### Workload
180 Stunden | hours

### Attendance
45 Stunden | hours

### Independent study
120 Stunden | hours

### Hours of week
3.0

### Recommended semester
nur im Wintersemester

### Pflicht/Wahlpflicht (P/WP)

### Contents
An introduction to fundamental questions, methods and techniques of computer design and computer architecture is given. The following topics are included:

### Examination achievement
Siehe Modulebene | See module level

### Course achievement
Siehe Modulebene | See module level

### Literature
Mainly:
- David A. Patterson, John L. Hennesey - "Computer Organization and Design - The Hardware Software Interface [RISC-V Edition]"

Also helpful:
<table>
<thead>
<tr>
<th>Compulsory requirement</th>
</tr>
</thead>
</table>
| keine | none  

<table>
<thead>
<tr>
<th>Recommended requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grundlegendes Wissen und Kenntnisse aus dem Bereich der technischen Informatik (analog zum Modul Technische Informatik), Grundlagen binärer Mathematik; Grundlagen zu digitalen Schaltkreisen; Programmierkenntnisse in C / C ++</td>
</tr>
<tr>
<td>Basic knowledge and in the area of technical informatics (analogous to the module Technische Informatik), fundamentals of binary mathematics; basic knowledge of digital circuits; programming skills in C / C ++</td>
</tr>
</tbody>
</table>
**Name of module**  |  **Number of module**  
--- | ---  
Rechnerarchitektur / Computer Architecture  |  11LE13MO-2020_PO 2020  

**Veranstaltung**  
Rechnerarchitektur / Computer Architecture  

**Event type**  |  **Number**  
--- | ---  
Übung  |  11LE13Ü-2020  

**Organizer**  
Institut für Informatik Rechnerarchitektur  
Institut für Informatik Betriebssysteme  

| **ECTS-Points** |  
--- | ---  
Attendance  |  15 Stunden | hours  
Hours of week  |  1.0  
Recommended semester  |  
Frequency  |  nur im Wintersemester  
Pflicht/Wahlpflicht (P/WP)  |  

**Contents**  
Die Übungen sollen den Studenten ein besseres Verständnis der wichtigsten Techniken vermitteln, die sie während der Vorlesungen lernen, indem sie die Prinzipien und Methoden anwenden. 

The exercises are intended to give students a better understanding of the most important techniques they learn during lectures by applying the principles and methods.  

**Examination achievement**  
Siehe Modulebene  
See module level  

**Course achievement**  
Siehe Modulebene  
See module level  

**Compulsory requirement**  

# Name of module

Softwaretechnik / Software Engineering

## Number of module

11LE13MO-2030_PO 2020

## Responsible

Prof. Dr. Andreas Podelski

## Organizer

Institut für Informatik Programmiersprache
Institut für Informatik Softwaretechnik

## Faculty

Technische Fakultät

## ECTS-Points

6.0

## Workload

180 Stunden | hours

## Recommended semester

1

## Duration

1 Semester

## Pflicht/Wahlpflicht (P/WP)

Wahlpflicht

## Frequency

nur im Sommersemester

## Compulsory requirement

keine | none

## Recommended requirement

Basic knowledge about practical Computer Science concepts, algorithms and datastructure, Programming Skills

## Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softwaretechnik / Software Engineering</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>3.0</td>
<td>180 Stunden</td>
<td>hours</td>
</tr>
<tr>
<td>Softwaretechnik / Software Engineering</td>
<td>Übung</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Qualification

Students know the basic modeling techniques and construction principles for software systems, they have an overview over the challenges of software engineering and the techniques and tools to address these challenges. They have knowledge of the main activities during software development (in particular project management, requirements engineering, design, testing, formal verification) with an emphasis on formal methods. Students know the foundations of process models, software metrics, approaches to requirements specification and analysis, (formal) modelling and analysis techniques, design and architecture patterns, testing, and program verification, and can apply these techniques on a small scale and can acquire advanced techniques on their own. Students have applied formal methods in example scenarios and are able to assess in which situations such methods are useful.

## Examination achievement

Written exam (usually 90 to 180 minutes)
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

Course achievement

Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of points.

Usability

Compulsory elective module for students of the study program

Part of the specialization Cyber-Physical Systems in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softwaretechnik / Software Engineering</td>
<td>11LE13MO-2030_PO 2020</td>
</tr>
</tbody>
</table>

**Veranstaltung**

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Number of module</th>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softwaretechnik / Software Engineering</td>
<td></td>
<td>Vorlesung</td>
<td>11LE13V-2030</td>
</tr>
</tbody>
</table>

**Organizer**

Institut für Informatik Programmiersprache  
Institut für Informatik Softwaretechnik

**ECTS-Points**  
6.0

**Workload**  
180 Stunden | hours

**Attendance**  
40 Stunden | hours

**Independent study**  
127 Stunden | hours

**Hours of week**  
3.0

**Recommended semester**

nur im Sommersemester

**Frequency**

nur im Sommersemester

**Pflicht/Wahlpflicht (P/WP)**


**Contents**

Software engineering is "the application of engineering to software". This lecture provides knowledge of the fundamental techniques in software engineering:

- Revision Control
- Process Models
- Requirements Analysis
- Formal and Semiformal Modeling Techniques
- Object Oriented Analysis
- Object Oriented Design
- Design Patterns
- Testing.

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level

**Literature**

- Ludewig, J. and Lichter, H. Software Engineering
- Jacobson, I. et al. Object Oriented Software-Engineering - A Use Case Driven Approach
- Davis, A. Software Requirements - Analysis and Specification

**Compulsory requirement**

keine | none

**Recommended requirement**

Basic knowledge about practical Computer Science concepts, algorithms and datastructure, Programming Skills  
(for Bachelor of Science: Participation in Softwarepraktikum)
The exercises consist of theoretical assignments and programming assignments, to apply the methods and concepts from the lecture.
<table>
<thead>
<tr>
<th>Name of node</th>
<th>Number of node</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spezialvorlesung</td>
<td>11LE13KT-Spez Vorlesung</td>
</tr>
<tr>
<td>Faculty</td>
<td></td>
</tr>
<tr>
<td>Technische Fakultät</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pflicht/Wahlpflicht (P/WP)</th>
<th>Pflicht</th>
</tr>
</thead>
</table>

**Comment**

Students have to take at least 5 Specialization Courses and are allowed at most 6 Specialization Courses (depending on number of Advanced Lectures - together it must be 7 courses).

Please note:
If you choose to take an additional Computer Science lecture in the Customized Course Selection, that one will be counted as an 8th lecture, overall.
### Advanced Algorithms

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Algorithms</td>
<td>11LE13MO-1326_PO 2020</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. Dr. Fabian Kuhn</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Organizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institut für Informatik Algorithmen und Komplexität</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Faculty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technische Fakultät</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>2</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
</tr>
</tbody>
</table>

#### Compulsory requirement

keine | none

#### Recommended requirement

some background in algorithm design/analysis and probability theory is expected (as gained in the course "Algorithms Theory")

#### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
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<tbody>
<tr>
<td>Advanced Algorithms</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>2.0</td>
<td>180 Stunden</td>
<td>hours</td>
</tr>
<tr>
<td>Advanced Algorithms</td>
<td>Übung</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Qualification

Students have advanced knowledge about modern algorithmic techniques. They know the advantages and disadvantages of various methods for different applications.

#### Examination achievement

Oral exam (usually 30 or 45 minutes)

#### Course achievement

none
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Usability</th>
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<tbody>
<tr>
<td>Compulsory elective module for students of the study program</td>
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<tr>
<td>M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung</td>
</tr>
<tr>
<td>M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science</td>
</tr>
</tbody>
</table>

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering
Advanced Algorithms

Event type  
Vorlesung  
11LE13V-1326

Organizer  
Institut für Informatik Algorithmen und Komplexität

ECTS-Points  
6.0

Workload  
180 Stunden | hours

Attendance  
28

Independent study  
124

Hours of week  
2.0

Recommended semester

Frequency  
unregelmäßig

Pflicht/Wahlpflicht (P/WP)

Contents

In the course, we discuss modern algorithmic techniques. The course covers a variety of topics, such as for example:

- approximation algorithms
- randomized algorithms
- graph embeddings
- graph sparsification
- theory of learning
- sketching and streaming algorithms
- continuous methods in combinatorial optimization

Examination achievement

See module level

Course achievement

See module level

Literature

Literature will be provided in the lecture.

Compulsory requirement

none

Recommended requirement

There is no formal requirement, however some background in algorithm design/analysis and probability theory is expected. Having passed the algorithm theory course (or a similar course) prior to taking the advanced algorithms lecture is highly recommended.
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Algorithms</td>
<td>11LE13MO-1326_PO 2020</td>
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**Veranstaltung**

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>Advanced Algorithms</td>
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<table>
<thead>
<tr>
<th>Event type</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Übung</td>
<td>11LE13Ü-1326</td>
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**Organizer**

Institut für Informatik Algorithmen und Komplexität

**ECTS-Points**

<table>
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<tr>
<th>Attendance</th>
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<tr>
<td>Hours of week</td>
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<td>Recommended semester</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
</tr>
</tbody>
</table>

**Contents**

The lecture will be complemented by theoretical exercises that allow to apply and further develop ideas and techniques discussed in the lecture. The exercises are an integral part of the lecture, the topics covered by the exercises will also be part of the oral exam. There are two graded homework assignments that count 30% towards the final grade of the course.

**Examination achievement**

See module level

**Course achievement**

See module level

**Compulsory requirement**


## Advanced Computer Graphics

### Responsible
Prof. Dr.-Ing. Matthias Teschner

### Organizer
Institut für Informatik Graphische Datenverarbeitung

### Faculty
Technische Fakultät

### ECTS-Points
6.0

### Workload
180 Stunden | hours

### Recommended semester
2

### Duration
1 Semester

### Pflicht/Wahlpflicht (P/WP)
Wahlpflicht

### Frequency
nur im Wintersemester

### Compulsory requirement
keine | none

### Recommended requirement
Programming skills
Knowledge in Algorithms and Data Structures, Linear Algebra and Analysis
Knowledge in Image Processing and Computer Graphics

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
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<tr>
<td>Advanced Computer Graphics</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>2.0</td>
<td>180 Stunden</td>
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<tr>
<td>Advanced Computer Graphics</td>
<td>Übung</td>
<td></td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Qualification
Students know the main concepts for image synthesis as well as global illumination approaches. They are able to use formal governing equation and solution techniques and know how to describe light. They know bidirectional reflectance distribution functions for material modeling and can apply Monte-Carlo techniques for approximately solving the rendering equation that describes the interaction of light with surfaces.

### Examination achievement
Written exam (usually 90 to 180 minutes)

### Course achievement
none
### Recommendation

Working on the exercise sheets is voluntary, but strongly recommended.

### Usability

**Compulsory elective module for students of the study program**
- M.Sc. Informatik / Computer Science (2020) in Spezialvortrag | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

**Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering**

**Wahlpflichtmodul für Studierende des Studiengangs**
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
Advanced Computer Graphics

**Contents**

The course addresses all aspects of the raytracing technique. The curriculum covers photometric quantities to describe light, bidirectional reflectance distribution functions for material modeling and Monte-Carlo techniques for approximately solving the rendering equation that describes the interaction of light with surfaces. The curriculum also addresses the homogeneous notation, spatial data structures for ray-object intersections and sampling strategies.

**Examination achievement**

See module level

**Course achievement**

See module level

**Literature**

- Dutre, Bala, Bekaert: Advanced Global Illumination, A K Peters, 2006
- Pharr, Humphreys: Physically Based Rendering, Elsevier, 2010
<table>
<thead>
<tr>
<th>Compulsory requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended requirement</td>
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</tbody>
</table>

Programming skills
Knowledge in Algorithms and Data Structures, Linear Algebra and Analysis
Knowledge in Image Processing and Computer Graphics
## Advanced Computer Graphics

### Veranstaltung

**Event type**

- Übung

**Organizer**

- Institut für Informatik Graphische Datenverarbeitung

### ECTS-Points

- **Attendance**: 30 Stunden
- **Hours of week**: 2.0
- **Recommended semester**: nur im Wintersemester

### Contents

- Practical development of ray tracing components based on concepts from lectures

### Examination achievement

- See module level

### Course achievement

- See module level

### Compulsory requirement
### Advanced Deep Learning

**Name of module**
Advanced Deep Learning

**Number of module**
11LE13MO-1146_PO 2020

**Responsible**
Prof. Dr. Abhinav Valada

**Organizer**
Institut für Informatik Robot Learning

**Faculty**
Technische Fakultät

**ECTS-Points**
6.0

**Workload**
180 hours

**Recommended semester**
2

**Duration**
1 Semester

**Pflicht/Wahlpflicht (P/WP)**
Wahlpflicht

**Frequency**
nur im Sommersemester

---

**Compulsory requirement**
none

**Recommended requirement**
Fundamentals of Deep Learning
Machine Learning

---

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
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<td>Übung</td>
<td>2.0</td>
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</tbody>
</table>

**Qualification**

Students have a clear understanding of advanced deep learning techniques and know how to apply them in various domains. They know modern architectures including topics in Graph Neural Networks, Multi-dimensional Deep Learning, Transformers, Metric Learning, Cross-modal Learning, Transfer Learning, Domain Adaptation, Self-supervised Learning, Multi-task Learning, Meta-Learning, and Continual Learning.

**Examination achievement**
Oral examination (usually 30 or 45 minutes)

**Course achievement**
Presentation
## Usability

Compulsory elective module for students of the study program

- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Artificial Intelligence in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering
Advanced Deep Learning

Veranstaltung

Advanced Deep Learning

Event type

Vorlesung

Organizer

Institut für Informatik Robot Learning

ECTS-Points

6.0

Workload

180 hours

Attendance

32 Stunden

Independent study

116 Stunden

Hours of week

2.0

Recommended semester

nur im Sommersemester

Contents

Deep learning techniques are constantly evolving and are nowadays recognized as the state-of-the-art solution in many problems in various domains. This course will provide a clear understanding of advanced deep learning techniques and modern architectures include topics in Graph Neural Networks, Multi-dimensional Deep Learning, Transformers, Metric Learning, Cross-modal Learning, Transfer Learning, Domain Adaptation, Self-supervised Learning, Multi-task Learning, Meta-Learning, and Continual Learning.

Examination achievement

See module level

Course achievement

See module level

Compulsory requirement

Recommended requirement

Fundamentals of Deep Learning
Machine Learning
### Veranstaltung

<table>
<thead>
<tr>
<th>Name of module</th>
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<td>Advanced Deep Learning</td>
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**Event type**

<table>
<thead>
<tr>
<th>Übung</th>
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</tr>
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<tbody>
<tr>
<td></td>
<td>11LE13Ü-1146_PO 2020</td>
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</table>

**Organizer**

Institut für Informatik Robot Learning

**ECTS-Points**

<table>
<thead>
<tr>
<th>Attendance</th>
<th>32 Stunden</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours of week</td>
<td>2.0</td>
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<td>Recommended semester</td>
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<td>Frequency</td>
<td>nur im Sommersemester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
</tr>
</tbody>
</table>

**Contents**

Students learn to apply some of the techniques from the lecture.

**Examination achievement**

See module level

**Course achievement**

See module level

**Compulsory requirement**
### Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algorithms for Wireless Communication</td>
<td>11LE13MO-1157_PO 2020</td>
</tr>
</tbody>
</table>

#### Responsible
Prof. Dr. Christian Schindelhauer

#### Organizer
Institut für Informatik Rechnernetze u.Telematik

#### Faculty
Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
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<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
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<tr>
<td>Recommended semester</td>
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<tr>
<td>Duration</td>
<td>1 Semester</td>
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<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
</tr>
</tbody>
</table>

#### Compulsory requirement
keine | none

#### Recommended requirement
Basic knowledge about Distributed Systems, Computer Networks, Algorithms and Data Structures

#### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
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<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<td>Algorithms for Wireless Communication</td>
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<td>2.0</td>
<td>180 Stunden</td>
<td>hours</td>
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<td>Übung</td>
<td></td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Qualification

After this course students can apply existent theoretical communication models of computer science and information theory to a given problem and analyse the quality of a given algorithmic solutions.

#### Examination achievement

If there are 20 or fewer registered participants, an oral exam (usually 30 or 45 minutes); if there are more than 20 registered participants, a written exam (usually 90 to 180 minutes). Details will be announced in due time.

#### Course achievement

Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of the achievable points.
Usability

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Cyber-Physical Systems in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering
Name of module | Number of module
---|---
Algorithms for Wireless Communication | 11LE13MO-1157_PO 2020

Veranstaltung

Algorithms for Wireless Communication

Event type | Number
---|---
Vorlesung | 11LE13V-1157_PO 2020

Organizer

Institut für Informatik Rechnernetze u. Telematik

ECTS-Points | 6.0
---|---
Workload | 180 Stunden | hours
Attendance | 32 Stunden
Independent study | 116 Stunden
Hours of week | 2.0
Recommended semester | unregelmäßig

Contents

The course offers a selected view from the wide area of topics regarding wireless communication under the algorithmic and partly also the information theoretic view. E.g. wireless communication models in computer science and information theory. Physical foundations of wireless communication: electromagnetic and acoustical communication. Medium access from Radio Networking to MACAW. Multi- and single-commodity flow problems, shortest path for route detection and optimization for congestions, delay and energy. Network coding, graph embedding, MIMO power gain and diversity gain. Models for nearfield and quantum communication.

Examination achievement

See module level

Course achievement

See module level

Literature

Current research papers to be announced in the course.

Compulsory requirement

none

Recommended requirement

Distributed Systems, Computer Networks, Algorithms and Data Structures

Recommendation

The lecture will be recorded (unlike the exercise class). All course material will be made available online to participants.

Technische Fakultät
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
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**Veranstaltung**

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</table>

**Organizer**

Institut für Informatik Rechnernetze u. Telematik

**ECTS-Points**

<table>
<thead>
<tr>
<th>Attendance</th>
<th>32 Stunden</th>
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<tbody>
<tr>
<td>Hours of week</td>
<td>2.0</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>unregelmäßig</td>
</tr>
</tbody>
</table>

**Contents**

Exercise class with tasks in discrete optimization for network routing, path loss estimations for SNR models, mathematical simulations of networks in computer algebra systems, the mathematics of basic signal processing, algorithm design and analysis of routing algorithms and shortest path algorithms, lower bound analysis.

**Examination achievement**

See module level

**Course achievement**

See module level

**Compulsory requirement**
**Name of module**: Automated Machine Learning  
**Number of module**: 11LE13MO-1415_PO 2020

**Responsible**
Prof. Dr. Frank Roman Hutter

**Organizer**
Institut für Informatik Maschinelles Lernen

**Faculty**
Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
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<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
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<td>Recommended semester</td>
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<tr>
<td>Duration</td>
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<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>nur im Sommersemester</td>
</tr>
</tbody>
</table>

**Compulsory requirement**
- either lecture: "Machine Learning"
- or lecture: "Foundations of Deep Learning"

**Recommended requirement**
- Solid understanding of machine learning  
- Hands-on experience with deep learning  
- Programming skills in Python

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tr>
<td>Automated Machine Learning</td>
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<td>2.0</td>
<td>180 hours</td>
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</tbody>
</table>

**Qualification**

Based on machine learning (ML), AI achieved major breakthroughs in the last years. However, applying machine learning and in particular deep learning (DL) in practice is a challenging task and requires a lot of expertise. Among other things, the success of ML/DL applications depends on many design decisions, including an appropriate preprocessing of the data, choosing a well-performing machine learning algorithm and tuning its hyperparameters, giving rise to a complex pipeline. Unfortunately, even experts need days, weeks or even months to find well-performing pipelines and can still make mistakes when optimizing their pipelines.

After completion of this course students will be able to discuss meta-algorithmic approaches to automatically search for, and obtain well-performing machine learning systems by means of automated machine learning (AutoML).
Such AutoML systems allow for faster development of new ML/DL applications, require far less expert knowledge than doing everything from scratch and often even outperform human developers. Students know how to use such AutoML systems, to develop their own systems and to understand ideas behind state-of-the-art AutoML approaches.

<table>
<thead>
<tr>
<th>Examination achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>oral examination (usually 30 or 45 minutes)</td>
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</table>

<table>
<thead>
<tr>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doing a project (workload about 80h)</td>
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</table>

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Compulsory elective module for students of the study program</td>
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</table>

- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

and

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering
### Automated Machine Learning

**Name of module**
Automated Machine Learning

**Number of module**
11LE13MO-1415_PO 2020

**Veranstaltung**
Automated Machine Learning

**Event type**
Vorlesung

**Number**
11LE13V-1415

**Organizer**
Institut für Informatik Maschinelles Lernen

**ECTS-Points**
6.0

**Workload**
180 hours

**Attendance**
30

**Independent study**
90

**Hours of week**
2.0

**Recommended semester**

**Frequency**
nur im Sommersemester

**Pflicht/Wahlpflicht (P/WP)**

### Contents
* Design of configuration spaces for automated machine learning
* Hyperparameter Optimization with Bayesian Optimization
* Neural architecture search with Reinforcement learning, Bayesian Optimization and Evolutionary strategies
* Transfer-learning, meta-learning, pre-training and fine-tuning
* Learning-to-learn
* Hyperparameter importance analysis

### Examination achievement
See module level

### Course achievement
See module level

### Literature
Selected material from the book "AutoML: Methods, Systems, Challenges" by Hutter, Kotthoff and Van-Schoren (freely available online at www.automl.org/book), as well as other surveys and research articles.

### Compulsory requirement
* Lecture: "Machine Learning"
* Lecture: "Foundations of Deep Learning"

### Recommended requirement
* Solid understanding of machine learning
* Hands-on experience with deep learning
# Automated Machine Learning

## Veranstaltung

<table>
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## Organizer

Institut für Informatik Maschinelles Lernen

## ECTS-Points

<table>
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<th>Attendance</th>
<th>Hours of week</th>
<th>Recommended semester</th>
<th>Frequency</th>
<th>Pflicht/Wahlpflicht (P/WP)</th>
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<td>30</td>
<td>2.0</td>
<td>11</td>
<td>nur im Sommersemester</td>
<td></td>
</tr>
</tbody>
</table>

## Contents


The exercises follow the lectures. In the practically-oriented exercises students will independently implement the lecture material. In the end there is a large project (80h), in which the students apply the contents of the course to a new problem domain. This project will be presented in the first part of the oral exam.

## Examination achievement

See module level

## Course achievement

See module level

## Compulsory requirement
## Name of module
Bioinformatics I

## Number of module
11LE13MO-1309_PO 2020

### Responsible
Prof. Dr. Rolf Backofen

### Organizer
Institut für Informatik Bioinformatik

### Faculty
Technische Fakultät

### ECTS-Points
6.0

### Workload
180 Stunden | hours

### Recommended semester
2

### Duration
1 Semester

### Pflicht/Wahlpflicht (P/WP)
Wahlpflicht

### Frequency
nur im Wintersemester

### Compulsory requirement
keine | none

### Recommended requirement
Von Vorteil bzw. stark empfohlen sind:
- Grundlegende, einfache molekularbiologische Kenntnisse
- Grundlegende Kenntnisse in Algorithmen, wie aus Informatik Grundstudium/Bachelor

Advantageous or strongly recommended prerequisites:
- Basic, simple knowledge of molecular biology
- Basic knowledge of algorithms, such as from computer science undergraduate / bachelor's degree

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioinformatics I</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>2.0</td>
<td>180 Stunden</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Bioinformatics I</td>
<td>Übung</td>
<td></td>
<td></td>
<td>2.0</td>
<td></td>
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</tbody>
</table>

### Qualification
The course shall give an overview of basic bioinformatics topics and understanding of some fundamental algorithms. The special focus of the course is on sequence analysis. In the module we fundamental principles in biology are revised and illustrate target problems and associated applications. Students will be able to explain and apply fundamental algorithms regarding sequence alignment and phylogenetic trees and will be capable to design and analyze algorithms that elaborate discrete sequences. Students will understand how to solve an optimization problem using Dynamic Programming techniques and...
be able to design and analyze new algorithms. By the end of the module, students will become familiar with applications of Markov models in Bioinformatics and be able to compute phylogenetic trees.

### Examination achievement

**Written exam (usually 90 to 180 minutes)**

If the number of participants is small (< 20), an oral examination may be held instead. The students will be informed in good time.

### Course achievement

**none**

### Recommendation

Solving exercise sheets is optional but highly recommended.

### Usability

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptsäch-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
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</thead>
<tbody>
<tr>
<td>Bioinformatics I</td>
<td>11LE13MO-1309_PO 2020</td>
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**Veranstaltung**

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Number</th>
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<tbody>
<tr>
<td>Bioinformatics I</td>
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<table>
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<th>Event type</th>
<th>Number</th>
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<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE13V-1309</td>
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<table>
<thead>
<tr>
<th>ECTS-Points</th>
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<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
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<tr>
<td>Attendance</td>
<td>30</td>
</tr>
<tr>
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<tr>
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<tr>
<td>Frequency</td>
<td>nur im Wintersemester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
</tr>
</tbody>
</table>

**Contents**

- **Sequenzalignment:**
  - global und lokal, Distanz und Ähnlichkeit
  - affine and beliebige Gap-Kostenfunktionen

- **Substitutionsmatrizen und Markov-Ketten:**
  - Markov-Modelle und deren Eigenschaften
  - Markov-Ketten und Substitutionsmatrizen, z.B. PAM

- **Phylogenetische Bäume:**
  - hierarchische Methoden und clustering
  - Markov-Prozesse und maximum likelihood
  - quartet puzzling

**Examination achievement**

See module level

**Course achievement**

See module level

**Compulsory requirement**

Von Vorteil bzw. vorausgesetzt sind
Grundlegende, einfache molekularbiologische Kenntnisse
Grundlegende Kenntnisse in Algorithmen, wie aus Informatik Grundstudium/Bachelor
### Name of module

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### Veranstaltung

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<tbody>
<tr>
<td>Übung</td>
<td>11LE13Ü-1309</td>
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<tbody>
<tr>
<td>Institut für Informatik Bioinformatik</td>
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</table>

### ECTS-Points

<table>
<thead>
<tr>
<th>Attendance</th>
<th>28 Stunden</th>
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<tbody>
<tr>
<td>Independent study</td>
<td>124 Stunden</td>
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<td>Hours of week</td>
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<tr>
<td>Recommended semester</td>
<td>nur im Wintersemester</td>
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<table>
<thead>
<tr>
<th>Frequency</th>
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</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

### Contents

Participating in the exercise sessions and solving the sheets deepens your understanding. You can use the exercise session for (supervised) solving the sheets or to ask questions. You can solve them independently or as group.

<table>
<thead>
<tr>
<th>Examination achievement</th>
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</thead>
<tbody>
<tr>
<td>See module level</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>See module level</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compulsory requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
### Name of module

| Bioinformatics II |

### Number of module

| 11LE13MO-1310_PO 2020 |

### Responsible

| Prof. Dr. Rolf Backofen |

### Faculty

| Technische Fakultät |

### ECTS-Points

| 6.0 |

### Workload

| 180 Stunden | hours |

### Recommended semester

| 2 |

### Duration

| 1 Semester |

### Pflicht/Wahlpflicht (P/WP)

| Wahlpflicht |

### Frequency

| nur im Sommersemester |

### Compulsory requirement

| Bioinformatics I |

### Recommended requirement

The foundations laid in "Bioinformatics I" will be assumed to be known.

### Additional prerequisites:

- Basic, simple knowledge of molecular biology
- Basic knowledge of algorithms, such as from computer science undergraduate / bachelor's degree

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<td>Bioinformatics II</td>
<td>Vorlesung</td>
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<td>6.0</td>
<td>2.0</td>
<td>180 Stunden</td>
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<tr>
<td>Bioinformatics II</td>
<td>Übung</td>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
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</table>

### Qualification

This module is designed as a follow up for the course “Bioinformatics 1” or a similar one. Students will be given an advanced overview of bioinformatics topics with a deeper understanding of many fundamental algorithms.

They will learn well known multiple sequence alignment and analysis algorithms like BLAST and t-coffee and be able to explain them in detail. They will understand Hidden Markov modelling and will apply them to specific problems in Bioinformatics. Students will be able to distinguish various protein models and to compile folding kinetics information based on energy landscape models. Finally, they can calculate optimal RNA structures based on central prediction algorithms and explain the according methods.
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Examination achievement</th>
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</thead>
<tbody>
<tr>
<td>Oral exam (usually 30 or 45 minutes)</td>
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<tr>
<td>If the number of participants is very high (&gt; 30), a written examination may be held instead. The students will be informed in good time.</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
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<table>
<thead>
<tr>
<th>Recommendation</th>
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</thead>
<tbody>
<tr>
<td>Solving exercise sheets is optional but highly recommended.</td>
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<table>
<thead>
<tr>
<th>Usability</th>
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<tbody>
<tr>
<td>Compulsory elective module for students of the study program</td>
</tr>
<tr>
<td>- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung</td>
</tr>
<tr>
<td>- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science</td>
</tr>
<tr>
<td>Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering</td>
</tr>
<tr>
<td>Wahlpflichtmodul für Studierende des Studiengangs</td>
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<tr>
<td>- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik</td>
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### Name of module

<table>
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### Number of module

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### Veranstaltung

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### Event type

<table>
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<tr>
<th>Vorlesung</th>
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</thead>
</table>

### Number

| 11LE13V-1310 |

### Organizer

Institut für Informatik Bioinformatik

### ECTS-Points

| 6.0 |

### Workload

| 180 Stunden | hours |

### Attendance

| 32 Stunden |

### Independent study

| 116 Stunden |

### Hours of week

| 2.0 |

### Recommended semester

nur im Sommersemester

### Frequency

See module level

### Pflicht/Wahlpflicht (P/WP)

See module level

### Contents

- Multiple sequence alignment
  - Scoring schemes
  - Exact and heuristic methods (progressive approaches, t-coffee etc.)

- Hidden markov models
  - Profile HMMs for multiple alignment
  - Learning profile HMMs

- Protein structure
  - Simple protein models

- Fast sequence search
  - BLAST
  - BLAT
  - Suffix trees

- Energy Landscapes
  - Monte-Carlo sampling
  - Abstractions
  - Folding dynamics

- Examination achievement

See module level

- Course achievement

See module level
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

### Literature

- D.W. Mount: Bioinformatics - Sequence and Genome Analysis Cold Spring Harbor

### Compulsory requirement

**Bioinformatics I**

### Recommended requirement

The foundations laid in Bioinformatics I will be assumed to be known.

**Additional prerequisites:**

- Basic, simple knowledge of molecular biology
- Basic knowledge of algorithms, such as from computer science undergraduate / bachelor's degree
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
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<tr>
<td>Bioinformatics II</td>
<td>11LE13MO-1310_PO 2020</td>
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**Veranstaltung**

<table>
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<tr>
<td>Übung</td>
<td>11LE13Ü-1310</td>
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**Organizer**

Institut für Informatik Bioinformatik

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**ECTS-Points**

<table>
<thead>
<tr>
<th>Attendance</th>
<th>32 Stunden</th>
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<tbody>
<tr>
<td>Hours of week</td>
<td>2.0</td>
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</tbody>
</table>

**Recommended semester**

nur im Sommersemester

**Frequency**

Pflicht/Wahlpflicht (P/WP)

---

**Contents**

Participating in the exercise sessions and solving the sheets deepens your understanding by applying the concepts from the lecture to real-life situations. It is recommended as a preparation for the examination at the end of the semester.

**Examination achievement**

See module level

**Course achievement**

See module level

**Compulsory requirement**
## Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
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</thead>
<tbody>
<tr>
<td>Blockchain and Cryptocurrencies</td>
<td>11LE13MO-1235_PO 2020</td>
</tr>
</tbody>
</table>

### Responsible
Prof. Dr. Peter Thiemann

### Organizer
Institut für Informatik Programmiersprache

### Faculty
Technische Fakultät

### ECTS-Points
6.0

### Workload
180 Stunden | hours

### Recommended semester
1

### Duration
1 Semester

### Pflicht/Wahlpflicht (P/WP)
Wahlpflicht

### Frequency
unregelmäßig

### Compulsory requirement
keine | none

### Recommended requirement
keine | none

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tbody>
<tr>
<td>Blockchain and Cryptocurrencies</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>2.0</td>
<td></td>
<td>180 Stunden</td>
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<tr>
<td>Blockchain and Cryptocurrencies</td>
<td>Übung</td>
<td></td>
<td></td>
<td>2.0</td>
<td></td>
</tr>
</tbody>
</table>

### Qualification

Students know the concepts of how blockchains work. They have insight in application scenarios, especially regarding the monetary background, Bitcoin and other cryptocurrencies. Cryptographic foundations, transaction ability, transaction legitimation, Consensus from Proof of Work to Proof of Stake are understood. Nonmonetary applications like Smart contracts from Ethereum to Tezos are known. Students are aware of security implications and risks.

### Examination achievement

Written exam (usually 90 to 180 minutes)
### Course achievement

| keine | none |

### Usability

<table>
<thead>
<tr>
<th>Compulsory elective module for students of the study program</th>
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</thead>
<tbody>
<tr>
<td>■ M.Sc. Informatik / Computer Science (2020) in Specialization Courses</td>
</tr>
<tr>
<td>■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science</td>
</tr>
</tbody>
</table>

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

<table>
<thead>
<tr>
<th>Wahlpflichtmodul für Studierende des Studiengangs</th>
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<tbody>
<tr>
<td>■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik</td>
</tr>
<tr>
<td>■ B.Sc. in Informatik (PO 2018)</td>
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↑
### Name of module
Blockchain and Cryptocurrencies

### Number of module
11LE13MO-1235_PO 2020

### Veranstaltung

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE13V-1235</td>
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</tbody>
</table>

### Organizer
Institut für Informatik Programmiersprache

### ECTS-Points
6.0

### Workload
180 Stunden | hours

### Attendance
28

### Independent study
124

### Hours of week
2.0

### Recommended semester
unregelmäßig

### Pflicht/Wahlpflicht (P/WP)
keine | none

### Contents
Monetary background, Bitcoin and other crypto currencies, Cryptographic foundations, Transaction ability, Transaction legitimation, Consensus from Proof of Work to Proof of Stake, Nonmonetary applications, Smart contracts from Ethereum to Tezos, Security implications and risks

### Examination achievement
See module level

### Course achievement
See module level

### Literature

### Compulsory requirement
keine | none

### Recommended requirement
keine | none
<table>
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### ECTS-Points

<table>
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<tr>
<th>Attendance</th>
<th>Hours of week</th>
<th>Recommended semester</th>
<th>Frequency</th>
<th>Pflicht/Wahlpflicht (P/WP)</th>
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<tbody>
<tr>
<td>28</td>
<td>2.0</td>
<td>unregelmäßig</td>
<td></td>
<td></td>
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</table>

### Contents

- Repetition, application, and consolidation of the lecture material with theoretical and practical tasks
- Examination achievement
  - See module level
- Course achievement
  - See module level
- Compulsory requirement
Name of module | Number of module
--- | ---
Compilerbau / Compiler Construction | 11LE13MO-1208_PO 2020

Responsible
Prof. Dr. Peter Thiemann

Organizer
Institut für Informatik Programmiersprache

Faculty
Technische Fakultät

ECTS-Points | 6.0
Workload | 180 Stunden | hours
Recommended semester | 1
Duration | 1 Semester
Pflicht/Wahlpflicht (P/WP) | Wahlpflicht
Frequency | unregelmäßig

Compulsory requirement
keine | none

Recommended requirement
keine | none

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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</thead>
</table>
| Compilerbau / Compiler Construction Vorlesung | Vorlesung | 6.0 | 2.0 | \[180 \text{ Stunden} | \text{ hours}\]
| Compilerbau / Compiler Construction Übung | Übung | | 2.0 |

Qualification
The students know basic techniques and tools of compiler construction and are able to apply them. They will be able to read and create specifications for syntactic and semantic analysis. They will know all stages of a simple compiler and be able to develop and assemble them into a working compiler. They know abstract intermediate representations and the concept of staging of different processing stages and are able to apply them.

Examination achievement
If there are 20 or fewer registered participants, an oral exam (usually 30 or 45 minutes); if there are more than 20 registered participants, a written exam (usually 90 to 180 minutes). Details will be announced in due time.

Course achievement
keine | none
Usability

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science
- M.Sc. in Sustainable Systems Engineering (PO 2021)

Part of the specialization Cyber-Physical Systems in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
Name of module  
Compilerbau / Compiler Construction  

Number of module  
11LE13MO-1208_PO 2020  

Veranstaltung  
Compilerbau / Compiler Construction Vorlesung  

Event type  
Vorlesung  

Number  
11LE13V-1208  

Organizer  
Institut für Informatik Programmiersprache  

ECTS-Points  
6.0  

Workload  
180 Stunden | hours  

Attendance  
28 Stunden | hours  

Independent study  
152 Stunden | hours  

Hours of week  
2.0  

Recommended semester  
unregelmäßig  

Pflicht/Wahlpflicht (P/WP)  

Contents  
■ Architektur eines Compilers  
■ Syntaktische und semantische Analyse  
■ Zwischensprachen und Transformation  
■ Instruktionsauswahl  
■ Registerallokation  
■ Analyse und Optimierung  
■ Garbage Collection  
■ Typen und Typinferenz  

■ Architecture of a compiler  
■ Syntactic and semantic analysis  
■ Intermediate representation and transformation  
■ Instruction selection  
■ Register allocation  
■ Code analysis and optimization  
■ Garbage collection  
■ Types and type inference  

Examination achievement  
See module level  

Course achievement  
See module level  

Literature  
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)


<table>
<thead>
<tr>
<th>Compulsory requirement</th>
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<tbody>
<tr>
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<table>
<thead>
<tr>
<th>Recommended requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>keine</td>
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</tbody>
</table>
Im Rahmen der Übung wird exemplarisch ein Compiler für eine kleine Programmiersprache entwickelt. Dabei kommen die Techniken und Inhalte der Vorlesung zum Einsatz.

The subject of the exercise is the development of a compiler for a small programming language. The development builds on the techniques and tools introduced in the lecture.
**Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)**

<table>
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<th>Name of module</th>
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</thead>
<tbody>
<tr>
<td>Computer Vision</td>
<td>11LE13MO-1123_PO 2020</td>
</tr>
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</table>

**Responsible**

Prof. Dr. Thomas Brox

**Organizer**

Institut für Informatik Mustererkennung u. Bildverarbeitung

**Faculty**

Technische Fakultät

**ECTS-Points**

6.0

**Workload**

180 Stunden | hours

**Recommended semester**

1

**Duration**

1 Semester

**Pflicht/Wahlpflicht (P/WP)**

Wahlpflicht

**Frequency**

unregelmäßig

**Compulsory requirement**

keine | none

**Recommended requirement**

Fundamental mathematical knowledge and programming skills (in C++ or Python)
Basic knowledge in image processing and/or computer graphics concepts

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Vision Vorlesung</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>2.0</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Computer Vision Übung</td>
<td>Übung</td>
<td></td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Qualification**

This course introduces the most important concepts in today's Computer Vision research. Students learn about some of the typical problems and methodologies in computer vision. After the module, they are capable to read current related literature and understand standard concepts used in computer vision research. Moreover, they can implement the techniques discussed in the lectures and to adapt them to their needs, if necessary.

**Examination achievement**

If there are 30 or fewer registered participants, an oral exam (usually 30 or 45 minutes); if there are more than 30 registered participants, a written exam (usually 90 to 180 minutes). Details will be announced in due time.
<table>
<thead>
<tr>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>keine</td>
</tr>
</tbody>
</table>

<p>| Usability |</p>
<table>
<thead>
<tr>
<th>Compulsory elective module for students of the study program</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung</td>
</tr>
<tr>
<td>■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science</td>
</tr>
<tr>
<td>Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wahlpflichtmodul für Studierende des Studiengangs</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ M.Ed. Informatik (PO 2018)</td>
</tr>
<tr>
<td>■ Master of Education Erweiterungsfach Informatik (PO 2021)</td>
</tr>
</tbody>
</table>
Computer Vision

**Veranstaltung**

Computer Vision Vorlesung

**Event type**

Vorlesung 11LE13V-1123

**Organizer**

Institut für Informatik Mustererkennung u. Bildverarbeitung

**ECTS-Points**

6.0

**Workload**

180 Stunden | hours

**Attendance**

32 Stunden

**Independent study**

148 Stunden

**Hours of week**

2.0

**Recommended semester**


**Frequency**

unregelmäßig

**Pflicht/Wahlpflicht (P/WP)**


**Contents**

The course presents the most relevant computer vision tasks and current solutions. It covers nonlinear diffusion, variational optimization, spectral clustering, image segmentation, optical flow, video segmentation, stereo reconstruction, camera calibration, structure from motion, recognition, and deep learning.

**Examination achievement**

See module level

**Course achievement**

See module level

**Literature**

current literature, as announced directly in lecture

**Compulsory requirement**

keine | none

**Recommended requirement**

Fundamental mathematical knowledge and programming skills (in C++ or Python)
Basic knowledge in image processing and/or computer graphics concepts

**Recommendation**

Usually the course is offered every winter semester; as there might be rare exceptions in some years, it's marked as "irregularly"
### Contents

The exercises consist of programming assignments (usually in C/C++), where students learn to implement the most important techniques presented in the lectures.

### Examination achievement

See module level

### Course achievement

See module level

### Compulsory requirement
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concurrency, Theory and Practice</td>
<td>11LE13MO-1225_PO 2020</td>
</tr>
</tbody>
</table>

Responsible
Prof. Dr. Peter Thiemann

Organizer
Institut für Informatik Programmiersprache

Faculty
Technische Fakultät

ECTS-Points 6.0
Workload 180 Stunden
Recommended semester 1
Duration 1 Semester
Pflicht/Wahlpflicht (P/WP) Wahlpflicht
Frequency unregelmäßig

Compulsory requirement
keine

Recommended requirement
keine

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tbody>
<tr>
<td>Concurrency, Theory and Practice</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>2.0</td>
<td></td>
<td>180 Stunden/hours</td>
</tr>
<tr>
<td>Concurrency, Theory and Practice</td>
<td>Übung</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Qualification
Knowledge of issues arising in writing correct concurrent programs; typical problems like race conditions, deadlocks, and techniques to address them; techniques for modeling and analyzing concurrency programs: calculi for concurrency, dynamic and static analysis; concurrency patterns and primitives

Examination achievement
Klausur/written exam

Literature
The Art of Multiprocessor Programming (Herlihy, Shavit)
Concurrency in Go (O'Reilly)
Fundamentals of Session Types (Vasconcelos)
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concurrency, Theory and Practice</td>
<td>11LE13MO-1225_PO 2020</td>
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**Veranstaltung**

Concurrency, Theory and Practice

<table>
<thead>
<tr>
<th>Event type</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE13V-1225</td>
</tr>
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</table>

Organizer

Institut für Informatik Programmiersprache

ECTS-Points 6.0

Workload 180 Stunden/hours

Attendance 32 Stunden/hours

Independent study 116 Stunden/hours

Hours of week 2.0

Recommended semester 2

Frequency unregelmäßig

Pflicht/Wahlpflicht (P/WP)

Contents

A concurrent language; dataraces, deadlocks and their detection; concurrent programming patterns; specification of concurrent programs; concurrent datastructures; a concurrency calculus with types

Examination achievement

See module level

Course achievement

See module level

Literature

The Art of Multiprocessor Programming (Herlihy, Shavit)
Concurrency in Go (O'Reilly)
Fundamentals of Session Types (Vasconcelos)

Further materials to be announced on the lecture webpage

Compulsory requirement

keine

Recommended requirement

keine
### Name of module: Concurrency, Theory and Practice

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concurrency, Theory and Practice</td>
<td>11LE13MO-1225_PO 2020</td>
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<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Übung</td>
<td>11LE13Ü-1225</td>
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</table>

**Organizer**
Institut für Informatik Programmiersprache

**ECTS-Points**

<table>
<thead>
<tr>
<th>Attendance</th>
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<td>Hours of week</td>
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<tr>
<td>Recommended semester</td>
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<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
</tr>
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<td>Pflicht/Wahlpflicht (P/WP)</td>
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</table>

**Contents**
Extension, consolidation, and practical exploration of lecture contents

**Examination achievement**
See module level

**Course achievement**
See module level

**Compulsory requirement**
### Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
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**Responsible**

Prof. Dr. Andreas Podelski

**Organizer**

Institut für Informatik Softwaretechnik

**Faculty**

Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
</tr>
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<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>1</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
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<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>nur im Wintersemester</td>
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</table>

**Compulsory requirement**

keine | none

**Recommended requirement**

Grundlegende Kenntnisse in den Themenbereichen Rechnerarchitektur und Softwaretechnik / Softwareentwurf | 

Basic knowledge in the areas of computer architecture and software engineering / software design

#### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyber-Physikalische Systeme – Diskrete Modelle / Cyber-Physical Systems – Discrete Models - Vorlesung</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>3.0</td>
<td>180 Stunden</td>
</tr>
</tbody>
</table>

**Qualification**

The course provides an introduction to discrete models of cyber-physical systems, their analysis and verification:

The students learn how to model cyber-physical systems as transition systems. Here, the main focus lies on software and hardware aspects of cyber-physical systems and on methods for modeling parallelism and communication.

The students learn how to express properties about such systems. The course covers different mechanisms to specify temporal properties including linear time properties and branching time properties such as LTL, CTL, and CTL* properties.
### Examination achievement

Written exam (usually 90 to 180 minutes)

If the number of participants is small (< 15), an oral examination may be held instead. The students will be informed in good time.

### Course achievement

Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points.

To pass the course work (Studienleistung), you must obtain at least 50% of the exercise points.

Also, every student must present his/her solution to an exercise in an exercise group at least once in the semester.

### Usability

Compulsory elective module for students of the study program

- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses

Part of the specialization Cyber-Physical Systems in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs

- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
### Contents

The course provides an introduction to discrete models of cyberphysical systems, their analysis and verification:

- The students learn how to model cyber-physical systems as transition systems. Here, the main focus lies on software and hardware aspects of cyber-physical systems and on methods for modeling parallelism and communication.
- Moreover, the students learn how to express properties about such systems. The course covers different mechanisms to specify temporal properties including linear time properties and branching time properties such as LTL, CTL, and CTL* properties.
- Finally, the course demonstrates how to develop algorithms for checking whether these properties hold. After presenting algorithms for explicit state systems we introduce symbolic BDD-based algorithms which are able to tackle the well-known "state explosion problem". In addition, the course covers basic "Bounded Model Checking" (BMC) techniques which restrict the analysis to computation paths up to a certain length and reduce the verification problem to a Boolean Satisfiability problem.
- All necessary foundations for these algorithms such as fixed point theory, data structures like Binary Decision Diagrams (BDDs), and Satisfiability (SAT) solvers are introduced in the course as well.

### Examination achievement

Siehe Modulebene | See module level

### Course achievement

Siehe Modulebene | See module level
### Literature

- E. Clarke, O. Grumberg, D. Peled, *"Model Checking"*, MIT Press 1999

### Compulsory requirement

keine | none

### Recommended requirement

Grundlegende Kenntnisse in den Themenbereichen Rechnerarchitektur und Softwaretechnik / Softwareentwurf |

Basic knowledge in the areas of computer architecture and software engineering / software design
Cyber-Physikalische Systeme - Diskrete Modelle / Cyber-Physical Systems – Discrete Models
11LE13MO-2070_PO 2020

**Veranstaltung**

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<thead>
<tr>
<th>Event type</th>
<th>Organizer</th>
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</thead>
<tbody>
<tr>
<td>Übung</td>
<td>Institut für Informatik Rechnerarchitektur</td>
</tr>
<tr>
<td></td>
<td>Institut für Informatik Programmiersprache</td>
</tr>
<tr>
<td></td>
<td>Institut für Informatik Softwaretechnik</td>
</tr>
<tr>
<td></td>
<td>Institut für Informatik Betriebssysteme</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>Attendance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15 Stunden</td>
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<table>
<thead>
<tr>
<th>Hours of week</th>
<th>Recommended semester</th>
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</thead>
<tbody>
<tr>
<td>1.0</td>
<td>nur im Wintersemester</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pflicht/Wahlpflicht (P/WP)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Contents
The lecture is accompanied by exercises. Students train themselves to write down things in a formally correct way.

Examination achievement
Siehe Modulebene |
See module level

Course achievement
Siehe Modulebene |
See module level

Compulsory requirement

↑
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

Name of module | Number of module
----------------|------------------
Cyber-Physical Systems – Program Verification | 11LE13MO-1207_v2_PO 2020

Responsible
Prof. Dr. Andreas Podelski

Organizer
Institut für Informatik Softwaretechnik

Faculty
Technische Fakultät

ECTS-Points | 6.0
Workload | 180 Stunden | hours
Recommended semester | 2
Duration | 1 Semester
Pflicht/Wahlpflicht (P/WP) | Wahlpflicht
Frequency | nur im Sommersemester

Compulsory requirement
keine | none

Recommended requirement
Basic concepts in logic (propositional logic, first-order logic), mathematics (sets, relations, functions, linear algebra), formal languages (regular expressions, automata).

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyber-Physische Systeme - Programmverifikation / Cyber-Physical Systems – Program Verification</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>2.0</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Cyber-Physische Systeme - Programmverifikation / Cyber-Physical Systems – Program Verification</td>
<td>Übung</td>
<td></td>
<td></td>
<td>2.0</td>
<td></td>
</tr>
</tbody>
</table>

Qualification

Often computers are used in embedded, networked, safety-critical applications. The cost of failure is high. The student learns the basic concepts, methods, and tools for ensuring that a system does not have bad behaviors. The student learns how to use propositional logic and first-order logic reasoning for specification, analysis, and verification. The student learns how to formally specify the correctness of a given program. In particular, correctness can be specified by an annotation of the program with a special kind of comments. The student learns how the correctness of the program can be reduced to the validity of a first-order logical formula and how the validity can be proven automatically by a new generation of powerful reasoning engines. The student also learns how verification can be done with static analysis methods, i.e., methods which have been developed originally in compiler optimization and which have been formalized by Patrick and Radhia Cousot's framework of abstract interpretation.
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Examination achievement</th>
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</thead>
<tbody>
<tr>
<td>Written exam (usually 90 to 180 minutes)</td>
</tr>
<tr>
<td>If the number of participants is small (&lt; 15), an oral examination may be held instead. The students will be informed in good time.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points.</td>
</tr>
<tr>
<td>To pass the course work (Studienleistung), you must obtain at least 50% of the exercise points.</td>
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<tr>
<td>Also, every student must present his/her solution to an exercise in an exercise group at least once in the semester.</td>
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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Compulsory elective module for students of the study program</td>
</tr>
<tr>
<td>■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung</td>
</tr>
<tr>
<td>■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science</td>
</tr>
<tr>
<td>Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering</td>
</tr>
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<table>
<thead>
<tr>
<th>Wahlpflichtmodul für Studierende des Studiengangs</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik</td>
</tr>
<tr>
<td>■ B.Sc. in Informatik (PO 2018)</td>
</tr>
<tr>
<td>■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)</td>
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<tr>
<td>■ M.Ed. Informatik (PO 2018)</td>
</tr>
<tr>
<td>■ Master of Education Erweiterungsfach Informatik (PO 2021)</td>
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</tbody>
</table>
### Name of module

Cyber-Physical Systems – Program Verification

### Number of module

11LE13MO-1207_v2_PO 2020

### Veranstaltung

Cyber-Physische Systeme - Programmverifikation / Cyber-Physical Systems – Program Verification

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE13V-1207_v2</td>
</tr>
</tbody>
</table>

### Organizer

Institut für Informatik Rechnerarchitektur
Institut für Informatik Programmiersprache
Institut für Informatik Softwaretechnik
Institut für Informatik Betriebssysteme

### ECTS-Points

6.0

### Workload

180 Stunden | hours

### Attendance

26 Stunden

### Independent study

128 Stunden

### Hours of week

2.0

### Recommended semester

nur im Sommersemester

### Pflicht/Wahlpflicht (P/WP)

### Contents

In this lecture we introduce basic concepts, methods, and tools for ensuring that a system does not have bad behaviors. We start with an introduction to propositional logic and first-order logic reasoning. We establish a formal setting for the specification, analysis, and verification of behaviors of programs. We show how correctness can be specified by an annotation of the program with a special kind of comments. We show how the correctness of a program can be reduced to the validity of a logical formula. The validity can be proven automatically by a new generation of powerful reasoning engines. Finally, we connect verification with static analysis methods which have been developed originally in compiler optimization and which are formalized by Patrick and Radhia Cousot's framework of abstract interpretation. To give an example of a verification problem, we take device driver programs for Windows and Linux operating systems; such programs come with rules that specify the order of certain operations and file accesses. A violation of such a rule leads to system crash or deadlock, unexpected exceptions, and the failure of runtime checks. An example of a rule is that calls to lock and unlock must alternate (an attempt to re-acquire an acquired lock or release a released lock will cause a deadlock). We can formalize the correctness properties expressed by such a rules in the form of a temporal property (safety or liveness) or a finite automaton.

### Examination achievement

Siehe Modulebene |
See module level

### Course achievement

Siehe Modulebene |
See module level

### Literature

Baier, C., Katoen, J. - Principles of Model Checking
<table>
<thead>
<tr>
<th>Compulsory requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>keine</td>
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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Basic concepts in logic (propositional logic, first-order logic), mathematics (sets, relations, functions, linear algebra), formal languages (regular expressions, automata).</td>
</tr>
<tr>
<td>Name of module</td>
</tr>
<tr>
<td>----------------------------------------</td>
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<tr>
<td>Cyber-Physical Systems – Program Verification</td>
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**Veranstaltung**

Cyber-Physische Systeme - Programmverifikation / Cyber-Physical Systems – Program Verification

<table>
<thead>
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<th>Event type</th>
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<tbody>
<tr>
<td>Übung</td>
<td>11LE13Ü-1207_v2</td>
</tr>
</tbody>
</table>

**Organizer**

- Institut für Informatik Rechnerarchitektur
- Institut für Informatik Programmiersprache
- Institut für Informatik Softwaretechnik
- Institut für Informatik Betriebssysteme

**ECTS-Points**

<table>
<thead>
<tr>
<th>Attendance</th>
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<tbody>
<tr>
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<tr>
<td>Recommended semester</td>
<td>nur im Sommersemester</td>
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<tr>
<td>Frequency</td>
<td>nur im Sommersemester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
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</table>

**Contents**

<table>
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</thead>
<tbody>
<tr>
<td>Siehe Modulebene</td>
</tr>
</tbody>
</table>

**Compulsory requirement**
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Das fehlende Semester -- Linux, Tools, und vieles mehr</td>
<td>11LE13MO-1159 PO 2020</td>
</tr>
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</table>

Responsible
Prof. Dr. Armin Biere

Organizer
Institut für Informatik Rechnerarchitektur

Faculty
Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>Workload</th>
<th>Recommended semester</th>
<th>Duration</th>
<th>Pflicht/Wahlpflicht (P/WP)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0</td>
<td>180 Stunden / Hours</td>
<td>1</td>
<td>1 Semester</td>
<td>Wahlpflicht</td>
<td>unregelmäßig</td>
</tr>
</tbody>
</table>

Compulsory requirement
keine | none

Recommended requirement
keine | none

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Das fehlende Semester -- Linux, Tools, und vieles mehr</td>
<td>Vorlesung</td>
<td></td>
<td>3.0</td>
<td>180 Stunden</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Das fehlende Semester -- Linux, Tools, und vieles mehr</td>
<td>Übung</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Qualification
After completing the module, students will be able to handle the command line and write their own small Bash programs. They will learn useful text editors (including IDEs) and will be able to work with virtualization (especially Linux) and will know some programming tools. We also introduce many tools (e.g. LSP server, LaTeX, LLM).

Examination achievement

Klausur / Schriftliche Prüfung
| Written exam |
**Course achievement**

Bearbeitung von Übungsblättern

Processing of exercise sheets (approximately one sheet per topic)

**Recommendation**

The course is inspired by

https://missing.csail.mit.edu/
http://teaching.pages.sai.jku.at/missing-semester/

**Usability**

Compulsory elective module for students of the study program

- M.Sc. Embedded Systems Engineering (PO 2021), Elective Courses in Computer Science
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses

Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science

and

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science

resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs

- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
## Veranstaltung

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Das fehlende Semester -- Linux, Tools, und vieles mehr</td>
<td>11LE13MO-1159 PO 2020</td>
</tr>
</tbody>
</table>

### Event type

- Vorlesung
  - Number: 11LE13V-1159 PO 2020

### Organizer

- Institut für Informatik Rechnerarchitektur

## ECTS-Points

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>Workload</th>
<th>Attendance</th>
<th>Independent study</th>
<th>Hours of week</th>
<th>Recommended semester</th>
<th>Frequency</th>
<th>Pflicht/Wahlpflicht (P/WP)</th>
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<tbody>
<tr>
<td></td>
<td>180 Stunden</td>
<td>48 Stunden</td>
<td>116 Stunden</td>
<td>3.0</td>
<td></td>
<td>unregelmäßig</td>
<td></td>
</tr>
</tbody>
</table>

## Contents

This course is oriented to the MIT/SAI "Missing Semester" and presents many useful tools. None of these tools requires a separate course, but each is useful, especially for manipulating text (e.g., log files, automating and evaluating experiments, ...).

This course covers the following topics, among others:
- Linux and desktop environment
- Text editors - Using Git - Shells and command line
- Makefile
- Draw graphs in programs

## Examination achievement

See module level

## Course achievement

See module level

## Literature


## Compulsory requirement

None

## Recommended requirement

None
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Das fehlende Semester -- Linux, Tools, und vieles mehr</td>
<td>11LE13MO-1159 PO 2020</td>
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**Veranstaltung**

<table>
<thead>
<tr>
<th>Veranstaltung</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Das fehlende Semester -- Linux, Tools, und vieles mehr</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Übung</td>
<td>11LE13Ü-1159 PO 2020</td>
</tr>
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<table>
<thead>
<tr>
<th>Organizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institut für Informatik Rechnerarchitektur</td>
</tr>
</tbody>
</table>

**ECTS-Points**

| Attendance | 16 Stunden/hours |
| Hours of week | 1.0 |
| Recommended semester |
| Frequency | unregelmäßig |
| Pflicht/Wahlpflicht (P/WP) |

**Contents**

The weekly exercises must be successfully completed.

**Examination achievement**

See module level

**Course achievement**

See module level

**Compulsory requirement**
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debugging and Fuzzing</td>
<td>11LE13MO-1158_PO 2020</td>
</tr>
</tbody>
</table>

**Responsible**
Prof. Dr. Armin Biere

**Organizer**
Institut für Informatik Rechnerarchitektur

**Faculty**
Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
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</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>1</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>nur im Wintersemester</td>
</tr>
</tbody>
</table>

**Compulsory requirement**
keine | none

**Recommended requirement**
Good programming experience necessary
Highly recommended: Advanced Programming Skills (in C, C++, Java, or Python)
Basic knowledge in Software Engineering, Algorithms and Data-Structures

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debugging and Fuzzing</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>2.0</td>
<td>180 Stunden</td>
<td>hours</td>
</tr>
<tr>
<td>Debugging and Fuzzing</td>
<td>Übung</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Qualification**
The main goal is to understand debugging from a scientific perspective and learn how to apply advanced debugging techniques to real world system design mostly in the context of software engineering and in combination with modern fuzzing and testing techniques.

**Examination achievement**
Written exam (usually 90 to 180 minutes)

**Course achievement**
You have to complete and hand in your solutions for exercise sheets and perform experiments on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of the overall number of achievable points for the semester.
### Usability

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering
Name of module | Number of module
--- | ---
Debugging and Fuzzing | 11LE13MO-1158_PO 2020

**Veranstaltung**

Debugging and Fuzzing

Event type | Number
--- | ---
Vorlesung | 11LE13V-1158_PO 2020

Organizer

Institut für Informatik Rechnerarchitektur

**ECTS-Points**
6.0

**Workload**
180 Stunden | hours

**Attendance**
30

**Independent study**
120

**Hours of week**
2.0

**Recommended semester**

**Frequency**
nur im Wintersemester

**Pflicht/Wahlpflicht (P/WP)**

**Contents**

We will discuss failures, tracking, contracts/assertions, delta-debugging, quick-check, symbolic debugging, coverage, automatic/unit/regression/combinatorial/model-based testing, data-races, deadlocks, sanitizers and also spend some time on fuzzing, including white/gray/black-box fuzzing, coverage, grammar-aware fuzzing, and symbolic execution.

**Examination achievement**

See module level

**Course achievement**

See module level

**Literature**

"Why Programs Fail", A. Zeller.
"The Fuzzing Book", A. Zeller et.al.

**Compulsory requirement**

**Recommended requirement**

Good programming experience necessary
Highly recommended: Advanced Programming Skills (in C, C++, Java, or Python)
Software Engineering, Algorithms and Data-Structures
## Name of module

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debugging and Fuzzing</td>
<td>11LE13MO-1158_PO 2020</td>
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## Veranstaltung

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Übung</td>
<td>11LE13Ü-1158_PO 2020</td>
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</tbody>
</table>

## Organizer

Institut für Informatik Rechnerarchitektur

## ECTS-Points

<table>
<thead>
<tr>
<th>Attendance</th>
<th>30</th>
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<tr>
<td>Hours of week</td>
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<td>Recommended semester</td>
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</tr>
<tr>
<td>Frequency</td>
<td>nur im Wintersemester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
</tr>
</tbody>
</table>

## Contents

Using the acquired debugging techniques in exercises on paper and applying debugging and fuzzing tools to real complex code from automated reasoning, electronic design automation or compilers.

## Examination achievement

See module level

## Course achievement

See module level

## Compulsory requirement

↑
Name of module: Digital Health (DH)
Number of module: 11LE13MO-1160_PO 2020

Responsible: Prof. Dr. Oliver Amft
Organizer: Institut für Informatik Intelligente Eingebettete Systeme
Faculty: Technische Fakultät

ECTS-Points: 6.0
Workload: 180 hours
Recommended semester: 1
Duration: 1 Semester
Pflicht/Wahlpflicht (P/WP): Wahlpflicht
Frequency: nur im Wintersemester

Compulsory requirement: none
Recommended requirement: Basic timeseries analysis methods, basic programming skills, coding in Python

Assigned Courses:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Health (DH)</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>2.0</td>
<td>180 hours</td>
<td></td>
</tr>
<tr>
<td>Digital Health (DH)</td>
<td>Übung</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Qualification:
* Understand the data sources and modalities in digital medicine and the processes of data integration in clinical information systems and DGAs
* Understand the German DGA regulation and issues relating to data privacy
* Apply ubiquitous technology (ambient, mobile, wearable, implantable) for digital health
* Apply context recognition and personalisation methods to qualify ubiquitous system data
* Apply data-based privacy preserving techniques (obfuscation)
* Design and implement digital biomarkers based on multimodal data
* Design and apply digital health twins and clinical data modelling
* Design medical decision support systems based on multimodal data

Examination achievement:
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes)

If there are too many students for a reasonably organized oral exam, it will be held as a written exam instead, announced well in advance.
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>written composition</td>
</tr>
<tr>
<td>Reports on exercises to be submitted</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up-to-date literature recommendations are provided during the lectures.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compulsory elective module for students of the study program</td>
</tr>
<tr>
<td>■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung</td>
</tr>
<tr>
<td>■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science <strong>OR</strong> in Microsystems Engineering Concentrations Area Biomedical Engineering</td>
</tr>
<tr>
<td>■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering</td>
</tr>
<tr>
<td>■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik</td>
</tr>
</tbody>
</table>

Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

and

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

**Name of module**

| Digital Health (DH) | 11LE13MO-1160_PO 2020 |

**Veranstaltung**

| Digital Health (DH) |

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE13V-1160_PO 2020</td>
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</table>

<table>
<thead>
<tr>
<th>Organizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institut für Informatik Intelligente Eingebettete Systeme</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ECTS-Points 6.0</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Workload 180 hours</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Attendance 32 hours</th>
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</table>

<table>
<thead>
<tr>
<th>Independent study 116 hours</th>
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<table>
<thead>
<tr>
<th>Hours of week 2.0</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Recommended semester 1</th>
</tr>
</thead>
</table>

| Frequency nur im Wintersemester |

| Pflicht/Wahlpflicht (P/WP) |

## Contents

Digital health is a branch of digital medicine that integrates and leverages multisource and multimodal data for medical knowledge extraction and decision support across a wide range of preventive, diagnostic, and therapeutic applications. The course starts by introducing the basic properties of medically relevant data sources and their different modalities. The course introduces the medical benefits of using ubiquitous technologies for data collection, in particular, between hospital visits. The process of medical data integration in clinical information systems and in digital health applications ("Digitale Gesundheitsanwendungen", DGA) is discussed. The German DGA regulations and their consequences are introduced, in particular relating to digital health application qualification and data privacy. Privacy preserving techniques are discussed and applied. Subsequently, data interpretation in telemedicine and digital biomarker design are analysed regarding context recognition and personalisation methods and algorithms. Decision support systems are dissected regarding their components and data analysis algorithms. Finally, the concept, realisation, and application of digital health twins in medicine is developed. The exercises will include practical experiments and implementation tasks, e.g. smartphone apps, 3D digital twin modelling, and data analysis for decision support.

## Examination achievement

see module level

## Course achievement

see module level

## Literature

Up-to-date literature recommendations are provided during the lectures.

## Compulsory requirement

None
<table>
<thead>
<tr>
<th>Recommended requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic timeseries analysis methods, basic programming skills, coding in Python</td>
</tr>
</tbody>
</table>
## Contents

Students will investigate concrete data science methods related to medical data, including context recognition, data interpretation and abstraction.

### Examination achievement

see module level

### Course achievement

see module level

### Compulsory requirement
### Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
</table>

**Responsible**

Prof. Dr. Christoph Scholl

**Organizer**

Institut für Informatik Betriebssysteme

**Faculty**

Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
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<td>Recommended semester</td>
<td>2</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
</tr>
</tbody>
</table>

**Compulsory requirement**

keine | none

**Recommended requirement**

Knowledge in computer architecture / Computer Architecture and software technology / Software Engineering

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echtzeitbetriebssysteme und Worst-Case-Execution-Times / Real-Time Operating Systems and Worst-Case Execution Times</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>3.0</td>
<td>180 hours</td>
</tr>
<tr>
<td>Echtzeitbetriebssysteme und Worst-Case-Execution-Times/ Real-Time Operating Systems and Worst-Case Execution Times</td>
<td>Übung</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Qualification**

The students are proficient in the basic methods for real-time operating systems. In particular, they know the essential differences between standard operating systems and real-time operating systems for embedded systems with respect to both requirements and implementation concepts (especially in the area of scheduling). The students have knowledge of the most important functions of real-time operating systems as well as programming experience with real-time systems.
<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
<tbody>
<tr>
<td>As compulsory elective in</td>
</tr>
<tr>
<td>- M.Sc. Informatik / Computer Science in Spezialvorlesung</td>
</tr>
<tr>
<td>- M.Sc. Embedded Systems Engineering (ESE) in Elective Courses in Computer Science</td>
</tr>
</tbody>
</table>

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering
Contents

After a brief review of standard operating systems and the hardware requirements for the implementation of operating systems the lecture deals with operating systems for embedded systems and the question how real-time requirements can be fulfilled. In order to answer this question the lecture looks into methods which compute upper bounds to the run time of processes (“worst case execution times”) and into scheduling methods which guarantee meeting certain deadlines under the condition that the run times do not exceed given worst case execution times. Various scheduling approaches are classified with respect to their application area and analyzed with respect to their quality and cost. Moreover, the lecture looks into basic concepts like synchronization and communication of several processes, shared resources, mutual exclusion etc. together with their role in the design of real-time operating systems.

Examination achievement

see module level

Course achievement

see module level

Literature

Will be announced at the beginning of the course.

Compulsory requirement

keine | none

Recommended requirement

Knowledge in computer architecture / Computer Architecture and software technology / Software Engineering
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
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</table>

**Veranstaltung**

Echtzeitbetriebssysteme und Worst-Case-Execution-Times / Real-Time Operating Systems and Worst-Case Execution Times

<table>
<thead>
<tr>
<th>Event type</th>
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<tbody>
<tr>
<td>Übung</td>
<td>11LE13Ü-1240</td>
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Organizer

Institut für Informatik Rechnerarchitektur

**ECTS-Points**

<table>
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<th>16 Stunden</th>
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<td>Recommended semester</td>
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<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
<td></td>
</tr>
</tbody>
</table>

Contents

Exercises are used to deepen the understanding of methods and algorithms introduced in the lectures by application to practical examples.

Examination achievement

see module level

Course achievement

see module level

Compulsory requirement

↑
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
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<tbody>
<tr>
<td>Einführung in die Kryptographie/Introduction to Cryptography</td>
<td>11LE13MO-1401_PO 2020</td>
</tr>
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Responsible
Prof. Dr. Christian Schindelhauer

Organizer
Institut für Informatik Rechnernetze u. Telematik

Faculty
Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>2</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
</tr>
</tbody>
</table>

Compulsory requirement
keine | none

Recommended requirement
keine | none

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Einführung in die Kryptographie/Introduction to Cryptography-Vorlesung</td>
<td>Vorlesung</td>
<td></td>
<td>2.0</td>
<td></td>
<td>180 Stunden</td>
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<tr>
<td>Einführung in die Kryptographie/Introduction to Cryptography-Übung</td>
<td>Übung</td>
<td></td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Qualification
Students know the meaning of symmetric and asymmetric cryptographic methods and understand their fundamentals. They gain the ability to understand current scientific literature.

Examination achievement
Bei mehr als 10 Teilnehmern findet eine schriftliche Prüfung statt (Dauer zwischen 90 und 180 Minuten). Ansonsten findet eine mündliche Prüfung statt (Dauer 20 bis 30 Minuten).

In case there are more than 10 students there will be an written exam (duration between 90 and 180 minutes). Otherwise an oral exam will take place (duration 20 to 30 minutes).
<table>
<thead>
<tr>
<th>Course achievement</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>keine</td>
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</table>

**Usability**

As compulsory elective in
- M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) in Elective Courses in Computer Science

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Einführung in die Kryptographie/Introduction to Cryptography</td>
<td>11LE13MO-1401_PO 2020</td>
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**Veranstaltung**

<table>
<thead>
<tr>
<th>Event type</th>
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<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE13V-1401</td>
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**Organizer**

Institut für Informatik Rechnernetze u. Telematik

**ECTS-Points**

<table>
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<th>Activity</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
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<tr>
<td>Attendance</td>
<td>32 Stunden</td>
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<tr>
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</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
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</table>

**Contents**

Vorlesungsthemen:
- Symmetrische Verschlüsselung
- Asymmetrische Verschlüsselung
- kryptographische Protokolle
- One-Way-Funktionen
- One-Time-Pads
- Quantum Cryptography

<table>
<thead>
<tr>
<th>Lecture topics</th>
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<tbody>
<tr>
<td>Symmetric-Key Cryptography</td>
</tr>
<tr>
<td>Public-Key-Cryptography</td>
</tr>
<tr>
<td>Cryptographic Protocols</td>
</tr>
<tr>
<td>One-Way-Functions</td>
</tr>
<tr>
<td>One-Time Pads</td>
</tr>
<tr>
<td>Quantum Cryptography</td>
</tr>
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</table>

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level

**Literature**

- Einführung in die Kryptographie, Johannes Buchmann, Springer, 2009
### Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Requirement</th>
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<tr>
<td><strong>Compulsory requirement</strong></td>
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<tr>
<td><strong>Recommended requirement</strong></td>
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</table>
# Name of module

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Einführung in die Kryptographie/Introduction to Cryptography</td>
<td>11LE13MO-1401_PO 2020</td>
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## Veranstaltung

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<td>Einführung in die Kryptographie/Introduction to Cryptography-Übung</td>
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### Organizer

Institut für Informatik Rechnernetze u. Telematik

### ECTS-Points

<table>
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<tr>
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</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
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</table>

## Contents

**Übung:**
- Analyse der Sicherheit kryptographischer Verfahren
- Algorithmen zur Berechnung
- Analyse kryptographischer Protokolle
- Anwendung von Verschlüsselungsverfahren

**Exercise:**
- Analysis of the security of cryptographic methods
- Algorithms for the computation
- Analysis of cryptographic protocols
- Using encryption methods

### Examination achievement

Siehe Modulebene | See module level

### Course achievement

Siehe Modulebene | See module level

### Compulsory requirement
### Name of module

| Einführung in die Multiagentensysteme / Introduction to Multiagent Systems |

### Number of module

11LE13MO-1118_PO 2020

### Responsible

Prof. Dr. Joschka Bödecker

### Organizer

Institut für Informatik Grundl.d.künstl.Intelligenz

### Faculty

Technische Fakultät

### ECTS-Points

6.0

### Workload

180 Stunden | hours

### Recommended semester

2

### Duration

1 Semester

### Pflicht/Wahlpflicht (P/WP)

Wahlpflicht

### Frequency

unregelmäßig

### Compulsory requirement

keine | none

### Recommended requirement

Knowledge of concepts such as search methods and formal logic is useful (as provided in the lecture Foundations of Artificial Intelligence (Grundlagen der Künstlichen Intelligenz)) Programming skills are required

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tbody>
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<td>Einführung in die Multiagentensysteme / Introduction to Multiagent Systems</td>
<td>Vorlesung</td>
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<td>3.0</td>
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<td>Übung</td>
<td></td>
<td>1.0</td>
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</table>

### Qualification

The participants have a basic understanding of multiagent systems and their use in modeling real world problems. They know about theoretical and practical aspects of multiagent systems. The rationale behind modeling problems in terms of agents in computer science and robotics can be discussed by the participants. They know the difference between this approach in relation to other programming paradigms, and can decide which types of problems can be solved using agent architectures.
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Examination achievement</th>
</tr>
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<tbody>
<tr>
<td>Klausur (i.d.R. 90 bis 180 Minuten)</td>
</tr>
<tr>
<td>Wenn die Teilnehmerzahl sehr klein ist, kann stattdessen eine mündliche Prüfung (i.d.R. 30 oder 45 Minuten) durchgeführt werden. Die Studierenden werden rechtzeitig informiert.</td>
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</table>

<table>
<thead>
<tr>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Es gibt Übungsaufgaben im regelmäßigen Rhythmus, die bearbeitet und abgegeben werden müssen. Diese werden korrigiert und mit Punkten bewertet. Die Studienleistung ist bestanden, wenn mindestens 50% der Gesamtpunkte im Semester erreicht sind.</td>
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<table>
<thead>
<tr>
<th>Usability</th>
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<tbody>
<tr>
<td>Compulsory elective module for students of the study program</td>
</tr>
<tr>
<td>M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung</td>
</tr>
<tr>
<td>M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science</td>
</tr>
<tr>
<td>Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering</td>
</tr>
<tr>
<td>Wahlpflichtmodul für Studierende des Studiengangs</td>
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<tr>
<td>B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik</td>
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<td>B.Sc. in Informatik (PO 2018)</td>
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<td>polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)</td>
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<td>M.Ed. Informatik (PO 2018)</td>
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<tr>
<td>Master of Education Erweiterungsfach Informatik (PO 2021)</td>
</tr>
<tr>
<td>Name of module</td>
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<tr>
<td>----------------</td>
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<tr>
<td>Einführung in die Multiagentensysteme / Introduction to Multiagent Systems</td>
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**Veranstaltung**

<table>
<thead>
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**Event type**

<table>
<thead>
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<th>Vorlesung</th>
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<tr>
<td>11LE13V-1118</td>
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**Organizer**

Institut für Informatik Grundl.d.künstl.Intelligenz

<table>
<thead>
<tr>
<th>ECTS-Points</th>
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<tr>
<td>Workload</td>
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<td>Frequency</td>
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<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
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**Contents**

Multi-agent systems have emerged as one of the most important areas of research and development in information technology. A multi-agent system is composed of multiple interacting software components known as agents, which are typically capable of cooperating to solve problems that are beyond the abilities of any individual member. Multi-agent systems are important primarily because they have been found to have very wide applicability. The difference between agents and objects from OOP could be stated as: "Objects do it for free, but agents do it for money". This course will address theoretical and practical aspects of multiagent systems. The rationale behind modeling problems in terms of agents in computer science and robotics will be explained. We will see how this approach is different from and relates to other programming paradigms, and which types problems can be solved using agent architectures.

Topics of this course are:

- Agent architectures
- Agent planning
- Methods of communication
- Game Theory
- Common sensing and world-modeling
- Distributed decision making
- Cooperation and coordination

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level
### Literature


### Compulsory requirement

keine | none

### Recommended requirement

Knowledge of concepts such as search methods and formal logic is useful (as provided in the lecture Foundations of Artificial Intelligence (Grundlagen der Künstlichen Intelligenz))

Programming skills are required
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Einführung in die Multiagentensysteme / Introduction to Multiagent Systems</td>
<td>11LE13MO-1118_PO 2020</td>
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**Veranstaltung**

<table>
<thead>
<tr>
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<th>Number</th>
</tr>
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<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
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<tbody>
<tr>
<td>Übung</td>
<td>11LE13Ü-1118</td>
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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Institut für Informatik Grundl.d.künstl.Intelligenz</td>
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<table>
<thead>
<tr>
<th>ECTS-Points</th>
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</thead>
<tbody>
<tr>
<td>Attendance</td>
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<tr>
<td>Hours of week</td>
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<table>
<thead>
<tr>
<th>Recommended semester</th>
<th>Frequency</th>
<th>Pflicht/Wahlpflicht (P/WP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>unregelmäßig</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Contents**

In the exercises, students will learn through example scenarios to apply the principles and methods from the lectures.

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level

**Compulsory requirement**

↑

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Technische Fakultät
**Name of module**  
Einführung in Embedded Systems / Introduction to Embedded Systems

**Number of module**  
11LE13MO-910_PO 2020

**Responsible**  
Prof. Dr. Christoph Scholl

**Organizer**  
Institut für Informatik Betriebssysteme  
Institut für Informatik Embedded Systems

**Faculty**  
Technische Fakultät

**ECTS-Points**  
6.0

**Workload**  
180 Stunden | hours

**Recommended semester**  
3

**Duration**  
1 Semester

**Pflicht/Wahlpflicht (P/WP)**  
Wahlpflicht

**Frequency**  
 nur im Wintersemester

**Compulsory requirement**  
keine | none

**Recommended requirement**  
Basic knowledge in the field of technical informatics, analog and digital circuits, programming knowledge in C / C++

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tbody>
<tr>
<td>Einführung in Embedded Systems / Introduction to Embedded Systems</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>3.0</td>
<td>180 Stunden</td>
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<tr>
<td>Einführung in Embedded Systems / Introduction to Embedded Systems</td>
<td>Übung</td>
<td></td>
<td>1.0</td>
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<td></td>
</tr>
</tbody>
</table>

**Qualification**


Students understand the specific properties of embedded systems, their architecture and components, their hardware and software interface, the communication between components, basic analog-digital-analog conversion methods, low-power designs and specification techniques. They will be able to specify embedded systems with VHDL, statechart and petri-nets and reason about properties of the modeled system, and write basic programs in C for an embedded platform.
### Examination achievement

Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes)

### Course achievement

Es gibt Übungsaufgaben im regelmäßigen Rhythmus, die bearbeitet und abgegeben werden müssen. Diese werden korrigiert und mit Punkten bewertet. Die Studienleistung ist bestanden, wenn mindestens 50% der Gesamtpunkte im Semester erreicht sind.

Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. The Studienleistung counts as passed if at least 50% of the overall number of achievable points for the semester has been reached.

### Recommendation

The lecture will be held in English (there are some recordings available in German from previous semesters).
The exercises will be offered in German as well as in English.

### Usability

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) in Essential Lectures in Computer Science

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Pflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018)

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Informatik (PO 2018)
- polyvalenten 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
- Bachelor of Science in Mikrosystemtechnik (PO 2018), im Wahlpflichtbereich, Bereich Mikrosystemtechnik
Embedded Systems are considered the key application in information technology for the years to come. As the name suggests, they are systems embedding information processing into an environment, where complex control or data processing tasks are executed. The lecture deals with the basic concepts for modelling and designing embedded systems. Among others it covers specification languages and methods for embedded systems (such as statecharts, petri nets, VHDL), the mapping of specifications on processes, hardware of Embedded Systems as well as hardware/software codesign. It addresses the construction elements of an embedded system (e.g. processors, AD/DA converters, sensors, sensor interfaces, memory devices) and presents methods for the design and optimization of the associated circuits with respect to speed, energy consumption and testability.
### Course achievement

Siehe Modulebene | See module level

### Literature


### Compulsory requirement

keine | none

### Recommended requirement

Grundkenntnisse im Bereich Technische Informatik, analoge und digitale Schaltkreise, Programmierkenntnisse in C / C++ | Basic knowledge in the field of technical informatics, analog and digital circuits, programming knowledge in C / C++
### Name of module

| Einführung in Embedded Systems / Introduction to Embedded Systems | 11LE13MO-910_PO 2020 |

### Veranstaltung

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<th>Einführung in Embedded Systems / Introduction to Embedded Systems</th>
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<tbody>
<tr>
<td>Event type</td>
</tr>
<tr>
<td>Übung</td>
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### Organizer

Institut für Informatik Betriebssysteme
Institut für Informatik Embedded Systems

### ECTS-Points

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<td>Recommended semester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>nur im Wintersemester</td>
<td></td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
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</tr>
</tbody>
</table>

### Contents

Die Übungen bestehen aus theoretischen Aufgaben und Programmieraufgaben, um die Methoden und Konzepte der Vorlesung in praktischen Anwendungen einzusetzen.

The exercises consist of theoretical assignments and programming assignments, to apply the methods and concepts from the lecture.

### Examination achievement

Siehe Modulebene | See module level

### Course achievement

Siehe Modulebene | See module level

### Compulsory requirement

↑
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
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<tbody>
<tr>
<td>Embedded Computing Entrepreneurship (2ES)</td>
<td>11LE13MO-1404_PO 2020</td>
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</tbody>
</table>

**Responsible**

Prof. Dr. Oliver Amft

**Organizer**

Institut für Informatik Intelligente Eingebettete Systeme

**Faculty**

Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>Workload</th>
<th>Recommended semester</th>
<th>Duration</th>
<th>Pflicht/Wahlpflicht (P WP)</th>
<th>Frequency</th>
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<tbody>
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<td>6.0</td>
<td>180 Stunden / Hours</td>
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<td>1 Semester</td>
<td>Wahlpflicht</td>
<td>unregelmäßig</td>
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</table>

**Compulsory requirement**

keine | none

**Recommended requirement**

keine | none

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tr>
<td>Embedded Computing Entrepreneurship (2ES)</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>1.0</td>
<td>180 Stunden / Hours</td>
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<td>Übung</td>
<td>2.0</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Qualification**

* Conceptualise and design embedded sensor systems along a specific application.
* Develop and demonstrate key components of embedded sensor systems, including signal and pattern analysis and recognition algorithms.
* Develop a basic market analysis and business plan.
* Implement an agile development process.

**Examination achievement**

Presentation followed by an oral examination  
(10 minutes per person, total duration depends on group size)
### Course achievement

Regular attendance of the course (seminar and exercise) according to §13 (2) of the General Examination Regulations for the Bachelor of Science/Master of Science, as otherwise the required group work and scientific discussion is not possible.

Further elements of the course work are the creation of demonstrators or software as well as a written elaboration/protocol.

### Usability

**Compulsory elective module for students of the study program**

- M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems
- M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme
- M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems or Concentration Biomedical Engineering OR Elective Courses in Computer Science
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses

Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

and

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering
### Embedded Computing Entrepreneurship (2ES)

**Event type**

<table>
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<tr>
<td>Embedded Computing Entrepreneurship (2ES)</td>
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**Veranstaltung**

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**Organizer**

Institut für Informatik Intelligente Eingebettete Systeme

**ECTS-Points**

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**Workload**

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**Attendance**

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**Recommended semester**

unregelmäßig

**Pflicht/Wahlpflicht (P/WP)**

| Pflicht/Wahlpflicht (P/WP) | |
|----------------------------||

**Contents**

The course combines technical and business-related lectures on embedded sensor systems with a practical system development project using agile development methods. Students will organise in groups and define together with their advisor(s) goals for the technical development, market analysis, etc. Student groups can enter their projects for an award of the VDE.

**Examination achievement**

see module details

**Course achievement**

see module details

**Literature**

Relevant literature will be provided during the lectures and consultations.

**Compulsory requirement**

None

**Recommended requirement**

Basic pattern recognition methods; basic programming skills
<table>
<thead>
<tr>
<th>Name of module</th>
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<tbody>
<tr>
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**Veranstaltung**

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### Embedded Computing Entrepreneurship (2ES)

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**Contents**

- Examination achievement
  - see module details
- Course achievement
  - see module details
- Compulsory requirement

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**Technische Fakultät**  
**Page:** 147 of 332
### Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

**Name of module** | **Number of module**
--- | ---
Formale Methoden für Java / Formal Methods for Java | 11LE13MO-1210_PO 2020

### Responsible

Prof. Dr. Andreas Podelski  
Prof. Dr. Peter Thiemann

### Organizer

Institut für Informatik Softwaretechnik

### Faculty

Technische Fakultät

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### Compulsory requirement

keine | none

### Recommended requirement

Kenntnisse in Programmierung, Algorithmen und Datenstrukturen, Logik und Softwaretechnik | Programming skills, knowledge of algorithms and data structures, logic and software engineering

### Assigned Courses

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### Qualification

The students have an overview of the different types of verification tools. They can assess what these tools can do, and use them to verify programs. Students will be able to use interactive theorem provers.

### Examination achievement

Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes)  
(Wenn die Teilnehmerzahl sehr klein ist, kann stattdessen eine mündliche Prüfung (i.d.R. 30 oder 45 Minuten) durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If number of participants is small, might be changed to oral exam (usually 30 or 45 minutes) instead. Students will be notified in good time.)
**Course achievement**

| keine | none |

**Recommendation**

Freiwillige Teilnahme an den Übungen wird stärkstens empfohlen. |
Voluntary participation in the exercises is highly recommended.

**Usability**

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

**Wahlpflichtmodul für Studierende des Studiengangs**
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
Name of module | Number of module
---|---
Formale Methoden für Java / Formal Methods for Java | 11LE13MO-1210_PO 2020

**Veranstaltung**
Formale Methoden für Java / Formal Methods for Java - Vorlesung

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Organizer
Institut für Informatik Softwaretechnik

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<td>Frequency</td>
<td>nur im Wintersemester</td>
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**Contents**

Recently, formal methods have been successfully used to specify and verify large software system. In this lecture we will investigate the existing methods for the language Java. The language Java was chosen because it is a mature language, with a semi-formal definition of its semantics (The Java Language Specification). However, to use mathematical reasoning, we need a precise definition of the semantics. Therefore, we will sketch the definition of an operational semantics for Java. Furthermore, we will investigate different formal methods for Java. The starting point will be the language extension JML that allows Design by Contract. This allows to add pre- and postconditions to methods and invariants to classes and loops. These assertions can be checked during runtime and this is the purpose of the JML runtime assertion checker (jml-rac). On the other hand, there are static methods, e.g., ESC/Java and Jahob, that automatically provide mathematical proofs that the Java code ensures the post-condition for each possible pre-condition. If these proofs cannot be find automatically, one can also use theorem provers that assists finding a proof manually. The lecture will present the different approaches for verification of Java code, which are applied to small practical examples in the exercise.

**Examination achievement**
Siehe Modulebene | See module level

**Course achievement**
Siehe Modulebene | See module level

**Compulsory requirement**
keine | none

**Recommended requirement**
Kenntnisse in Programmierung, Algorithmen und Datenstrukturen, Logik und Softwaretechnik
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<td>Formale Methoden für Java / Formal Methods for Java</td>
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**Organizer**

Institut für Informatik Softwaretechnik

**ECTS-Points**

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**Frequency**

<table>
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<th>Pflicht/Wahlpflicht (P/WP)</th>
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**Contents**

In den Übungen lernen die Studierenden anhand von Beispielszenarien, die Prinzipien und Methoden aus den Vorlesungen anzuwenden.

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level

**Compulsory requirement**
### Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

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**Responsible**

Prof. Dr. Frank Roman Hutter

**Organizer**

Institut für Informatik Maschinelles Lernen

**Faculty**

Technische Fakultät

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**Compulsory requirement**

none

**Recommended requirement**

Knowledge of linear algebra and machine learning

**Assigned Courses**

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**Qualification**


**Examination achievement**

Written exam (usually 90 to 180 minutes)

If the number of participants is small, an oral examination (usually 30 or 45 minutes) may be held instead. The students will be informed in good time.

**Course achievement**

Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of the overall number of achievable points for the semester.
**Usability**

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
In this course, we will cover the Foundations of Deep Learning, primarily using the book "Deep Learning" by Goodfellow, Bengio, and Courville.

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Knowledge of linear algebra and machine learning
### Name of module | Number of module
---|---
Foundations of Deep Learning | 11LE13MO-1145.PO 2020

#### Veranstaltung

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#### Organizer

Institut für Informatik Maschinelles Lernen

#### ECTS-Points

#### Hours of week

#### Recommended semester

#### Frequency

nur im Wintersemester

#### Pflicht/Wahlpflicht (P/WP)

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Siehe Modulebene |
See module level

#### Course achievement

Siehe Modulebene |
See module level

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<td>Funktionale Programmierung / Functional Programming</td>
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Responsible
Prof. Dr. Peter Thiemann

Organizer
Institut für Informatik Programmiersprache

Faculty
Technische Fakultät

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Compulsory requirement
keine | none

Recommended requirement
Spaß am Programmieren und am Lernen und Anwenden neuer Programmierkonzepte und -sprachen. Weiterhin empfehlenswert: Einführung in die Programmierung erfolgreich absolviert Eigener Laptop

Interest in learning and applying new programming concepts and languages. Also beneficial: Introduction to programming successfully completed Own laptop

Assigned Courses

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Contents
This course conveys fundamental concepts of functional programming using the programming language Haskell.
**Qualification**

Development of a non-procedural view on algorithms and data structures, confident handling of higher-order functions and data, knowledge and ability to apply fundamental functional programming techniques, knowledge of advanced programming concepts, ability to develop medium-size functional programs independently.

**Examination achievement**

Klausur (i.d.R. 90 bis 180 Minuten)  
Written exam (usually 90 to 180 minutes)

(Wenn die Teilnehmerzahl < 20 ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert.  
If number of participants is < 20, might be changed to oral exam instead. Students will be notified in good time.)

**Course achievement**

keine | none

**Usability**

Compulsory elective module for students of the study program

- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs

- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
In this course, fundamental and some advanced concepts of functional programming using the programming language Haskell are taught. The list of topics includes:

- Definition of functions, pattern matching, and higher-order functions
- Types and type classes
- Algebraic data types
- Functional data structures
- Applicative parsers
- Monads and monad transformers
- Arrows
- Verification of functional programs
- Generic programming with algebras

This course covers foundational and some advanced concepts of functional programming using the programming language Haskell. The list of topics includes:

- Definition of functions, pattern matching, and higher-order functions
- Types and type classes
- Algebraic data types
- Functional data structures
- I/O, monads, and monad transformers
- Parsers and applicatives
- Arrows
- Verification of functional programs
- Generic programming with algebras
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</tr>
<tr>
<td>The book Programming in Haskell by Graham Hutton is the basis for the first 30% of the lecture. This book is available in the TF-library. Stephen Diehl's WHAT I WISH I KNEW WHEN LEARNING HASKELL</td>
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Stephen Diehl's WHAT I WISH I KNEW WHEN LEARNING HASKELL
### Name of module | Number of module
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Funktionale Programmierung / Functional Programming | 11LE13MO-1216_PO 2020

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**Organizer**

Institut für Informatik Programmiersprache

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

| Pflicht/Wahlpflicht (P/WP) |  |

**Contents**

In den Übungen lernen die Studierenden anhand von Beispielszenarien, die Prinzipien und Methoden aus den Vorlesungen anzuwenden.

In the exercises, students will learn through example scenarios to apply the principles and methods from the lectures.

**Examination achievement**

Siehe Modulebene |

**Course achievement**

Siehe Modulebene |

**Compulsory requirement**


### Name of module
Grundlagen von Programmiersprachen / Essentials of Programming Languages

### Number of module
11LE13MO-1222_PO 2020

### Responsible
Prof. Dr. Peter Thiemann

### Organizer
Institut für Informatik Programmiersprache

### Faculty
Technische Fakultät

### ECTS-Points
6.0

### Workload
180 Stunden | hours

### Recommended semester
2

### Duration
1 Semester

### Pflicht/Wahlpflicht (P/WP)
Wahlpflicht

### Frequency
unregelmäßig

### Compulsory requirement
keine | none

### Recommended requirement
Interest in learning and applying new programming concepts and languages.
Also beneficial:
Basic programming knowledge
We recommend having and using your own laptop

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<td>Grundlagen von Programmiersprachen / Essentials of Programming Languages</td>
<td>Vorlesung</td>
<td></td>
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<td></td>
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<tr>
<td>Grundlagen von Programmiersprachen / Essentials of Programming Languages - Übung</td>
<td>Übung</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Qualification
Students have a basic understanding of the descriptive means that a programming language can provide. They have mastered methods for modeling the syntax and semantics of programming languages. Students know tools to support modeling and can use them for selected problems.
<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
</table>

As compulsory elective in
- M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) in Elective Courses in Computer Science

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering
### Name of module
Grundlagen von Programmiersprachen / Essentials of Programming Languages

### Number of module
11LE13MO-1222_PO 2020

### Veranstaltung
Grundlagen von Programmiersprachen / Essentials of Programming Languages

### Event type
Vorlesung

### Number
11LE13V-1222

### Organizer
Institut für Informatik Programmiersprache

### ECTS-Points
<table>
<thead>
<tr>
<th>Workload</th>
<th>180 Stunden</th>
<th>hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance</td>
<td>42 Stunden</td>
<td>hours</td>
</tr>
<tr>
<td>Independent study</td>
<td>124 Stunden</td>
<td>hours</td>
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<td>Hours of week</td>
<td>3.0</td>
<td></td>
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<td>2</td>
<td></td>
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<tr>
<td>Frequency</td>
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<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
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<td></td>
</tr>
</tbody>
</table>

### Contents
This course conveys the mathematical and logical concepts underlying programming languages using the language Agda. Agda is a functional language with an advanced type system that enables the encoding of many program properties in its types. Agda's type checker verifies proofs of these properties, so that one could also say this course is about verified programming.

The first part of the course covers the logical background needed to study the theory of programming languages to the extent that we can give formal guarantees about the execution of a program. The second part of the course puts this toolbox to work. We use Agda's features to model the syntax and the semantics of (simple) programming languages. We model type systems and connect them to the semantics through type soundness theorems.

### Examination achievement
schriftliche Hausarbeit | written homework

### Course achievement
siehe Übung | see exercises

### Literature
online book Programming Language Foundations in Agda (PLFA) by Philipp Wadler, Wen Kokke, and Jeremy Siek

### Compulsory requirement
keine | none

### Recommended requirement
Interest in learning and applying new programming concepts and languages. Basic programming knowledge as well as basic foundations in mathematical logic. We recommend having and using your own laptop.
### Name of module

| Grundlagen von Programmiersprachen / Essentials of Programming Languages | 11LE13MO-1222_PO 2020 |

### Veranstaltung

| Veranstaltung | Grundlagen von Programmiersprachen / Essentials of Programming Languages - Übung |

<table>
<thead>
<tr>
<th>Übung type</th>
<th>Number</th>
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<tr>
<td>Übung</td>
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| Organizer | Institut für Informatik Programmiersprache |

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>Attendance</th>
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<tr>
<td></td>
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<table>
<thead>
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</thead>
</table>

| Recommended semester | 2 |

| Frequency | unregelmäßig |

| Pflicht/Wahlpflicht (P/WP) |

### Contents

Repetition of lecture's material and deepening of selected topics.

We discuss the exercises of the corresponding chapters (contained in the online book "Programming Language Foundations in Agda" (PLFA) by Philipp Wadler, Wen Kokke, and Jeremy Siek), and answer general questions related to Agda, Theorem Proving and Programming Language Theory.

### Examination achievement

siehe Vorlesung | see lecture

### Course achievement

keine | none

Both the exercises and the exercise sessions are voluntary, but we highly recommend doing the exercises and participating in the discussions.

### Compulsory requirement
**Name of module**
Hardware Security and Trust

**Number of module**
11LE13MO-1227_PO 2020

**Responsible**
Prof. Dr. Christoph Scholl

**Organizer**
Institut für Informatik Betriebssysteme

**Faculty**
Technische Fakultät

**ECTS-Points**
6.0

**Workload**
180 Stunden | hours

**Recommended semester**
2

**Duration**
1 Semester

**Pflicht/Wahlpflicht (P/WP)**
Wahlpflicht

**Frequency**
unregelmäßig

**Compulsory requirement**
keine | none

**Recommended requirement**
Grundlagenwissen zu Kryptographie und Authentifizierung, VLSI Entwurf, Test und Verifikation | Basic knowledge of cryptography and authentication, VLSI design, testing and verification

Grundlagenwissen zu Technischer Informatik
Basic knowledge of technical computer science

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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</thead>
<tbody>
<tr>
<td>Hardware Security and Trust</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>3.0</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Hardware Security and Trust</td>
<td>Übung</td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Qualification**


Insbesondere:
Physical and invasive attacks, side-channel attacks, physically unclonable functions, hardware-based true random number generators, watermarking of Intellectual Property (IP) blocks, FPGA security, passive and active metering for prevention of piracy, access control, hardware Trojan detection and isolation in IP cores and integrated circuits (ICs).
Students know the basics of cryptography, authentication, secret sharing, VLSI design, testing, reliability and verification. Based on this, they will have an overview of the current state of research in the field of "Hardware Security and Trust". They know about various potential attack techniques and know how to avert or minimize these dangers. Especially:

Physical and invasive attacks, side-channel attacks, physically unclonable functions, hardware-based true random number generators, watermarking of Intellectual Property (IP) blocks, FPGA security, passive and active metering for prevention of piracy, access control, hardware Trojan detection and isolation in IP cores and integrated circuits (ICs).

Examination achievement

Klausur (i.d.R. 90 bis 180 Minuten) |
Written exam (usually 90 to 180 minutes)

(Wenn die Teilnehmerzahl sehr klein ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert. |
If number of participants is small, might be changed to oral exam instead. Students will be notified in good time.)

Course achievement

keine | none

Usability

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
**Name of module**  
Hardware Security and Trust

**Number of module**  
11LE13MO-1227_PO 2020

**Veranstaltung**  
Hardware Security and Trust

**Event type**  
Vorlesung

**Number**  
11LE13V-1227

**Organizer**  
Institut für Informatik Rechnerarchitektur  
Institut für Informatik Betriebssysteme

**ECTS-Points**  
6.0

**Workload**  
180 Stunden | hours

**Attendance**  
48 Stunden

**Independent study**  
116 Stunden

**Hours of week**  
3.0

**Recommended semester**  
unregelmäßig

**Pflicht/Wahlpflicht (P/WP)**

**Contents**


Zu Beginn werden die (notwendigen) Grundlagen über Kryptographie, Authentifizierung, Secret Sharing, VLSI Entwurf, Test, Zuverlässigkeit und Verifikation gelegt. Dann erfolgt eine Einführung in "Hardware Security and Trust", bei der folgende Themen angesprochen werden: Physical and invasive attacks, side-channel attacks, physically unclonable functions, hardware-based true random number generators, watermarking of Intellectual Property (IP) blocks, FPGA security, passive and active metering for prevention of piracy, access control, hardware Trojan detection and isolation in IP cores and integrated circuits (ICs).

The convergence of IT systems, data networks (including but not limited to the Internet) and ubiquitous embedded devices within the cyber-physical system paradigm has led to the emergence of new security threats associated with the system hardware. Manipulating the hardware components that implement security functions can compromise system integrity, provide unauthorized access to protected data, and endanger intellectual property. Addressing these vulnerabilities is essential in order to prevent the hardware from becoming the weak spot of today's systems. At least a basic knowledge of hardware security and trust issues is of importance to all system designers.

Starting with (necessary) basics on cryptography, authentication, secret sharing, VLSI design, test, reliability and verification the course will provide an introduction to hardware security and trust covering the following topics: physical and invasive attacks, side-channel attacks, physically unclonable functions, hard-
ware-based true random number generators, watermarking of Intellectual Property (IP) blocks, FPGA security, passive and active metering for prevention of piracy, access control, hardware Trojan detection and isolation in IP cores and integrated circuits (ICs).

Examination achievement

Siehe Modulebene | See module level

Course achievement

Siehe Modulebene | See module level

Literature

Introduction to Hardware Security and Trust
Editors: Tehranipoor, Mohammad, Wang, Cliff (Eds.), Springer

Compulsory requirement

keine | none

Recommended requirement

Grundlagenwissen zu Kryptographie und Authentifizierung, VLSI Entwurf, Test und Verifikation | Basic knowledge of cryptography and authentication, VLSI design, testing and verification

Grundlagenwissen zu Technischer Informatik
Basic knowledge of technical computer science
**Name of module**
- Hardware Security and Trust  

**Number of module**
- 11LE13MO-1227_PO 2020

**Veranstaltung**

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Übung</td>
<td>11LE13Ü-1227</td>
</tr>
</tbody>
</table>

**Organizer**

- Institut für Informatik Rechnerarchitektur
- Institut für Informatik Betriebssysteme

**ECTS-Points**

**Attendance**
- 16 Stunden

**Hours of week**
- 1.0

**Recommended semester**

**Frequency**
- unregelmäßig

**Pflicht/Wahlpflicht (P/WP)**

**Contents**

Übungen vertiefen Methoden und Algorithmen, die in der Vorlesung eingeführt wurden, anhand von praktischen Beispielen.

<table>
<thead>
<tr>
<th>Examination achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siehe Modulebene</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siehe Modulebene</td>
</tr>
</tbody>
</table>

**Compulsory requirement**
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-throughput data analysis with Galaxy</td>
<td>11LE13MO-1350_PO 2020</td>
</tr>
</tbody>
</table>

**Responsible**

Prof. Dr. Rolf Backofen

**Organizer**

Institut für Informatik Bioinformatik

**Faculty**

Technische Fakultät

<table>
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<tr>
<th>ECTS-Points</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden/hours</td>
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<tr>
<td>Recommended semester</td>
<td>2</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>in jedem Semester</td>
</tr>
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</table>

**Compulsory requirement**

None

**Recommended requirement**

Basic knowledge in bioinformatics. It is highly recommended to attend the lecture and exercise "Introduction to data driven life sciences" (11LE13V-1335) before attending this course. This course builds on the content of this lecture.

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tbody>
<tr>
<td>High-throughput data analysis with Galaxy</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>1.0</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>High-throughput data analysis with Galaxy</td>
<td>Übung</td>
<td></td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Qualification**

In biological and medical research big data analysis is urgently needed for understanding the information which is encoded in the molecules of life. Many diseases, such as cancer, are caused by aberrations in those molecules. This lecture and exercise gives an practical introduction to the analysis of big data in life sciences. The open source web-based framework Galaxy (usegalaxy.eu) is used for data intensive biomedical research. Galaxy provides access to a powerful analysis infrastructure and allows for reproducible and transparent data analysis. Creating pipelines and workflows in Galaxy ensure a transparent and reproducible analysis of data.

After attending the course, students:
- can name different data formats
- know tools for bioinformatics data analysis
- know about different data analysis concepts
- know basic workflows of bioinformatics data analysis
### Exams
- Klausur / written exam

### Course requirement
- schriftliche Ausarbeitung, Protokoll / written composition

### Usability
- Compulsory elective module for students of the study program
  - M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
  - M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science
### Name of module
High-throughput data analysis with Galaxy

### Number of module
11LE13MO-1350_PO 2020

### Veranstaltung
High-throughput data analysis with Galaxy

### Event type
Vorlesung

### Number
11LE13V-1350_PO 2020

### ECTS-Points
6.0

### Workload
180 Stunden | hours

### Attendance
10 Stunden / hours

### Independent study
140 Stunden / hours

### Hours of week
1.0

### Recommended semester
2

### Frequency
in jedem Semester

### Pflicht/Wahlpflicht (P/WP)

---

### Contents
The course is offered as block course of one week. In the morning, a theoretical introduction gives an overview of the topic of the day and the underlying theoretical background of data types, tools, workflows and Galaxy functions.

### Examination achievement
See module level

### Course achievement
See module level

### Literature
Resources used in the course
- about the Galaxy project: https://galaxyproject.org
- the European Galaxy server: https://usegalaxy.eu

### Compulsory requirement
none

### Recommended requirement
Basic knowledge in bioinformatics It is highly recommended to attend the lecture and exercise "Introduction to data driven life sciences" (11LE13V-1335) before attending this course. This course builds on the content of this lecture.
**Name of module**
High-throughput data analysis with Galaxy

**Number of module**
11LE13MO-1350_PO 2020

### Veranstaltung

**High-throughput data analysis with Galaxy**

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
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<tbody>
<tr>
<td>Übung</td>
<td>11LE13Ü-1350_PO 2020</td>
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</table>

**Organizer**
Institut für Informatik Bioinformatik

### ECTS-Points

<table>
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<th>30 Stunden / hours</th>
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<td>2</td>
</tr>
<tr>
<td>Frequency</td>
<td>in jedem Semester</td>
</tr>
</tbody>
</table>

### Contents

Afterwards the gained knowledge is applied by hands-on experience of real data analysis. The course is led by different experts and supervisors to assist the participants in the practical part.

**Examination achievement**
See module level

**Course achievement**
See module level

**Compulsory requirement**
Name of module | Number of module
---|---
High-Performance Computing: Fluid Mechanics with Python | 11LE50MO-5285

Responsible
Prof. Dr. Lars Pastewka

Organizer
Institut für Mikrosystemtechnik Simulation

Faculty
Technische Fakultät

| ECTS-Points | 6.0 |
| Workload | 180 Stunden | hours |
| Recommended semester | 2 |
| Duration | 1 Semester |
| Pflicht/Wahlpflicht (P/WP) | Wahlpflicht |
| Frequency | nur im Sommersemester |

Compulsory requirement
None

Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

Assigned Courses

<table>
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<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
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<tbody>
<tr>
<td>High-Performance Computing: Fluid Mechanics with Python</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>2.0</td>
<td>180 Stunden</td>
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<tr>
<td>High-Performance Computing: Fluid Mechanics with Python</td>
<td>Übung</td>
<td></td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Qualification

The student
- can use Python for solving numerical problems using the numpy and scipy libraries and knows strategies for writing efficient code
- can apply the Message Passing Interface (MPI) libraries to parallelize specific numerical problems
- can use job submission systems on parallel computers to run their Python codes.

Examination achievement

Written examination. The students have to submit a written report, describing numerical results and scaling tests obtained with their simulation code.

Course achievement
none
Usability

Wahlpflichtmodul für Studierende des Studiengangs
- Bachelor of Science in Mikrosystemtechnik (PO 2018), im Wahlpflichtbereich, Bereich Mikrosystemtechnik
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Mikrosystemtechnik

As compulsory elective module for students of the study program
- M.Sc. Microsystems Engineering and M.Sc. Mikrosystemtechnik
- M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) in Microsystems Engineering Concentrations Area: Materials and Fabrication

Students enrolled in the Master of Science in Sustainable Systems Engineering (2021 version of the examination regulations) can complete this elective module in the technical concentration area Sustainable Materials Engineering or Interdisciplinary Profile - Modules related to the Subject Area.
This class teaches parallel scientific computing with Python using the numpy library for fast array operations. Parallelization strategies that use the Message Passing Interface (MPI) will be presented. These technical concepts will be applied to the solution of fluid mechanical problems using the lattice Boltzmann method.

Scientific computing:
1. Efficient Python: basics, numpy arrays, numpy operations, scipy
2. Translating mathematical expressions into efficient array operations
3. The Message Passing Interface (MPI)
4. Parallelization strategies
5. Practical aspects of working with High-Performance clusters

Fluid mechanics and the Lattice Boltzmann method:
6. Phenomenology of fluid mechanics
7. Lattice gas and lattice Boltzmann
8. Boundary conditions

Literature
A. Scopatz, K.D. Huff, "Effective Computation in Physics" (O'Reilly 2015)
<table>
<thead>
<tr>
<th>Compulsory requirement</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended requirement</td>
<td>Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)</td>
</tr>
</tbody>
</table>
### Contents

The students will implement their own parallel Lattice Boltzmann simulation code in the computer lab accompanying this lecture series.

### Examination achievement

See module level

### Course achievement

See module level

### Compulsory requirement

None

### Recommended requirement

Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)
### Name of module

High-Performance Computing: Molecular Dynamics with C++

### Number of module

11LE50MO-5288 PO 2021

### Responsible

Prof. Dr. Lars Pastewka

### Organizer

Institut für Mikrosystemtechnik Simulation

### Faculty

Technische Fakultät

### ECTS-Points

6.0

### Workload

180 Stunden | hours

### Recommended semester

2

### Duration

1 semester

### Pflicht/Wahlpflicht (P/WP)

Wahlpflicht

### Frequency

nur im Sommersemester

### Compulsory requirement

None

### Recommended requirement

Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
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<th>HoW</th>
<th>Workload</th>
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<tbody>
<tr>
<td>High-Performance Computing: Molecular Dynamics with C++</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>2.0</td>
<td>180</td>
<td>hours</td>
</tr>
<tr>
<td>High-Performance Computing: Molecular Dynamics with C++</td>
<td>Übung</td>
<td>2.0</td>
<td>-</td>
<td></td>
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</tr>
</tbody>
</table>

### Qualification

The student
- understands the physics of interatomic bonds, potential energy landscapes and the statistical foundations of thermodynamics
- can transfer these concepts to molecular simulations, in particular interatomic potentials, transition paths, thermostats and barostats
- can select initial conditions and interatomic potentials, run a molecular dynamics simulation and evaluate and interpret the simulation results

### Examination achievement

Written report
### Course achievement

There are exercises at regular intervals that have to be worked on and handed in. These are corrected and assessed with points. The course work is passed if 50% of the exercise sheets have been successfully completed.

### Usability

As compulsory elective in
- M.Sc. Microsystems Engineering (PO 2021), Concentrations Area: Materials and Fabrication
- M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse
- M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) in Microsystems Engineering Concentrations Area: Materials and Fabrication

- Students enrolled in the Master of Science in Sustainable Systems Engineering (2021 version of the exam regulations) can complete this elective module in the technical concentration area Sustainable Materials Engineering.
Name of module | Number of module
--- | ---
High-Performance Computing: Molecular Dynamics with C++ | 11LE50MO-5288 PO 2021

**Veranstaltung**

High-Performance Computing: Molecular Dynamics with C++

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE50V-5286</td>
</tr>
</tbody>
</table>

Organizer

Institut für Mikrosystemtechnik Simulation

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 hours</td>
</tr>
<tr>
<td>Attendance</td>
<td>56 Stunden</td>
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<tr>
<td>Independent study</td>
<td>124 Stunden</td>
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<td>Hours of week</td>
<td>2.0</td>
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<tr>
<td>Recommended semester</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>nur im Sommersemester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
</tr>
</tbody>
</table>

**Contents**

This lecture introduces atomic-scale simulation techniques with a focus on solid mechanics.

1. Materials physics
2. Interatomic potentials
3. Molecular statics and potential energy landscapes
4. Molecular dynamics
5. Classical statistical mechanics
6. Thermostats and barostats
7. Analysis and visualization

**Examination achievement**

see module details

**Course achievement**

see module details

**Literature**


**Compulsory requirement**

None

**Recommended requirement**

Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)
High-Performance Computing: Molecular Dynamics with C++

**Veranstaltung**

High-Performance Computing: Molecular Dynamics with C++

**Event type**

Übung

**Number**

11LE50Ü-5286

**Organizer**

Institut für Mikrosystemtechnik Simulation

**ECTS-Points**

- 

**Workload**

- 

**Attendance**

- 

**Independent study**

- 

**Hours of week**

2.0

**Recommended semester**

2.0

**Frequency**

nur im Sommersemester

**Pflicht/Wahlpflicht (P/WP)**


**Contents**

The students will solve problems from materials science with a widely used molecular simulation code.

Successful completion of >=50% of exercise sheets

**Examination achievement**

see module details

**Course achievement**

see module details

**Compulsory requirement**

None

**Recommended requirement**

Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)
### Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Retrieval</td>
<td>11LE13MO-1304_PO 2020</td>
</tr>
</tbody>
</table>

**Responsible**

Prof. Dr. Hannah Bast

**Organizer**

Institut für Informatik Algorithmen u. Datenstrukturen

**Faculty**

Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
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<tr>
<td>Workload</td>
<td>180 Stunden</td>
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<tr>
<td>Recommended semester</td>
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<tr>
<td>Duration</td>
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<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
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</table>

**Compulsory requirement**

keine | none

**Recommended requirement**

Fundamental knowledge about algorithms and data structures, programming skills (C++ / C)

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suchmaschinen / Information Retrieval</td>
<td>Vorlesung</td>
<td>2.0</td>
<td>6.0</td>
<td>2.0</td>
<td>180 Stunden</td>
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<tr>
<td>Suchmaschinen / Information Retrieval</td>
<td>Übung</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Qualification**

Students should be able to understand and apply the basics of information systems, especially search engines. This applies to both the algorithmic aspects (e.g. index data structures) and quality aspects (e.g. ranking of search results), as well as network communication and user interfaces (e.g. AJAX programming).

**Examination achievement**

Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes)
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Es gibt Übungsaufgaben im regelmäßigen Rhythmus, die bearbeitet und abgegeben werden müssen. Diese werden korrigiert und mit Punkten bewertet. Die Studienleistung ist bestanden, wenn mindestens 50% der Gesamtpunkte im Semester erreicht sind.</td>
</tr>
<tr>
<td>Exercise sheets have to be completed and handed in on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of the overall number of achievable points for the semester.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compulsory elective module for students of the study program</td>
</tr>
<tr>
<td>■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung</td>
</tr>
<tr>
<td>■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science</td>
</tr>
<tr>
<td>Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering</td>
</tr>
<tr>
<td>Wahlpflichtmodul für Studierende des Studiengangs</td>
</tr>
<tr>
<td>■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik</td>
</tr>
<tr>
<td>■ B.Sc. in Informatik (PO 2018)</td>
</tr>
<tr>
<td>■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)</td>
</tr>
<tr>
<td>■ M.Ed. Informatik (PO 2018)</td>
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<tr>
<td>■ Master of Education Erweiterungsfach Informatik (PO 2021)</td>
</tr>
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</table>
**Name of module**: Information Retrieval  
**Number of module**: 11LE13MO-1304_PO 2020

**Veranstaltung**

**Suchmaschinen / Information Retrieval**

**Event type**: Vorlesung  
**Number**: 11LE13V-1304

**Organizer**: Institut für Informatik Algorithmen u. Datenstrukturen

<table>
<thead>
<tr>
<th>ECTS-Points</th>
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<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
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<tr>
<td>Attendance</td>
<td>30 Stunden</td>
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<td>Independent study</td>
<td>120 Stunden</td>
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<td>Hours of week</td>
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<tr>
<td>Recommended semester</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>nur im Wintersemester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
</tr>
</tbody>
</table>

**Contents**

In dieser Vorlesung werden alle Themen behandelt, die man zur Realisierung der typischen Funktionalität eines Informationssystems / einer Suchmaschine nach dem Stand der Kunst braucht, und die nicht oder nicht in der erforderlichen Tiefe in Bachelor- oder Mastervorlesungen zum Thema Algorithmen oder Netzwerke vermittelt werden. Dazu gehören:

- Algorithmen und Datenstrukturen, z.B.: invertierter Index, Präfixsuche, fehlertolerante Suche, I/O-Effizienz.
- Qualitätsaspekte: Ranking von Suchergebnissen, Clustering, maschinelle Lernverfahren.

This course teaches all topics required to understand and implement a search engine with standard functionality according to the state of the art. Topics include: inverted index, ranking, list intersection, compression, fuzzy search, web applications, synonym search, clustering, text classification, and ontology search.

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level

**Literature**

Wird in der Veranstaltung bekanntgegeben.

Ein Standardbuch das einen Großteil des Veranstaltungsinhalts abdeckt, ist “Manning, Raghavan, Schütze: Introduction to Information Retrieval” (auch online verfügbar: http://nlp.stanford.edu/IR-book). All materials needed for the course are provided during the course.
A standard text book covering much of the course material is “Manning, Raghavan, Schütze: Introduction to Information Retrieval”, which is also available online: http://nlp.stanford.edu/IR-book.

<table>
<thead>
<tr>
<th>Compulsory requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>keine</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommended requirement</th>
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</thead>
<tbody>
<tr>
<td>Grundlagen zu Algorithmen und Datenstrukturen, Programmierkenntnisse (C++ / C)</td>
</tr>
</tbody>
</table>
### Name of module
Information Retrieval

### Number of module
11LE13MO-1304_PO 2020

### Veranstaltung

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suchmaschinen / Information Retrieval</td>
<td></td>
</tr>
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</table>

### Event type

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>Übung</td>
<td>11LE13Ü-1304</td>
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### Organizer
Institut für Informatik Algorithmen u. Datenstrukturen

### ECTS-Points

<table>
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<tr>
<td>Hours of week</td>
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</tbody>
</table>

### Recommended semester
nur im Wintersemester

### Frequency
nur im Wintersemester

### Pflicht/Wahlpflicht (P/WP)

### Contents
Praktische Anwendung der Methoden aus der Vorlesung |
Practical application of the methods from the lecture

### Examination achievement
Siehe Modulebene |
See module level

### Course achievement
Siehe Modulebene |
See module level

### Compulsory requirement
Introduction to data driven life sciences

Responsible
Prof. Dr. Rolf Backofen

Organizer
Institut für Informatik Bioinformatik

Faculty
Technische Fakultät

ECTS-Points 6.0
Workload 180 Stunden | hours
Recommended semester 3
Duration 1 Semester
Pflicht/Wahlpflicht (P/WP) Wahlpflicht
Frequency nur im Wintersemester

Compulsory requirement
None

Recommended requirement
None

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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</thead>
<tbody>
<tr>
<td>Introduction to data driven life sciences</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>2.0</td>
<td>2.0</td>
<td>180 hours</td>
</tr>
<tr>
<td>Introduction to data driven life sciences</td>
<td>Übung</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Qualification
In biological and medical research big data analysis is urgently needed for understanding the information that is encoded in the molecules of life. Many diseases, such as cancer, are caused by aberrations in those molecules. Students understand the theoretical biological and bioinformatics background and know about techniques for generation and analysis of high-throughput data in life sciences.

Examination achievement
Oral exam (usually 30 or 45 minutes)
If the number of participants is very high (> 30), a written examination may be held instead. The students will be informed in good time.

Course achievement
none

Recommendation
Solving exercise sheets is optional but highly recommended.
### Usability

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (PO 2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Elective Courses in Computer Science

Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

**Important note for M.Sc. Informatik / Computer Science:**
This module is available as both
- a specialization lecture in Computer Science (with a graded assessment / Prüfungsleistung)
- as a course in the application area Applied Bioinformatics (as pass/fail course / Studienleistung) (see according module in online module handbook / planner of studies)

Take care during the booking process, as that will define the category in which the course is considered. **You can't change the category afterwards!** So, you can't change it from PL to SL or vice versa.

Wahlpflichtmodul für Studierende des Studiengangs
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
Introduction to data driven life sciences

Veranstaltung

Introduction to data driven life sciences

Event type

Vorlesung

Organizer

Institut für Informatik Bioinformatik

ECTS-Points 6.0
Workload 180 hours
Attendance 30 hours
Independent study 120 hours
Hours of week 2.0
Recommended semester
Frequency nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)

Contents
In biological and medical research big data analysis is urgently needed for understanding the information that is encoded in the molecules of life. Many diseases, such as cancer, are caused by aberrations in those molecules. In this lecture you will learn the theoretical biological and bioinformatics background and techniques for generation and analysis of high-throughput data in life sciences.

Examination achievement
see module details

Course achievement
see module details

Compulsory requirement
None

Recommended requirement
None

Recommendation
Important note for M.Sc. Computer Science:
This module is available as both
- a specialization lecture in Computer Science (with a graded assessment / Prüfungsleistung)
- as a course in the application area Applied Bioinformatics (as pass/fail course / Studienleistung)

Take care during the booking process, as that will define the category in which the course is considered.
You can't change the category afterwards!
So, you can't change it from PL to SL or vice versa.

↑
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to data driven life sciences</td>
<td>11LE13MO-1335_PO 2020</td>
</tr>
</tbody>
</table>

Veranstaltung

<table>
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<tr>
<th>Veranstaltung</th>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to data driven life sciences</td>
<td>Übung</td>
<td>11LE13Ü-1335</td>
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Organizer

Institut für Informatik Bioinformatik

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>Attendance</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Hours of week</td>
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</tr>
<tr>
<td>Recommended semester</td>
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<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>nur im Wintersemester</td>
<td></td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Contents

To apply the gained knowledge from the lecture, exercises to various topics of high-throughput data analysis are offered. Moreover, we will get to know the workflow management framework Galaxy which is an open source tool for life science data analysis.

Examination achievement

See module level

Course achievement

See module level

Compulsory requirement

↑
Name of module | Number of module
--- | ---
Introduction to Mobile Robotics | 11LE13MO-1115_PO 2020

Responsibility
Dr. Tim Welschehold

Organizer
Institut für Informatik Autonome intelligente Systeme

Faculty
Technische Fakultät

ECTS-Points | 6.0
--- | ---
Workload | 180 Stunden | hours
Recommended semester | 2
Duration | 1 Semester
Pflicht/Wahlpflicht (P/WP) | Wahlpflicht
Frequency | nur im Sommersemester

Compulsory requirement
keine | none

Recommended requirement
Vorausgesetzt: Grundlegende Kenntnisse in Algorithmen, Programmierkenntnisse
Von Vorteil: Grundlagen im Bereich Künstliche Intelligenz, grundlegende, einfache molekularbiologische Kenntnisse
Required: Basic knowledge of algorithms, programming skills
Advantageous: Basic knowledge about Artificial Intelligence, basic, simple knowledge of molecular biology

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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</thead>
<tbody>
<tr>
<td>Introduction to Mobile Robotics</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>3.0</td>
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<tr>
<td>Introduction to Mobile Robotics</td>
<td>Übung</td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

Qualification
The goal of this course is to understand the basic principles of mobile robotics. They include different types of drives and sensors for mobile robots including their characteristics, the recursive Bayes filter, the Kalman filter, the particle filter, and the discrete filter. In addition, successful participants will understand the principles of probabilistic localization, mapping, simultaneous localization and mapping as well as path planning, collision avoidance, sensor interpretation, and exploration.
### Examination achievement

<table>
<thead>
<tr>
<th>Klausur (i.d.R. 90 bis 180 Minuten)</th>
<th>Written exam (usually 90 to 180 minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wenn die Teilnehmerzahl sehr klein ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert.</td>
<td>If number of participants is small, might be changed to oral exam instead. Students will be notified in good time.</td>
</tr>
</tbody>
</table>

### Course achievement

<table>
<thead>
<tr>
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<th>none</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solving the exercise sheets is recommended but not mandatory</td>
<td></td>
</tr>
</tbody>
</table>

### Usability

<table>
<thead>
<tr>
<th>Compulsory elective module for students of the study program</th>
</tr>
</thead>
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<tr>
<td>■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung</td>
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<tr>
<td>Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Wahlpflichtmodul für Studierende des Studiengangs</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik</td>
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<tr>
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<td>■ Master of Education Erweiterungsfach Informatik (PO 2021)</td>
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</table>
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
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</thead>
<tbody>
<tr>
<td>Introduction to Mobile Robotics</td>
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</table>

**Veranstaltung**

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Event type</th>
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</tr>
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<tbody>
<tr>
<td>Introduction to Mobile Robotics</td>
<td>Vorlesung</td>
<td>11LE13V-1115</td>
</tr>
</tbody>
</table>

**Organizer**

Institut für Informatik Autonome intelligente Systeme

**ECTS-Points**

6.0

**Workload**

180 Stunden | hours

**Attendance**

39 Stunden

**Independent study**

128 Stunden

**Hours of week**

3.0

**Recommended semester**

nur im Sommersemester

**Pflicht/Wahlpflicht (P/WP)**


**Contents**

This course will introduce basic concepts and techniques used within the field of mobile robotics. We analyze the fundamental challenges for autonomous intelligent systems and present the state of the art solutions. Among other topics, we will discuss:

- Kinematics
- Sensors
- Vehicle localization
- Map building
- SLAM
- Path planning

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level

**Literature**


**Compulsory requirement**

keine | none

**Recommended requirement**

Von Vorteil bzw. vorausgesetzt sind

- Grundlegende, einfache molekularbiologische Kenntnisse
- Grundlegende Kenntnisse in Algorithmen, wie aus Informatik Grundstudium/Bachelor
Advantageous or required
- Basic, simple knowledge of molecular biology
- Basic knowledge of algorithms, such as from computer science undergraduate / bachelor's degree
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
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<tr>
<td>Introduction to Mobile Robotics</td>
<td></td>
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<tr>
<td>Event type</td>
<td>Number</td>
</tr>
<tr>
<td>Übung</td>
<td>11LE13Ü-1115</td>
</tr>
<tr>
<td>Organizer</td>
<td>Institut für Informatik Autonome intelligente Systeme</td>
</tr>
</tbody>
</table>

**ECTS-Points**

| Attendance | 13 Stunden |
| Hours of week | 1.0          |
| Recommended semester |                |
| Frequency | nur im Sommersemester |
| Pflicht/Wahlpflicht (P/WP) |                |

**Contents**

In the exercises, students will learn the practical application of principles and methods from the lectures. Each exercise session consists of two parts: a short recap of the lecture and the discussion of the exercise sheets.

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level

**Compulsory requirement**
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isabelle/HOL: programming, verified!</td>
<td>11LE13MO-1336_PO 2020</td>
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</table>

**Responsible**

Prof. Dr. Armin Biere

**Organizer**

Institut für Informatik Rechnerarchitektur

**Faculty**

Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>2</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
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<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
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</table>

**Compulsory requirement**

None

**Recommended requirement**

There is no formal requirement, but this course will deal with proofs of correctness (of programs, data structures). Therefore, you should not be scared by reading quantifiers and understanding properties.

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isabelle/HOL: programming, verified!</td>
<td>Vorlesung</td>
<td></td>
<td>2.0</td>
<td></td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Isabelle/HOL: programming, verified!</td>
<td>Übung</td>
<td></td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Qualification**

The student knows how write proofs in the proof assistant Isabelle/HOL and verify programs and data structures. In particular, they are familiar with the concept of induction, inductive predicates, program refinement, and program generation.

**Examination achievement**

Written graded assessment

(Please see "Bemerkung / Empfehlung" resp. "Remark / Recommendation" for more information)

**Course achievement**

Weekly exercise with proofs to do in Isabelle will be given every week. You need to (at least try to) solve those.
Recommendation

There will be no exam, but instead there will be a project: You will work on your own formalization.

Usability

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Informatik (PO 2018)
- B.Sc. in Embedded Systems Engineering (PO 2018)
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isabelle/HOL: programming, verified!</td>
<td>11LE13MO-1336_PO 2020</td>
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### Veranstaltung

<table>
<thead>
<tr>
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<th>Event type</th>
<th>Number</th>
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<tbody>
<tr>
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<td>Vorlesung</td>
<td>11LE13V-1336_PO 2020</td>
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<table>
<thead>
<tr>
<th>Organizer</th>
<th></th>
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<tbody>
<tr>
<td>Institut für Informatik Rechnerarchitektur</td>
<td></td>
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<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Attendance</td>
<td>28 Stunden</td>
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<tr>
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<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
</tr>
</tbody>
</table>

| Pflicht/Wahlpflicht (P/WP)               |                         |

### Contents

This course is divided in two parts. In the first one, you will learn to use the proof assistant Isabelle/HOL and how to convince the system that your proof is correct. In the second part, you will work on verifying programs in Isabelle/HOL and exporting them such that you can also execute them outside of the proof assistant.

### Examination achievement

Siehe Modulebene | See module level

### Course achievement

Siehe Modulebene | See module level

### Literature

The part of the lecture that focuses on Isabelle can be nicely completed by reading the first part of "Concrete Semantics in Isabelle/HOL" book by Nipkow and Klein (http://concrete-semantics.org/, PDF available). The second part of lecture focuses on program verification. It will draw some inspiration from the "Functional Algorithms Verified" book (https://functional-algorithms-verified.org/, PDF available) that focuses on data structures and their performance.

### Compulsory requirement

None

### Recommended requirement

There is no formal requirement, but this course will deal with proofs of correctness (of programs, data structures). Therefore, you should not be scared by reading quantifiers and understanding properties.
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isabelle/HOL: programming, verified!</td>
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**Veranstaltung**

<table>
<thead>
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<tr>
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<td>Übung</td>
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<tr>
<td>Organizer</td>
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**ECTS-Points**

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<th>hours</th>
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<td></td>
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<tr>
<td>Recommended semester</td>
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</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Contents**

You are required to bring a laptop for the exercise session. During the exercises, you will practice theorems proving and refinement in Isabelle. At the end of the course, you will have a larger project to do (most likely over three weeks) that will replace the exercise sessions in order for you to practice on a larger scale proofs.

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level

**Compulsory requirement**
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science</td>
<td>11LE13MO-1112_PO 2020</td>
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</tbody>
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Responsible
Prof. Dr. Rolf Backofen

Faculty
Technische Fakultät

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<td>Workload</td>
<td>180 hours</td>
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<td>Recommended semester</td>
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<tr>
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<td>Wahlpflicht</td>
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<tr>
<td>Frequency</td>
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</tr>
</tbody>
</table>

Compulsory requirement
none

Recommended requirement
Knowledge in Machine Learning and Bioinformatics, basic knowledge in Molecular biology

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tbody>
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<td>Vorlesung</td>
<td>6.0</td>
<td>2.0</td>
<td>180 Stunden</td>
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<td>Übung</td>
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<td></td>
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</tbody>
</table>

Qualification
Students learn to consider machine learning applications in life sciences from different perspectives. They understand the biological point of view in regards to problems in the domains of genomics, proteomics, systems biology and biological literature information mining. They also have an understanding of different questions from the machine learning point of view, such as underlying assumptions in predictive models, the quality assessment problem, the design choices for supervised and unsupervised models.

Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) |  
Written exam (usually 90 to 180 minutes)

Wenn die Teilnehmerzahl gering ist (< 20), kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert.

If the number of participants is small (< 20), an oral examination may be held instead. The students will be informed in good time.
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Course achievement</th>
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</table>

**Usability**

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Students of the M.Sc. programmes Microsystems Engg. and Mikrosystemtechnik (PO 2021) can select this module in the concentration area Biomedical Engineering (Biomedizinische Technik).
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science

Veranstaltung

Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science

Event type

Vorlesung

Organizer

Institut für Informatik Bioinformatik

ECTS-Points

6.0

Workload

180 Stunden | hours

Attendance

30 Stunden

Independent study

120 Stunden

Hours of week

2.0

Recommended semester

nur im Wintersemester

Contents

The course will maintain a double perspective: from the biological point of view we consider problems in the domains of genomics, proteomics, systems biology and biological literature information mining; from the machine learning point of view, we consider questions such as the underlying assumptions in predictive models, the quality assessment problem, the design choices for supervised and unsupervised models.

Examination achievement

Siehe Modulebene | See module level

Course achievement

Siehe Modulebene | See module level

Literature

The course material is based on influential publications both in the Machine Learning and/or Bioinformatics literature:

- P Baldi, S Brunak, Y Chauvin, C.A.F Andersen, H Nielsen, Assessing the accuracy of prediction algorithms for classification: an overview, Bioinformatics 2000
- T Fawcett, An introduction to ROC analysis, Pattern Recognition Letters 2006
- T Dietterich, Approximate statistical tests for comparing supervised classification learning algorithms, Neural Computation 1998
- D Jiang, C Tang, A Zhang, Cluster analysis for gene expression data: A survey, IEEE transactions on knowledge and data engineering 2004
- S.C Madeira, A.L Oliveira, Biclustering algorithms for biological data analysis: a survey, IEEE Transactions on computational Biology and Bioinformatics 2004
- A Krause, J Stoye, Large scale hierarchical clustering of protein sequences, BMC bioinformatics 2005
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

- X.W. Chen, Prediction of protein-protein interactions using random decision forest framework, Bioinformatics 2005

<table>
<thead>
<tr>
<th>Compulsory requirement</th>
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</thead>
<tbody>
<tr>
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</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Recommended requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge in Machine Learning and Bioinformatics, basic knowledge in Molecular biology</td>
</tr>
</tbody>
</table>

↑
### Name of module

Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science

### Number of module

11LE13MO-1112_PO 2020

---

#### Veranstaltung

Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science

#### Event type

Übung

#### Organizer

Institut für Informatik Bioinformatik

#### ECTS-Points

<table>
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<tr>
<td>Frequency</td>
<td>nur im Wintersemester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
</tr>
</tbody>
</table>

---

#### Contents

In the exercises, students will learn through example scenarios to apply the principles and methods from the lectures.

---

#### Examination achievement

Siehe Modulebene | See module level

#### Course achievement

Siehe Modulebene | See module level

#### Compulsory requirement

↑
### Name of module
Modellbildung und Systemidentifikation

### Number of module
11LE50MO-2080_PO 2020

### Responsible
Prof. Dr. Moritz Diehl

### Organizer
Institut für Mikrosystemtechnik Systemtheorie

### Faculty
Technische Fakultät

### ECTS-Points
6.0

### Workload
180 hours

### Recommended semester
1

### Duration
1 Semester

### Pflicht/Wahlpflicht (P/WP)
Wahlpflicht

### Frequency
nur im Wintersemester

### Compulsory requirement
keine | none

### Recommended requirement
fundamental knowledge in higher mathematics

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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</thead>
<tbody>
<tr>
<td>Modellbildung und Systemidentifikation / Modelling and System Identification</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>2.0</td>
<td>180 hours</td>
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<tr>
<td>Modellbildung und Systemidentifikation / Modelling and System Identification</td>
<td>Übung</td>
<td></td>
<td>2.0</td>
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<td></td>
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</tbody>
</table>

### Qualification

Aim of the module is to enable the students to create and identify models that help to describe and predict the behaviour of dynamic systems. In particular, students shall become able to use input-output measurement data in form of time series to identify unknown system parameters and to assess the validity and accuracy of the obtained models.

### Examination achievement
Written exam (180 minutes)
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The course work is successfully completed if both of the following criteria are met:</td>
</tr>
<tr>
<td>1) Passing the exercise: For each exercise sheet, the achieved points are determined in percentage points with respect to the maximum score of the respective exercise sheet. The two exercise sheets with the lowest percentage points achieved will not be included in the assessment. The exercise is considered passed if the average of the achieved percentage points in the remaining exercise sheets is at least 50 percentage points.</td>
</tr>
<tr>
<td>2) Passing the micro-examinations: For each micro-examination, the points achieved are determined in percentage points with respect to the maximum number of points. The micro-exam in which the fewest percentage points were obtained will not be included in the evaluation. The microclauses are considered passed if the average of the percentage points achieved in the remaining microclauses is at least 50 percentage points.</td>
</tr>
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<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>- Master of Science Informatik / Computer Science in Spezialvorlesung</td>
</tr>
<tr>
<td>- Master of Science Embedded Systems Engineering (ESE) in Advanced Microsystems Engineering</td>
</tr>
<tr>
<td>- Master of Science Microsystems Engineering (PO 2021) in Advanced Microsystems</td>
</tr>
<tr>
<td>- Master of Science Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme</td>
</tr>
<tr>
<td>Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering</td>
</tr>
<tr>
<td>Wahlpflichtmodul für Studierende des Studiengangs</td>
</tr>
<tr>
<td>- Master of Education Erweiterungsfach Informatik (PO 2021)</td>
</tr>
</tbody>
</table>
### Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
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</thead>
<tbody>
<tr>
<td>Modellbildung und Systemidentifikation</td>
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#### Veranstaltung

**Modellbildung und Systemidentifikation / Modelling and System Identification**

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE50V-2080</td>
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</table>

**Organizer**

Institut für Mikrosystemtechnik Systemtheorie

<table>
<thead>
<tr>
<th>ECTS-Points</th>
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<tbody>
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<td>Recommended semester</td>
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<tr>
<td>Frequency</td>
<td>nur im Wintersemester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
</tr>
</tbody>
</table>

#### Contents

Linear and Nonlinear Least Squares, Maximum Likelihood and Bayesian Estimation, Cramer-Rao-Inequality, Recursive Estimation, Dynamic System Model Classes (Linear and Nonlinear, Continuous and Discrete Time, State Space and Input Output, White Box and Black Box Models), Application of identification methods to several case studies. The lecture course will also review necessary concepts from the three fields Statistics, Optimization, and Systems Theory, where needed.

#### Examination achievement

see module details

#### Course achievement

see module details

#### Literature

1. Lecture manuscript
3. Lecture manuscript "System Identification" by J

#### Compulsory requirement

None

#### Recommended requirement

Undergraduate knowledge in analysis, algebra, differential equations as well as in systems theory and feedback control.
### Name of module
- Modellbildung und Systemidentifikation

### Number of module
- 11LE50MO-2080_PO 2020

### Veranstaltung
- Modellbildung und Systemidentifikation / Modelling and System Identification

### Event type
- Übung

### Number
- 11LE50Ü-2080

### Organizer
- Institut für Mikrosystemtechnik Systemtheorie

### ECTS-Points
| Hours of week | 2.0 |

### Recommended semester

### Frequency
- nur im Wintersemester

### Pflicht/Wahlpflicht (P/WP)

### Contents
- The exercises accompany the lecture content and are mostly computer exercises and case studies.

### Examination achievement
- see module details

### Course achievement
- see module details

### Compulsory requirement
- none

### Recommended requirement
- none
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

Name of module | Number of module
---|---
Netzwerkalgorithmen / Network Algorithms | 11LE13MO-1313_PO 2020

Responsible
Prof. Dr. Fabian Kuhn

Organizer
Institut für Informatik Algorithmen und Komplexität

Faculty
Technische Fakultät

ECTS-Points | 6.0
---|---
Workload | 180 Stunden | hours
Recommended semester | 2
Duration | 1 Semester
Pflicht/Wahlpflicht (P/WP) | Wahlpflicht
Frequency | unregelmäßig

Compulsory requirement
keine | none

Recommended requirement
Basic knowledge in algorithm design/analysis, mathematical maturity (in particular, we use some graph theory and probability theory)

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tr>
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<td>Übung</td>
<td></td>
<td></td>
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</tbody>
</table>

Qualification
Networks and distributed computing are essential in modern computing and information systems. The objective of the course is to learn fundamental principles and mathematical/algorithmic techniques underlying the design of distributed algorithms for solving tasks in networks and distributed systems.

Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes)
(Wenn die Teilnehmerzahl sehr klein ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If number of participants is small, might be changed to oral exam instead. Students will be notified in good time.)
<table>
<thead>
<tr>
<th>Course achievement</th>
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<tbody>
<tr>
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Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
Name of module | Number of module
---|---
Netzwerkalgorithmen / Network Algorithms | 11LE13MO-1313_PO 2020

Veranstaltung

Netzwerkalgorithmen / Network Algorithms - Vorlesung

Event type | Number
---|---
Vorlesung | 11LE13V-1313

Organizer

Institut für Informatik Algorithmen und Komplexität

ECTS-Points | 6.0
---|---
Workload | 180 Stunden | hours
Attendance | 39 Stunden
Independent study | 128 Stunden
Hours of week | 3.0
Recommended semester

Frequency | nur im Sommersemester

Pflicht/Wahlpflicht (P/WP)

Contents

The topics are taught by going through many key example problems. Particular topics that are covered include: communication, coordination, fault-tolerance, locality, parallelism, self-organization, symmetry breaking, synchronization, uncertainty

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Compulsory requirement

Recommended requirement

Basic knowledge in algorithm design/analysis, mathematical maturity (in particular, we use some graph theory and probability theory)
<table>
<thead>
<tr>
<th>Name of module</th>
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</tr>
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<td>Netzwerkalgorithmen / Network Algorithms</td>
<td>11LE13MO-1313_PO 2020</td>
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**Veranstaltung**

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<th>Netzwerkalgorithmen / Network Algorithms - Übung</th>
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<tbody>
<tr>
<td>Event type</td>
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<tr>
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</table>

**Organizer**

Institut für Informatik Algorithmen und Komplexität

**ECTS-Points**

<table>
<thead>
<tr>
<th>Attendance</th>
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</tr>
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**Recommended semester**

nur im Sommersemester

**Pflicht/Wahlpflicht (P/WP)**

---

**Contents**

**Examination achievement**

<table>
<thead>
<tr>
<th>Siehe Modulebene</th>
<th>See module level</th>
</tr>
</thead>
</table>

**Course achievement**

<table>
<thead>
<tr>
<th>Siehe Modulebene</th>
<th>See module level</th>
</tr>
</thead>
</table>

**Compulsory requirement**

---
### Name of module

Numerical Optimization

### Number of module

11LE50MO-5243_PO 2020

### Responsible

Prof. Dr. Moritz Diehl

### Organizer

Institut für Mikrosystemtechnik Systemtheorie

### Faculty

Technische Fakultät

### ECTS-Points

6.0

### Workload

180 Stunden | hours

### Recommended semester

3

### Duration

1 Semester

### Pflicht/Wahlpflicht (P/WP)

Wahlpflicht

### Frequency

nur im Wintersemester

### Compulsory requirement

none

### Recommended requirement

Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tbody>
<tr>
<td>Numerische Optimierung / Numerical Optimization</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>4.0</td>
<td>180 hours</td>
<td></td>
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<tr>
<td>Numerische Optimierung / Numerical Optimization</td>
<td>Übung</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Qualification

The students know different types of optimization problems and can discuss their theoretical background and implement and analyze numerical methods for solving them.

### Examination achievement

Written exam (180 minutes)

### Course achievement

The course work is completed if students pass the mid-term online quiz.
Usability

Compulsory elective module for students of the study program

- M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Elective Courses in Computer Science
- M.Sc. Microsystems Engineering in Microsystems Engineering (PO 2021) Concentrations Area: Circuits and Systems
- M.Sc. Informatik / Computer Science (PO 2020), in Spezialvorlesung | Specialization Courses

Part of the specialization Cyber-Physical Systems in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering

Important note for M.Sc. Informatik / Computer Science:
This module is available as both
- a specialization lecture in Computer Science (with a graded assessment / Prüfungsleistung)
- as a course in the application area Applied Bioinformatics (as pass/fail course / Studienleistung) (see according module in online module handbook / planner of studies)

Take care during the booking process, as that will define the category in which the course is considered. You can't change the category afterwards! So, you can't change it from PL to SL or vice versa.

Wahlpflichtmodul für Studierende des Studiengangs

- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
### Contents

The course is divided into four major parts:

1. **Fundamental Concepts of Optimization**: Definitions, Types, Convexity, Duality
2. **Unconstrained Optimization and Newton Type Algorithms**: Stability of Solutions, Gradient and Conjugate Gradient, Exact Newton, Quasi-Newton, BFGS and Limited Memory BFGS, and Gauss-Newton, Line Search and Trust Region Methods, Algorithmic Differentiation
3. **Equality Constrained Optimization Algorithms**: Newton Lagrange and Generalized Gauss-Newton, Range and Null Space Methods, Quasi-Newton and Adjoint Based Inexact Newton Methods
4. **Inequality Constrained Optimization Algorithms**: Karush-Kuhn-Tucker Conditions, Linear and Quadratic Programming, Active Set Methods, Interior Point Methods, Sequential Quadratic and Convex Programming, Quadratic and Nonlinear Parametric Optimization

### Examination achievement

see module details

### Course achievement

see module details

### Literature


### Compulsory requirement

None

### Recommended requirement

Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerical Optimization</td>
<td>11LE50MO-5243_PO 2020</td>
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**Veranstaltung**

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerische Optimierung / Numerical Optimization</td>
<td>Übung</td>
<td>11LE50Ü-5243</td>
</tr>
</tbody>
</table>

**Organizer**

Institut für Mikrosystemtechnik Systemtheorie

**ECTS-Points**

| Hours of week | 2.0 |

**Recommended semester**

| Frequency       | nur im Wintersemester |

**Pflicht/Wahlpflicht (P/WP)**

**Contents**

In der Übung werden die Inhalte der Vorlesung anhand theoretischer Beispielaufgaben sowie mit Rechnerübungen vertieft.

**Examination achievement**

see module details

**Course achievement**

see module details

**Compulsory requirement**

None

**Recommended requirement**

Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses
**Name of module** | **Number of module**
--- | ---
Peer-to-Peer Netzwerke / Peer-to-Peer Networks | 11LE13MO-1314_PO 2020

**Responsible**
Prof. Dr. Christian Schindelhauer

**Organizer**
Institut für Informatik Rechnernetze u. Telematik

**Faculty**
Technische Fakultät

---

**ECTS-Points** | **6.0**
--- | ---
**Workload** | 180 Stunden | hours
**Recommended semester** | 2
**Duration** | 1 Semester

**Pflicht/Wahlpflicht (P/WP)** | **Wahlpflicht**
**Frequency** | unregelmäßig

**Compulsory requirement**
keine | none

**Recommended requirement**
Basic knowledge in algorithms and data structures, computer networks, telecommunication systems and distributed systems

---

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tr>
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<td>Vorlesung</td>
<td></td>
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<td>180 Stunden</td>
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<td>Peer-to-Peer Netzwerke / Peer-to-Peer Networks - Übung</td>
<td>Übung</td>
<td></td>
<td>2.0</td>
<td></td>
<td>180 Stunden</td>
</tr>
</tbody>
</table>

**Qualification**

Students know the underlying methods and algorithms for peer-to-peer network architectures. They know and can apply different methods for storing, resulting in various networks for different purposes. They understand the application of cryptographic methods to peer-to-peer networks, especially Block-chain technology. Students have knowledge about self-organizing networks, allowing for the use of repair mechanisms of peer-to-peer networks under churn and attacks.

**Examination achievement**
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes)
### Course achievement

keine | none

### Usability

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
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<tbody>
<tr>
<td>Peer-to-Peer Netzwerke / Peer-to-Peer Networks</td>
<td>11LE13MO-1314_PO 2020</td>
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**Veranstaltung**

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Peer-to-Peer Netzwerke / Peer-to-Peer Networks - Vorlesung</th>
</tr>
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<tbody>
<tr>
<td>Event type</td>
<td>Vorlesung</td>
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<tr>
<td>Number</td>
<td>11LE13V-1314</td>
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<table>
<thead>
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<th>Organizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institut für Informatik Rechnernetze u. Telematik</td>
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**ECTS-Points**

<table>
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<tr>
<th>Workload</th>
<th>180 Stunden</th>
<th>hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance</td>
<td>32 Stunden</td>
<td></td>
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<tr>
<td>Independent study</td>
<td>116 Stunden</td>
<td></td>
</tr>
<tr>
<td>Hours of week</td>
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</tr>
<tr>
<td>Recommended semester</td>
<td>unregelmäßig</td>
<td></td>
</tr>
</tbody>
</table>

**Contents**

After a brief introduction to the history of peer-to-peer networks relevant topics related to the Internet and distributed systems are deepened. First, the example of unstructured networks Gnutella are discussed, followed by structured networks. These, e.g. such as CAN, Chord, Pastry and Tapestry, are presented in very detail. We concentrate on data and network structures, as well the theoretical analysis of peer-to-peer networks. Other issues are minimal networks, networks with tree structures and self-organizing networks. As special issues we discuss security, anonymity and game theory in peer-to-peer networks.

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level

**Literature**

- Shen, X.; Yu, H.; Buford, J.; Akon, M. (Eds.): Handbook of Peer-to-Peer Networking, Springer 2010

**Compulsory requirement**

keine | none

**Recommended requirement**

Basic knowledge in algorithms and data structures, computer networks, telecommunication systems and distributed systems
### Name of module

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peer-to-Peer Netzwerke / Peer-to-Peer Networks</td>
<td>11LE13MO-1314_PO 2020</td>
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### Veranstaltung

**Peer-to-Peer Netzwerke / Peer-to-Peer Networks - Übung**

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<tbody>
<tr>
<td>Übung</td>
<td>11LE13Ü-1314</td>
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</table>

### Organizer

Institut für Informatik Rechnernetze u. Telematik

### ECTS-Points

<table>
<thead>
<tr>
<th>Workload</th>
<th>180 Stunden</th>
<th>hours</th>
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<tbody>
<tr>
<td>Attendance</td>
<td>32 Stunden</td>
<td></td>
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<tr>
<td>Hours of week</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Recommended semester</td>
<td>unregelmäßig</td>
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</tbody>
</table>

### Contents

- Siehe Modulebene | See module level
- Siehe Modulebene | See module level
- Compulsory requirement

### Examination achievement

- Siehe Modulebene | See module level

### Course achievement

- Siehe Modulebene | See module level
### Name of module
- Probabilistic Graphical Models

### Number of module
- 11E13MO-1228_PO 2020

### Responsible
- Prof. Dr. Joschka Bödecker

### Organizer
- Institut für Informatik Neurorobotik

### Faculty
- Technische Fakultät

### ECTS-Points
- 6.0

### Workload
- 180 Stunden / hours

### Recommended semester
- 1

### Duration
- 1 Semester

### Pflicht/Wahlpflicht (P/WP)
- Wahlpflicht

### Frequency
- nur im Sommersemester

### Compulsory requirement
- keine / none

### Recommended requirement
- Prior knowledge of probability theory, machine learning, deep learning, reinforcement learning is an advantage.

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tr>
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<td>3.0</td>
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<td>Probabilistic Graphical Models</td>
<td>Übung</td>
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</tbody>
</table>

### Qualification

Students understand the concepts of probabilistic graphical models, including the mathematical foundations, representation, structure, inference, learning, identifying causal relations, as well as connections to deep learning and control. They are able to apply these methods to practical modeling and control problems from various domains of science and engineering.

### Examination achievement
- Klausur / written exam

### Course achievement
- Bearbeitung von Übungsblättern / Completing exercise assignments
<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
</table>

Compulsory elective module for students of the study program

- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

and

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering
## Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
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</thead>
<tbody>
<tr>
<td>Probabilistic Graphical Models</td>
<td>11E13MO-1228_PO 2020</td>
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### Veranstaltung

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Number</th>
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<tbody>
<tr>
<td>Probabilistic Graphical Models</td>
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<table>
<thead>
<tr>
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<th>Number</th>
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<tbody>
<tr>
<td>Vorlesung</td>
<td>11E13V-1228_PO 2020</td>
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### Organizer

| Institut für Informatik Neurorobotik |

<table>
<thead>
<tr>
<th>ECTS-Points</th>
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<tr>
<td>Workload</td>
<td>180 Stunden / hours</td>
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<tr>
<td>Attendance</td>
<td>48 Stunden / hours</td>
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<tr>
<td>Independent study</td>
<td>116 Stunden / Hours</td>
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<td>Hours of week</td>
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<tr>
<td>Recommended semester</td>
<td>1</td>
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<tr>
<td>Frequency</td>
<td>nur im Sommersemester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
</tr>
</tbody>
</table>

### Contents

Lectures will cover: Introduction, Review of fundamental concepts from probability and graph theory, Bayesian classifiers, Hidden Markov Models, Bayesian Networks, Extension to dynamic and temporal variants, Decision Graphs, Markov Decision Processes, Control as Inference, Graphical Causal Models, Causal Discovery, Deep Learning and Graphical Models

### Examination achievement

See module level

### Course achievement

See module level

### Literature


### Compulsory requirement

keine / none

### Recommended requirement

Prior knowledge of probability theory, machine learning, deep learning, reinforcement learning is an advantage.

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**Edition: 28. March 2024**

**Technische Fakultät**

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## Name of module

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<tr>
<th>Name of module</th>
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</tr>
</thead>
<tbody>
<tr>
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## Veranstaltung

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Übung</td>
<td>11E13Ü-1228_PO 2020</td>
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</table>

## Organizer

Institut für Informatik Neurorobotik

## ECTS-Points

<table>
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<tr>
<th>Hours of week</th>
<th>Recommended semester</th>
<th>Frequency</th>
<th>Pflicht/Wahlpflicht (P/WP)</th>
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<tbody>
<tr>
<td>1.0</td>
<td>1</td>
<td>nur im Sommersemester</td>
<td></td>
</tr>
</tbody>
</table>

## Contents

Theoretical and coding-based exercises in Python will accompany the lectures to help deepen the understanding of concepts from lectures, as well as provide the opportunity to gain some hands-on experience in applying the methods to solve selected problems.

## Examination achievement

See module level

## Course achievement

See module level

## Compulsory requirement
### Name of module
Quantitative Verifikation / Quantitative Verification

### Number of module
11LE13MO-1346_PO 2020

### Responsible
Prof. Dr. Armin Biere  
Prof. Dr. Ralf Wimmer

### Organizer
Institut für Informatik Rechnerarchitektur

### Faculty
Technische Fakultät

### ECTS-Points
6.0

### Workload
180 Stunden | hours

### Recommended semester
2

### Duration
1 Semester

### Pflicht/Wahlpflicht (P/WP)
Wahlpflicht

### Frequency
unregelmäßig

### Compulsory requirement
keine | none

### Recommended requirement
Mathematikkenntnisse im Bereich Analysis und Differentialgleichungen, formale Beweismethoden, Wahr-
scheinlichkeiten |

Knowledge of mathematics in the field of analysis and differential equations, formal proof methods, probabi-
lities

### Assigned Courses
<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
</table>
| Quantitative Verifikation / Quantitative Veri-
cification                                   | Vorlesung |      | 6.0  | 3.0     | 180 Stunden | hours |
| Quantitative Verifikation / Quantitative Veri-
cification                                   | Übung   |      |      |         | 1.0              |

### Qualification
Die Studierenden in der Veranstaltung "Quantitative Verification" sind in der Lage, Modelle und Algorithmen
darzustellen, die es erlauben, Sicherheitseigenschaften quantitativ zu untersuchen und Kostenmaße zu
determine. "Wie lange dauert es im Mittel, bis die Nachricht angekommen ist?"

Die Studierenden kennen die wichtigsten Modelle zur quantitativen Evaluation von Systemen. Sie können
effiziente Algorithmen anwenden, um Eigenschaften wie Ausfallwahrscheinlichkeiten, mittlerer Durchsatz,
erwartete Kosten bis zum Erreichen eines Zieles oder erwartete Langzeitkosten zu bestimmen. Sie sind in
der Lage, aktuelle Arbeiten aus dem Bereich "Probabilistic Model Checking" zu verstehen.

Technische Fakultät
The students in "Quantitative Verification" are able to develop models and algorithms that allow to quantitatively investigate security properties and to calculate cost measures ("How long does it take on average for the message to arrive?"). The students know the most important models for the quantitative evaluation of systems. You can use efficient algorithms to calculate properties such as failure probability, average throughput and expected costs. Determine achievement of a goal or expected long-term costs. You will be able to understand current work in the field of "Probabilistic Model Checking".

<table>
<thead>
<tr>
<th>Examination achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Klausur (i.d.R. 90 bis 180 Minuten)</td>
</tr>
<tr>
<td>Wenn die Teilnehmerzahl sehr klein ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>keine</td>
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<table>
<thead>
<tr>
<th>Usability</th>
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<tbody>
<tr>
<td>Compulsory elective module for students of the study program</td>
</tr>
<tr>
<td>M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung</td>
</tr>
<tr>
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</tbody>
</table>

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
Quantitative Verifikation / Quantitative Verification

**Event type**

Vorlesung 11LE13V-1346

**Organizer**

Institut für Informatik Rechnerarchitektur

**ECTS-Points**

6.0

**Workload**

180 Stunden | hours

**Attendance**

39 Stunden

**Independent study**

128 Stunden

**Hours of week**

3.0

**Recommended semester**

unregelmäßig

**Pflicht/Wahlpflicht (P/WP)**


---

### Contents

Die Studierenden lernen die wichtigsten Modellklassen zur quantitativen Evaluation von Systemen kennen:

* Markov-Ketten mit diskreter und kontinuierlicher Zeit
* Markov-Entscheidungsprozesse
* Markov-Automaten

Wir behandeln Algorithmen zur Berechnung diverser Eigenschaften wie Erreichbarkeitswahrscheinlichkeiten, erwartete Kosten, PCTL- und LTL-Eigenschaften sowie zur Bestimmung des Langzeitverhaltens der Systeme (z.B. Verfügbarkeit, erwartete Kosten auf lange Sicht etc.).

Students get to know the most important model classes for the quantitative evaluation of systems:

* Markov chains with discrete and continuous time
* Markov decision-making processes
* Markov automatons

We deal with algorithms for calculating various properties such as availability probabilities, expected costs, PCTL and LTL properties as well as for determining the long-term behavior of the systems (e.g. availability, expected costs in the long term, etc.).

### Examination achievement

Siehe Modulebene |

See module level

### Course achievement

Siehe Modulebene |

See module level

### Literature

### Compulsory requirement

| keine | none |

### Recommended requirement

**Mathematikkenntnisse im Bereich Analysis und Differentialgleichungen, formale Beweismethoden, Wahr-**

**scheinlichkeiten**

**Knowledge of mathematics in the field of analysis and differential equations, formal proof methods, probabil**

**ities**
### Name of module

Quantitative Verifikation / Quantitative Verification

### Number of module

11LE13MO-1346_PO 2020

### Veranstaltung

Quantitative Verifikation / Quantitative Verification

<table>
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<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Übung</td>
<td>11LE13Ü-1346</td>
</tr>
</tbody>
</table>

### Organizer

Institut für Informatik Rechnerarchitektur

### ECTS-Points

- **Attendance**: 13 Stunden
- **Hours of week**: 1.0
- **Recommended semester**: unregelmäßig

### Contents

In den Übungen sollen die Vorlesungsinhalte vertieft und auf verschiedene Beispiele angewendet werden.

In the exercises, the lecture content should be deepened and applied to various examples.

### Examination achievement

Siehe Modulebene |

See module level

### Course achievement

Siehe Modulebene |

See module level

### Compulsory requirement
**Name of module**: Reinforcement Learning  
**Number of module**: 11LE13MO-1141_PO 2020  
**Responsible**: Prof. Dr. Joschka Bödecker  
**Organizer**: Institut für Informatik Neurorobotik  
**Faculty**: Technische Fakultät  

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>1</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
</tbody>
</table>

**Compulsory requirement**  
keine | none  

**Recommended requirement**  
Grundlagenkenntnisse in praktischer und angewandter Informatik, Algorithmen und Datenstrukturen, Programmierkenntnisse  
Grundlagenwissen zu Künstlicher Intelligenz und Machine Learning  
Basic knowledge of practical and applied computer science, algorithms and data structures, programming skills  
Basic knowledge of artificial intelligence and machine learning

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tbody>
<tr>
<td>Reinforcement Learning</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>3.0</td>
<td>180 Stunden</td>
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<tr>
<td>Reinforcement Learning</td>
<td>Übung</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Qualification**  
- Verständnis der grundlegenden Konzepte des optimierenden Lernes  
- Fähigkeit des Denkens auf unterschiedlichen Abstraktionsebenen  
- Kenntnis in exemplarischen Umsetzungen von Lernalgorithmen  
- Fähigkeit zum selbständigen Erkennen von Zusammenhängen der vorgestellten Konzepte  
- Kenntnisse in der praktischen Anwendung  
- Understanding the basic concepts of optimizing learning  
- Ability to think on different levels of abstraction  
- Knowledge of exemplary implementations of learning algorithms  
- Ability to independently recognize connections between the presented concepts

Technische Fakultät
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

**Knowledge of practical application**

**Examination achievement**

mündliche Prüfung (i.d.R. 30 oder 45 Minuten) / Oral exam (usually 30 or 45 minutes)

Wenn die Teilnehmerzahl sehr groß ist, kann stattdessen eine schriftliche Prüfung (i.d.R. 90 bis 180 Minuten) durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If number of participants is very high, might be exceptionally changed to written examination (usually 90 to 180 minutes) instead. Students will be notified in good time.

**Course achievement**

keine / none

**Usability**

Compulsory elective module for students of the study program

M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses

M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs

B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik

B.Sc. in Informatik (PO 2018)

polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)

M.Ed. Informatik (PO 2018)

Master of Education Erweiterungsfach Informatik (PO 2021)
**Name of module**

Reinforcement Learning

**Number of module**

11LE13MO-1141_PO 2020

**Veranstaltung**

Reinforcement Learning

**Event type**

Vorlesung

**Number**

11LE13V-1141

**Organizer**

Institut für Informatik Neurorobotik

**ECTS-Points**

6.0

**Workload**

180 Stunden | hours

**Attendance**

45 Stunden

**Independent study**

120 Stunden

**Hours of week**

3.0

**Recommended semester**

nur im Wintersemester

| Pflicht/Wahlpflicht (P/WP) |

---

**Contents**

The lecture deals with methods of Reinforcement Learning that constitute an important class of machine learning algorithms. Starting with the formalization of problems as Markov decision processes, a variety of Reinforcement Learning methods are introduced and discussed in-depth. The connection to practice-oriented problems is established by basing the lecture on many examples.

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level

**Literature**

Sutton, Barton: Reinforcement Learning – An Introduction.


**Compulsory requirement**

keine | none

**Recommended requirement**

Grundlagenkenntnisse in praktischer und angewandter Informatik, Algorithmen und Datenstrukturen, Programmierkenntnisse

Grundlagenwissen zu Künstlicher Intelligenz und Machine Learning

Basic knowledge of practical and applied computer science, algorithms and data structures, programming skills

Basic knowledge of artificial intelligence and machine learning
### Name of module

| Reinforcement Learning |

### Number of module

| 11LE13MO-1141_PO 2020 |

### Veranstaltung

| Reinforcement Learning |

### Event type

| Übung |

### Number

| 11LE13Ü-1141 |

### Organizer

| Institut für Informatik Neurorobotik |

### ECTS-Points

| Attendance | 15 Stunden |

| Hours of week | 1.0 |

| Recommended semester |

| Frequency | nur im Wintersemester |

| Pflicht/Wahlpflicht (P/WP) |

### Contents

In the exercises, students will learn through example scenarios to apply the principles and methods from the lectures.

### Examination achievement

Siehe Modulebene | See module level

### Course achievement

Siehe Modulebene | See module level

### Compulsory requirement
**Name of module**  
RNA Bioinformatik / RNA Bioinformatics

**Number of module**  
11LE13MO-1318_PO 2020

**Responsible**  
Prof. Dr. Rolf Backofen

**Organizer**  
Institut für Informatik Bioinformatik

**Faculty**  
Technische Fakultät

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<tr>
<th>ECTS-Points</th>
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<tbody>
<tr>
<td>Workload</td>
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<td>Recommended semester</td>
<td>2</td>
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<tr>
<td>Duration</td>
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<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
</tr>
</tbody>
</table>

**Compulsory requirement**  
keine | none

**Recommended requirement**  
Fundamental understanding of RNA sequence/structure analysis  
Knowledge about principle methods used in Bioinformatics

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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</thead>
<tbody>
<tr>
<td>RNA Bioinformatik / RNA Bioinformatics</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>2.0</td>
<td>180 Stunden</td>
<td>hours</td>
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<tr>
<td>RNA Bioinformatik / RNA Bioinformatics</td>
<td>Übung</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Qualification**

The goal of this module is to get a deeper understanding of the essential algorithms and methods for RNA sequence/structure analysis going beyond the topics covered in Bioinformatics 1 and 2. Students will learn about fundamental algorithms and methods for sequence and structure analysis of the biological macromolecule RNA.  
Students will be able to predict optimal RNA secondary structure and to explain the methods. At the end of the course, they can use probabilistic analysis of structure by partition function approaches, and thus compute base pair probabilities. Furthermore, participants will be able to compare and align RNAs according to their sequence and structural information. This will be possible using techniques for the alignment of folded RNA as well as for the simultaneous operations of alignment and folding. As special topics, students will be able to explain fundamental concepts of and methods for RNA-RNA-interaction prediction, as well as the algorithmic treatment of pseudoknots.
<table>
<thead>
<tr>
<th>Examination achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Klausur (i.d.R. 90 bis 180 Minuten)</td>
</tr>
<tr>
<td>Written exam (usually 90 to 180 minutes)</td>
</tr>
</tbody>
</table>

(Wenn die Teilnehmerzahl gering ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert.)

(If number of participants is small, might be changed to oral exam instead. Students will be notified in good time.)

<table>
<thead>
<tr>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>keine</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
</table>

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
Name of module
RNA Bioinformatik / RNA Bioinformatics

Event type
Vorlesung

Organizer
Institut für Informatik Bioinformatik

ECTS-Points
6.0

Workload
180 Stunden | hours

Attendance
26 Stunden

Independent study
128 Stunden

Hours of week
2.0

Recommended semester
nur im Sommersemester

Contents
Introduction
Structure prediction
- Nussinov algorithm
- Zuker algorithm
- McCaskill algorithm

Comparative RNA analysis:
- Plan A: first align, then fold
- Plan C: first fold, then align
- Plan B: simultaneous alignment and folding

Overview of RNA related tasks and algorithms
- RNA-RNA interactions
- Pseudoknot prediction - Eddy algorithm
- Binding sites of RNA-binding proteins

Examination achievement
Siehe Modulebene | See module level

Course achievement
Siehe Modulebene | See module level

Literature

<table>
<thead>
<tr>
<th>Compulsory requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>keine</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommended requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental understanding of RNA sequence/structure analysis</td>
</tr>
<tr>
<td>Knowledge about principle methods used in Bioinformatics</td>
</tr>
</tbody>
</table>
In the exercises, students will learn through example scenarios to apply the principles and methods from the lectures.
### Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAT Solving</td>
<td>11LE13MO-1165_PO 2020</td>
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</table>

#### Responsible
Prof. Dr. Armin Biere

#### Organizer
Institut für Informatik Rechnerarchitektur

#### Faculty
Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>2</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>nur im Sommersemester</td>
</tr>
</tbody>
</table>

#### Compulsory requirement
none

#### Recommended requirement
none

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tbody>
<tr>
<td>SAT Solving</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>3.0</td>
<td>180 Stunden</td>
<td>hours</td>
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<tr>
<td>SAT Solving</td>
<td>Übung</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Qualification
Proficiency in applying and developing state-of-the-art algorithms for solving propositional satisfiability problems (SAT).

#### Examination achievement
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) |
Oral exam (usually 30 or 45 minutes)

#### Course achievement
You have to complete and hand in your solutions for exercise sheets/projects and perform experiments on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of the overall number of achievable points for the semester.
### Usability

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAT Solving</td>
<td>11LE13MO-1165_PO 2020</td>
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**Veranstaltung**

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE13V-1165</td>
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</table>

Organizer: Institut für Informatik Rechnerarchitektur

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
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<tr>
<td>Attendance</td>
<td>41 Stunden</td>
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<tr>
<td>Independent study</td>
<td>126 Stunden</td>
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<td>Hours of week</td>
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</table>

**Recommended semester**: 3.0

**Frequency**: nur im Sommersemester

**Pflicht/Wahlpflicht (P/WP)**: none

**Contents**

- Encoding: NNF, Tseitin, AIGs, cardinality constrains encoding, bit-blasting.
- Preprocessing: DP, BVE, BVA, blocked clauses, autarkies, Stalmarck, Recursive Learning, clause redundancy, probing.
- Solving: DPLL, CDCL, learning, implication graph, failed literals, UIP, clause minimization, restarts, clause reduction.

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level

**Compulsory requirement**: none

**Recommended requirement**: none
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAT Solving</td>
<td>11LE13MO-1165_PO 2020</td>
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</table>

**Veranstaltung**

- **SAT Solving**
- **Event type**: Übung
- **Number**: 11LE13Ü-1165

**ECTS-Points**

- **Attendance**: 13 Stunden | hours
- **Hours of week**: 1.0
- **Recommended semester**: nur im Sommersemester
- **Pflicht/Wahlpflicht (P/WP)**

**Contents**

- Examination achievement
  - Siehe Modulebene | See module level
- Course achievement
  - Siehe Modulebene | See module level
- Compulsory requirement
### Name of module
Simulation in Computer Graphics

### Number of module
11LE13MO-1113_PO 2020

### Responsible
Prof. Dr.-Ing. Matthias Teschner

### Organizer
Institut für Informatik Graphische Datenverarbeitung

### Faculty
Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
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</tr>
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<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>3</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
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<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
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</tbody>
</table>

### Compulsory requirement
keine | none

### Recommended requirement
- Programming Skills
- Knowledge in Algorithms and Data Structures, Linear Algebra and Analysis

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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</thead>
<tbody>
<tr>
<td>Simulation in der Computergraphik / Simulation in Computer Graphics</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>2.0</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Simulation in der Computergraphik / Simulation in Computer Graphics</td>
<td>Übung</td>
<td></td>
<td></td>
<td>2.0</td>
<td></td>
</tr>
</tbody>
</table>

### Qualification
The module offers insights into physically-based animation techniques. Various models, numerical techniques, data structures and algorithms for rigid or deformable solids and for fluids are covered. The students learn a variety of relevant techniques. They also learn how to combine, e.g., fluids and solids in animation frameworks.
**Examination achievement**

- mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes)

(Wenn die Teilnehmerzahl groß ist, kann stattdessen eine schriftliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If number of participants is high, might be exceptionally changed to written examination instead. Students will be notified in good time.)

**Course achievement**

- keine | none

**Usability**

- Compulsory elective module for students of the study program
  - M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
  - M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

- Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

- Wahlpflichtmodul für Studierende des Studiengangs
  - B.Sc. in Informatik (PO 2018)
  - polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
  - M.Ed. Informatik (PO 2018)
  - Master of Education Erweiterungsfach Informatik (PO 2021)
Name of module: Simulation in Computer Graphics  
Number of module: 11LE13MO-1113_PO 2020

**Veranstaltung**
Simulation in der Computergraphik / Simulation in Computer Graphics

**Event type**
Vorlesung  
Number: 11LE13V-1113

**Organizer**
Institut für Informatik Graphische Datenverarbeitung

**ECTS-Points**  6.0
**Workload**  180 Stunden | hours
**Attendance**  30 Stunden
**Independent study**  120 Stunden
**Hours of week**  2.0
**Recommended semester**

**Contents**
The course addresses high-performance approaches for the particle-based simulation of fluids, elastic solids, rigid bodies and their interactions. The course introduces relevant concepts with a strong focus on high-performance implementations. The introduced concepts are used in interactive games and in the entertainment industry in general, but also for large-scale simulations in engineering.

Topics:
1. Equations for the motion of particle-based fluids, elastic solids and rigid bodies.
2. Time derivatives to compute particle motion.
3. Spatial derivatives with SPH to compute particle forces.
4. Efficient matrix-free implementations of linear solvers for robust implicit formulations.
5. Spatial data structures for accelerated fluid-rigid and rigid-rigid interactions.
6. Efficient implementations of spatial data structures with hashing and sorting.

**Examination achievement**
Siehe Modulebene  
See module level

**Course achievement**
Siehe Modulebene  
See module level

**Literature**
<table>
<thead>
<tr>
<th>Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>Compulsory requirement</td>
</tr>
<tr>
<td>Recommended requirement</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Teaching method</td>
</tr>
</tbody>
</table>
### Contents

In the exercises, students will learn to apply the methods from the lectures in a practical setting.

### Examination achievement

Siehe Modulebene | See module level

### Course achievement

Siehe Modulebene | See module level

### Compulsory requirement
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft Robotics</td>
<td>11LE13MO-5374_PO 2020</td>
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<table>
<thead>
<tr>
<th>Responsible</th>
<th>JProf. Dr. Edoardo Milana</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organizer</td>
<td>Institut für Mikrosystemtechnik Professur für Soft Machines</td>
</tr>
<tr>
<td>Faculty</td>
<td>Technische Fakultät</td>
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<th>ECTS-Points</th>
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<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden/hours</td>
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<tr>
<td>Recommended semester</td>
<td>3</td>
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<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>nur im Wintersemester</td>
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<table>
<thead>
<tr>
<th>Compulsory requirement</th>
<th>none</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended requirement</td>
<td>none</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Assigned Courses</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Type</td>
</tr>
<tr>
<td>Soft Robotics</td>
<td>Vorlesung</td>
</tr>
<tr>
<td>Soft Robotics - Projekt</td>
<td>Projekt</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Qualification</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The objective of this course it to provide students of engineering with the basics of Soft Robotics. Thus, the following topics will be addressed:</td>
<td></td>
</tr>
<tr>
<td>- design and modeling of soft robots</td>
<td></td>
</tr>
<tr>
<td>- soft actuation principles</td>
<td></td>
</tr>
<tr>
<td>- materials and fabrication processes</td>
<td></td>
</tr>
<tr>
<td>- control of soft robots</td>
<td></td>
</tr>
<tr>
<td>- multifunctional embodiment</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Examination achievement</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>oral examination</td>
<td></td>
</tr>
<tr>
<td>oral presentation</td>
<td></td>
</tr>
</tbody>
</table>

The final grade will be a weighted average of the project presentation (30%) and oral exam (70%)

<table>
<thead>
<tr>
<th>Course achievement</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td></td>
</tr>
</tbody>
</table>
### Usability

Compulsory elective module for students of the study program
- M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication
- M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse
- M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication
- M.Sc. Informatik / Computer Science (PO 2020), in Spezialvorlesung | Specialization Courses

Wahlpflichtmodul für Studierende des Studiengangs
- Master of Science in Sustainable Systems Engineering - Interdisciplinary Profile
**Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)**

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft Robotics</td>
<td>11LE13MO-5374_PO 2020</td>
</tr>
</tbody>
</table>

**Veranstaltung**

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft Robotics</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE50V-5374</td>
</tr>
</tbody>
</table>

**Organizer**

Institut für Mikrosystemtechnik Professur für Soft Machines

| ECTS-Points | 6.0 |
| Workload    | 180 hours |
| Hours of week | 2.0 |
| Recommended semester | 3 |
| Frequency       | nur im Wintersemester |

**Pflicht/Wahlpflicht (P/WP)**

**Contents**

The students will learn how to design, fabricate and control robots made of soft and deformable materials. Models of soft manipulators based on beam theory and piecewise constant strain approximation will be introduced. We will study the main soft actuation mechanisms, such as inflatable actuators, electroactive polymers, magnetorheological elastomers, liquid crystal elastomers. Different manufacturing techniques will be analysed, in the context of polymer molding and additive manufacturing. Further, we will see some examples of model-based control for soft robots. Finally, the concept of multifunctional embodiment of sensing, actuation, control and energy will be discussed. During the course there will be a project assignment, where the students will be divided in groups and will be given a design challenge for a soft robotic system with specific requirements in terms of operational environment and locomotion modes.

**Examination achievement**

See module level

**Course achievement**

See module level

**Literature**


**Compulsory requirement**

None

**Recommended requirement**

Continuum Mechanics (Solid and Fluid), Electromagnetism, Thermodynamics

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Technische Fakultät
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### Name of module | Number of module
---|---
Soft Robotics | 11LE13MO-5374_PO 2020

### Veranstaltung

| Event type | Number |
---|---|
Projekt | 11LE50P-5374 |

### Organizer
Institut für Mikrosystemtechnik Professur für Soft Machines

### ECTS-Points
- Hours of week: 2.0
- Recommended semester: 3
- Frequency: nur im Wintersemester

### Contents
- Examination achievement: See module level
- Course achievement: See module level
- Compulsory requirement: 

---


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EXA 830 (03/2024) MODULE DESCRIPTION
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spieltheorie / Game Theory</td>
<td>11LE13MO-1117_PO 2020</td>
</tr>
</tbody>
</table>

Responsible
Prof. Dr. Joschka Bödecker

Organizer
Institut für Informatik Grundl.d.künstl.Intelligenz

Faculty
Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>Workload</th>
<th>Recommended semester</th>
<th>Duration</th>
<th>Pflicht/Wahlpflicht (P/WP)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0</td>
<td>180 Stunden</td>
<td>2</td>
<td>1 Semester</td>
<td>Wahlpflicht</td>
<td>nur im Sommersemester</td>
</tr>
</tbody>
</table>

Compulsory requirement
keine | none

Recommended requirement
For this course, no particular prerequisites are required.

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spieltheorie / Game Theory</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>3.0</td>
<td>180 Stunden</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Spieltheorie / Game Theory</td>
<td>Übung</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Qualification
After attending the module, students should be able to model simple strategic decision situations according to the game theory and to analyze them with regard to solutions (Nash equilibria, subgame perfect equilibria). Moreover, the students should be able to employ simple mechanisms.

Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) |
Written exam (usually 90 to 180 minutes)

Wenn die Teilnehmerzahl sehr klein ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert. |
If number of participants is small, might be changed to oral exam instead. Students will be notified in good time.)
Exercise sheets and projects have to be completed and handed in on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of the achievable points.

<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compulsory elective module for students of the study program</td>
</tr>
<tr>
<td>■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung</td>
</tr>
<tr>
<td>■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science</td>
</tr>
</tbody>
</table>

Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

<table>
<thead>
<tr>
<th>Wahlpflichtmodul für Studierende des Studiengangs</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik</td>
</tr>
<tr>
<td>■ B.Sc. in Informatik (PO 2018)</td>
</tr>
<tr>
<td>■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)</td>
</tr>
<tr>
<td>■ M.Ed. Informatik (PO 2018)</td>
</tr>
<tr>
<td>■ Master of Education Erweiterungsfach Informatik (PO 2021)</td>
</tr>
</tbody>
</table>
Game theory is about rational decision making to further ones own objectives. In particular, it is about interactions and conflicts between the objectives of different players, i.e., about the question how the knowledge about other players' objectives influences ones own behavior. In the lecture, we study strategic and extensive games and discuss formalizations and solution concepts as well as algorithms for the computation of such solutions.

In addition, the course is concerned with the mechanism design problem, i.e., with the question of how the rules of a social system should be designed in order to incentivize all participants to behave in a way that maximizes social welfare.
<table>
<thead>
<tr>
<th>Required reading</th>
</tr>
</thead>
</table>

**Compulsory requirement**

keine | none

**Recommended requirement**

For this course, no particular prerequisites are required.
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spieltheorie / Game Theory</td>
<td>11LE13MO-1117_PO 2020</td>
</tr>
</tbody>
</table>

**Veranstaltung**

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

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Übung</td>
<td>11LE13Ü-1117</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Organizer</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Institut für Informatik Grundl.d.künstl.Intelligenz</td>
<td></td>
</tr>
</tbody>
</table>

**ECTS-Points**

| Attendance | 13 Stunden |
| Hours of week | 1.0         |

**Recommended semester**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>nur im Sommersemester</th>
</tr>
</thead>
</table>

**Pflicht/Wahlpflicht (P/WP)**

**Contents**

During the semester there will be weekly theoretical exercise sheets and sporadic practical exercises and didactic web-based experiments in game theory. To complete the practical exercise sheets, Python 3 foundations are assumed.

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level

**Compulsory requirement**
Name of module: State Space Control Systems

Number of module: 11LE50MO-5267_PO 2020

Responsible: Prof. Dr. Moritz Diehl

Organizer: Institut für Mikrosystemtechnik Systemtheorie

Faculty: Technische Fakultät

ECTS-Points: 6.0

Workload: 180 Stunden | hours

Recommended semester: 2

Duration: 1 Semester

Pflicht/Wahlpflicht (P/WP): Wahlpflicht

Frequency: unregelmäßig

Compulsory requirement: Keine | none

Recommended requirement: Students are expected to have an undergraduate knowledge in mathematics. It is furthermore recommended to have a good knowledge of differential equations, system theory and control.

Kenntnisse/Kompetenzen aus Mathematik I und II werden VORAUSGESETZT. Kenntnisse aus Differentialgleichungen, Systemtheorie und Regelungstechnik werden EMPFOHLEN.

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Space Control Systems</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>3.0</td>
<td>180</td>
<td>hours</td>
</tr>
<tr>
<td>State Space Control Systems</td>
<td>Übung</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Qualification

The students understand the mathematical foundations of state space control systems and are able to design and use state space control systems in engineering applications.

Examination achievement

Written exam (120 minutes)

Course achievement

none

Recommendation

Work on the weekly exercise sheets and participation in the exercises is voluntary.
<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
</table>

As compulsory elective in
- M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) in Microsystems Engineering Concentrations Area: Circuits and Systems
- M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme
- M.Sc. Microsystems Engineering, Concentration area Circuits and Systems

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- Bachelor of Science in Mikrosystemtechnik (PO 2018), im Wahlpflichtbereich, Bereich Mikrosystemtechnik
- B.Sc. in Informatik (PO 2018)
**Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)**

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Space Control Systems</td>
<td>11LE50MO-5267_PO 2020</td>
</tr>
</tbody>
</table>

**Veranstaltung**

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Space Control Systems</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE50V-5267-</td>
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</table>

<table>
<thead>
<tr>
<th>Organizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institut für Mikrosystemtechnik Systemtheorie</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 hours</td>
</tr>
<tr>
<td>Attendance</td>
<td>52 Stunden</td>
</tr>
<tr>
<td>Independent study</td>
<td>128 Stunden</td>
</tr>
<tr>
<td>Hours of week</td>
<td>3.0</td>
</tr>
<tr>
<td>Recommended semester</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
</tr>
</tbody>
</table>

**Contents**

Review of linear system theory in continuous time and ordinary differential equations; nonlinear and linear systems; discrete time and continuous time systems; eigenvalues and stability; Lyapunov functions; controllability, stabilizability, observability and detectability; control and observer normal form, Kalman normal form; pole placement, linear quadratic regulator (LQR); Luenberger observer, Kalman filter (KF); linear quadratic Gaussian (LQG) control and separation principle; disturbance modelling and offset free control; model predictive control (MPC); robustness; Extended and Unscented Kalman Filter (EKF/UKF); moving horizon estimation (MHE)

**Examination achievement**

see module details

**Course achievement**

see module details

**Literature**


**Compulsory requirement**

None
### Recommended requirement

Students are expected to have an undergraduate knowledge in mathematics. It is furthermore recommended to have a good knowledge of differential equations, system theory and control.

Kenntnisse/Kompetenzen aus Mathematik I und II werden VORAUSGESETZT.
Kenntnisse aus Differentialgleichungen, Systemtheorie und Regelungstechnik werden EMPFOHLEN.
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Space Control Systems</td>
<td>11LE50MO-5267_PO 2020</td>
</tr>
</tbody>
</table>

**Veranstaltung**

- State Space Control Systems

- Event type: Übung
- Number: 11LE50Ü-5267

**Organizer**

Institut für Mikrosystemtechnik Systemtheorie

**ECTS-Points**

- Hours of week: 1.0
- Recommended semester: 
- Frequency: unregelmäßig
- Pflicht/Wahlpflicht (P/WP): 

**Contents**

The weekly exercise sheets allows students to apply their acquired knowledge. During the voluntary weekly exercise sessions the content of both the lecture and the exercise sheets will be discussed in-depth and consolidated.

**Examination achievement**

see module details

**Course achievement**

see module details

**Compulsory requirement**

None

**Recommended requirement**

Students are expected to have an undergraduate knowledge in mathematics. It is furthermore recommended to have a good knowledge of differential equations, system theory and control.

Kenntnisse/Kompetenzen aus Mathematik I und II werden VORAUSGESETZT.

Kenntnisse aus Differentialgleichungen, Systemtheorie und Regelungstechnik werden EMPFOHLEN.
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical Pattern Recognition</td>
<td>11LE13MO-1114_PO 2020</td>
</tr>
</tbody>
</table>

**Responsible**

Prof. Dr. Thomas Brox

**Organizer**

Institut für Informatik Mustererkennung u. Bildverarbeitung

**Faculty**

Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>1</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>nur im Sommersemester</td>
</tr>
</tbody>
</table>

**Compulsory requirement**

keine | none

**Recommended requirement**

Fundamental mathematical knowledge, particularly statistic

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistische Mustererkennung / Statistical Pattern Recognition</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>2.0</td>
<td>180 Stunden</td>
<td>hours</td>
</tr>
<tr>
<td>Statistische Mustererkennung / Statistical Pattern Recognition</td>
<td>Übung</td>
<td></td>
<td>2.0</td>
<td></td>
<td>2.0</td>
</tr>
</tbody>
</table>

**Qualification**

Students know the most relevant techniques of pattern recognition. They are able to understand current related literature and can apply appropriate techniques to solve pattern recognition problems in different areas of application.

**Examination achievement**

Klausur (i.d.R. 90 bis 180 Minuten) |
Written exam (usually 90 to 180 minutes)

**Course achievement**

keine | none
<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compulsory elective module for students of the study program</td>
</tr>
<tr>
<td>■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung</td>
</tr>
<tr>
<td>■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science</td>
</tr>
<tr>
<td>Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering</td>
</tr>
<tr>
<td>Wahlpflichtmodul für Studierende des Studiengangs</td>
</tr>
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<tr>
<td>■ M.Ed. Informatik (PO 2018)</td>
</tr>
<tr>
<td>■ Master of Education Erweiterungsfach Informatik (PO 2021)</td>
</tr>
</tbody>
</table>
Name of module | Number of module
---|---
Statistical Pattern Recognition | 11LE13MO-1114_PO 2020

**Veranstaltung**

Statistische Mustererkennung / Statistical Pattern Recognition

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE13V-1114</td>
</tr>
</tbody>
</table>

Organizer
Institut für Informatik Mustererkennung u. Bildverarbeitung

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Attendance</td>
<td>28 Stunden</td>
</tr>
<tr>
<td>Independent study</td>
<td>126 Stunden</td>
</tr>
<tr>
<td>Hours of week</td>
<td>2.0</td>
</tr>
<tr>
<td>Recommended semester</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>nur im Sommersemester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
</tr>
</tbody>
</table>

**Contents**
The course introduces the basic ideas of recognition and learning, and reviews the most important terminology of probabilistic methods. Afterwards the most common techniques for classification, regression, and clustering are presented, among them linear regression, Gaussian processes, logistic regression, support vector machines, non-parametric density estimation, and expectation-maximization. Additionally, the course includes dimensionality reduction methods and inference in graphical models. Programming assignments in Matlab or Python help deepen the understanding of the material.

**Examination achievement**
Siehe Modulebene | See module level

**Course achievement**
Siehe Modulebene | See module level

**Literature**
"Pattern Recognition and Machine Learning" by Christopher Bishop

**Compulsory requirement**
keine | none

**Recommended requirement**
Fundamental mathematical knowledge, particularly statistic
### Recommendation

<table>
<thead>
<tr>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usually the course is offered every summer semester; as there might be rare exceptions in some years, it's marked as &quot;irregularly&quot;</td>
</tr>
</tbody>
</table>

↑
The exercises consist of theoretical assignments and programming assignments, to apply the methods and concepts from the lecture.
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test und Zuverlässigkeit / Test and Reliability</td>
<td>11LE13MO-1202_PO 2020</td>
</tr>
</tbody>
</table>

Responsible
Prof. Dr. Armin Biere

Organizer
Institut für Informatik Rechnerarchitektur

Faculty
Technische Fakultät

ECTS-Points 6.0

Workload 180 Stunden | hours

Recommended semester 1

Duration 1 Semester

Pflicht/Wahlpflicht (P/WP) Wahlpflicht

Frequency unregelmäßig

Compulsory requirement
keine | none

Recommended requirement
Kenntnisse in Technische Informatik und Rechnerarchitektur / Computer Architecture |
Knowledge of technical informatics and computer architecture

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>3.0</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Test und Zuverlässigkeit / Test and Reliability</td>
<td>Übung</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Qualification
The students know the basic questions of testing digital circuits and, based on this, know, apply and, if necessary, adapt important algorithmic techniques to new needs. Students are able to carry out "Design for Testability" and assess the advantages and disadvantages of these measures. They are familiar with the challenges of the new technologies and they can assess state-of-the-art approaches.
<table>
<thead>
<tr>
<th>Examination achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Klausur (i.d.R. 90 bis 180 Minuten)</td>
</tr>
<tr>
<td>Written exam (usually 90 to 180 minutes)</td>
</tr>
</tbody>
</table>

(If number of participants is small, might be changed to oral exam instead. Students will be notified in good time.)

<table>
<thead>
<tr>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>keine</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
</table>

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
The manufacturing process of integrated circuits (ICs, chips) is a yield process, i.e. some of the ICs will be inherently prone to failures. Since shipping of defective chips implies high follow-up costs, a test phase is necessary to detect defective chips as early as possible. Today, the so-called structural test flow is widely accepted. Here, defects are abstracted with the help of fault models and test patterns are generated that guarantee a high fault coverage with respect to the fault model considered. Taken together, test costs are responsible for up to 40% of the IC’s production costs. Furthermore, it is widely accepted that already during the design phase testability has to be taken into account (design for testability, DFT). Because of this, at least a basic knowledge of IC test issues is of importance also for IC designers.

Consequently, the course starts with standard test topics like fault models, (stuck-at)-fault simulation and automatic test pattern generation (ATPG). We will also provide an introduction to DFT methods, in particular scan design and built-in self-test. Finally, current research topics such as defect based testing, non-standard fault models, test for systems-on-a-chip (SOCs), variation aware testing, robustness analysis are addressed.

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature


<table>
<thead>
<tr>
<th>Compulsory requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>keine</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommended requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenntnisse in Technische Informatik und Rechnerarchitektur / Computer Architecture</td>
</tr>
<tr>
<td>Knowledge of technical informatics and computer architecture</td>
</tr>
<tr>
<td>Name of module</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Test und Zuverlässigkeit / Test and Reliability</td>
</tr>
</tbody>
</table>

### Veranstaltung

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Event type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test und Zuverlässigkeit / Test and Reliability</td>
<td>Übung</td>
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</table>

| Organizer              | Institut für Informatik Rechnerarchitektur |

### ECTS-Points

<table>
<thead>
<tr>
<th>Attendance</th>
<th>15 Stunden</th>
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### Recommended semester

<table>
<thead>
<tr>
<th>Frequency</th>
<th>nur im Wintersemester</th>
</tr>
</thead>
</table>

### Pflicht/Wahlpflicht (P/WP)

### Contents

- Examination achievement
  - Siehe Modulebene | See module level

- Course achievement
  - Siehe Modulebene | See module level

- Compulsory requirement

↑
Name of module | Number of module
---|---
Verifikation Digitaler Schaltungen / Verification of Digital Circuits | 11LE13MO-1223_PO 2020

Responsible
Prof. Dr. Christoph Scholl

Organizer
Institut für Informatik Rechnerarchitektur
Institut für Informatik Betriebssysteme

Faculty
Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>3</td>
</tr>
<tr>
<td>Duration</td>
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<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
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</table>

Compulsory requirement
keine | none

Recommended requirement
Requires basic knowledge in Technical Computer Science

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
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<tbody>
<tr>
<td>Verifikation Digitaler Schaltungen / Verification of Digital Circuits</td>
<td>Vorlesung</td>
<td></td>
<td>3.0</td>
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<td>180 Stunden</td>
</tr>
<tr>
<td>Verifikation Digitaler Schaltungen / Verification of Digital Circuits</td>
<td>Übung</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Qualification
Students know about formal methods used in semiconductor industries to systematically search for faults and, optimally, prove their absence.

Students know data structures and can apply methods that form the basis for formal verification of digital circuits, like binary decision diagrams, SAT solvers, And-Inverter-Graphs. Based on these methods, students will be able to analyze and use symbolic methods for equivalence checks and automatic model checking for digital circuits.
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes)

Wenn die Teilnehmerzahl sehr klein ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If number of participants is small, might be changed to oral exam instead. Students will be notified in good time.

Course achievement
keine | none

Usability
Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verifikation Digitaler Schaltungen / Verification of Digital Circuits</td>
<td>11LE13MO-1223_PO 2020</td>
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</table>

Veranstaltung

Verifikation Digitaler Schaltungen / Verification of Digital Circuits

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE13V-1223</td>
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</tbody>
</table>

Organizer

Institut für Informatik Rechnerarchitektur
Institut für Informatik Betriebssysteme

ECTS-Points

<table>
<thead>
<tr>
<th>Workload</th>
<th>180 Stunden</th>
</tr>
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<tbody>
<tr>
<td>Hours of week</td>
<td>3.0</td>
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<tr>
<td>Recommended semester</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
</tr>
</tbody>
</table>

Contents

Viele moderne Produkte basieren auf mikroelektronischen Komponenten. Oftmals ist das korrekte Funktionieren dieser Produkte lebenswichtig, etwa in Medizintechnik oder Autoelektronik. Daher werden hohe Anforderungen an die Qualität der darin eingesetzten mikroelektronischen Systeme gestellt. Die Anforderungen lassen sich in drei Gruppen unterteilen: (1) Das System muss korrekt entsprechend der Spezifikation entworfen sein. (2) Das gemäß Entwurf physikalisch gefertigte System soll zum Zeitpunkt seiner Herstellung fehlerfrei funktionieren. (3) Darüber hinaus soll das System für einen gegebenen Zeitraum zuverlässig (d.h. ohne Ausfall) eingesetzt werden können.


Examination achievement

Siehe Modulebene | See module level

Course achievement

Siehe Modulebene | See module level

Literature

- Clarke, Grumberg, Peled, "Model Checking", MIT Press 1999
- Diverse Originalarbeiten
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

- Presentation of powerpoint slides. Slides and exercise sheets can be downloaded from the course website.

<table>
<thead>
<tr>
<th>Compulsory requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basiswissen in Technische Informatik</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommended requirement</th>
</tr>
</thead>
</table>
### Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verifikation Digitaler Schaltungen / Verification of Digital Circuits</td>
<td>11LE13MO-1223_PO 2020</td>
</tr>
</tbody>
</table>

### Veranstaltung

<table>
<thead>
<tr>
<th>Verifikation Digitaler Schaltungen / Verification of Digital Circuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event type</td>
</tr>
<tr>
<td>Übung</td>
</tr>
</tbody>
</table>

### Organizer

Institut für Informatik Rechnerarchitektur  
Institut für Informatik Betriebssysteme

### ECTS-Points

<table>
<thead>
<tr>
<th>Attendance</th>
<th>Hours of week</th>
<th>Recommended semester</th>
<th>Frequency</th>
<th>Pflicht/Wahlpflicht (P/WP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 Stunden</td>
<td>1.0</td>
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</table>

### Contents

Examination achievement

Siehe Modulebene | See module level

Course achievement

Siehe Modulebene | See module level

Compulsory requirement

↑
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verteilte Systeme / Distributed Systems</td>
<td>11LE13MO-1312_PO 2020</td>
</tr>
</tbody>
</table>

Responsible

Prof. Dr. Fabian Kuhn

Organizer

Institut für Informatik Algorithmen und Komplexität

Faculty

Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>1</td>
</tr>
<tr>
<td>Duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
</tr>
</tbody>
</table>

Compulsory requirement

keine | none

Recommended requirement

Basic knowledge in algorithm design & analysis, some mathematical maturity (in particular, we use some graph theory and probability theory)
Knowledge about databases and information systems

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verteilte Systeme / Distributed Systems</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>2.0</td>
<td></td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Verteilte Systeme / Distributed Systems Übung</td>
<td>Übung</td>
<td></td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Qualification

The students know the specific problems in distributed systems that arise from the interaction of concurrent processes. They know and apply solutions to such problems.

Examination achievement

mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes)
(Wenn die Teilnehmerzahl sehr groß ist, kann stattdessen eine schriftliche Prüfung (i.d.R. 90 bis 180 Minuten) durchgeführt werden. Die Studierenden werden rechtzeitig informiert. If number of participants is very high, might be exceptionally changed to written examination (usually 90 to 180 minutes) instead. Students will be notified in good time.)
Course achievement

keine | none

Recommendation

Please note: The exercises are an integral part of the lecture, the topics covered by the exercises will also be part of the exam.

Usability

Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

Wahlpflichtmodul für Studierende des Studiengangs
- B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Ed. Informatik (PO 2018)
- Master of Education Erweiterungsfach Informatik (PO 2021)
Name of module | Number of module
--- | ---
Verteilte Systeme / Distributed Systems | 11LE13MO-1312_PO 2020

**Veranstaltung**

Verteilte Systeme / Distributed Systems

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE13V-1312</td>
</tr>
</tbody>
</table>

Organizer
Institut für Informatik Algorithmen und Komplexität

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Attendance</td>
<td>26 Stunden</td>
</tr>
<tr>
<td>Independent study</td>
<td>128 Stunden</td>
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<tr>
<td>Hours of week</td>
<td>2.0</td>
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<tr>
<td>Recommended semester</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
</tr>
</tbody>
</table>

**Contents**

The course provides an introduction to the fundamentals of distributed systems and algorithms. The course will in particular cover the following topics:

- distributed systems models
- time and global states in distributed systems
- synchronous and asynchronous systems
- fault tolerance
- basic distributed algorithms for coordination and agreement tasks
- basic distributed network algorithms
- distributed and parallel graph algorithms
- impossibility results and lower bounds

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level

**Literature**

Some of the content is for example covered by the following books:

Distributed Computing: Fundamentals, Simulations and Advanced Topics
Hagit Attiya, Jennifer Welch.

Distributed Computing: A Locality-Sensitive Approach
David Peleg.
Additional literature will be provided in the lecture.

<table>
<thead>
<tr>
<th>Compulsory requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>keine</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommended requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic knowledge in algorithm design &amp; analysis, some mathematical maturity (in particular, we use some graph theory and probability theory)</td>
</tr>
</tbody>
</table>
Verteilte Systeme / Distributed Systems

Verteilte Systeme / Distributed Systems Übung

Event type

Übung

Organizer

Institut für Informatik Algorithmen und Komplexität

ECTS-Points

Attendance 26 Stunden

Hours of week 2.0

Recommended semester

Frequency unregelmäßig

Pflicht/Wahlpflicht (P/WP)

Contents

The lecture will be complemented by theoretical exercises that allow to apply and further develop ideas and techniques discussed in the lecture. The exercises are an integral part of the lecture, the topics covered by the exercises will also be part of the oral exam.

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Compulsory requirement
Name of module | Number of module
--- | ---
Wearable and Implantable Computing (WIC) | 11E13MO-1402_PO 2020

Responsible
Prof. Dr. Oliver Amft

Organizer
Institut für Informatik Intelligente Eingebettete Systeme

Faculty
Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
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</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 Stunden</td>
</tr>
<tr>
<td>Attendance</td>
<td>32 Stunden</td>
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<tr>
<td>Independent study</td>
<td>116 Stunden</td>
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<tr>
<td>Duration</td>
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<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Wahlpflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>nur im Sommersemester</td>
</tr>
</tbody>
</table>

Compulsory requirement
keine | none

Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wearable and Implantable Computing (WIC)</td>
<td>Vorlesung</td>
<td></td>
<td>6.0</td>
<td>2.0</td>
<td>180 Stunden / Hours</td>
</tr>
<tr>
<td>Wearable and Implantable Computing (WIC)</td>
<td>Übung</td>
<td></td>
<td></td>
<td>2.0</td>
<td></td>
</tr>
</tbody>
</table>

Qualification
Students are able to
- Understand design concepts and apply/analyse wearable and implantable system design methods.
- Analyse physical principles, select and optimise on-body energy harvesting and power management techniques.
- Create context recognition and energy-efficient pattern analysis pipelines using sparse sampling and pattern processing methods.
- Build wearable system prototypes and apply system evaluation methods, including design for biocompatibility.
### Examination achievement

<table>
<thead>
<tr>
<th>mündliche Prüfung (i.d.R. 30 oder 45 Minuten)</th>
<th>Oral exam (usually 30 or 45 minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>If there are too many students for a reasonably organized oral exam, it will be held as a written exam instead, announced well in advance.</td>
<td></td>
</tr>
</tbody>
</table>

### Course achievement

<table>
<thead>
<tr>
<th>Durchführung von Versuchen und Ergebnisprotokoll</th>
<th>Execution of experiments and written report of results</th>
</tr>
</thead>
</table>

### Usability

#### Compulsory elective module for students of the study program
- M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses
- M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science **OR** in Microsystems Engineering Concentrations Area Circuits and Systems/Biomedical Engineering
- M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems/Biomedical Engineering
- M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme/Biomedizinische Technik

Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

**and**

Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

**Name of module**

| Wearable and Implantable Computing (WIC) | 11E13MO-1402_PO 2020 |

**Veranstaltung**

| Wearable and Implantable Computing (WIC) |

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
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<tbody>
<tr>
<td>Vorlesung</td>
<td>11E13V-1402_PO 2020</td>
</tr>
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</table>

**Organizer**

Institut für Informatik Intelligente Eingebettete Systeme

**ECTS-Points** 6.0

**Workload** 180 Stunden / Hours

**Attendance** 32 Stunden / Hours

**Independent study** 116 Stunden / Hours

**Hours of week** 2.0

**Recommended semester**

**Frequency** nur im Sommersemester

**Pflicht/Wahlpflicht (P/WP)**

**Contents**

The course provides students with a comprehensive overview and in-depth skills on system design of sensor-based wearable and implantable computing systems. Course covers frequent sensors and actuators and their system integration, context recognition methods and selected algorithms, powering and energy management concepts (task scheduling, sparse sampling, and on-demand signal processing), energy harvesting methods, and system design topics (flexible electronics, electronics textile integration, multiprocess additive manufacturing), as well as principles of system validation.

**Examination achievement**

see module details

**Course achievement**

see module details

**Literature**

Up-to-date literature recommendations are provided during the lectures.

**Compulsory requirement**

None

**Recommended requirement**

Basic timeseries analysis methods, basic programming skills, coding in Python
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wearable and Implantable Computing (WIC)</td>
<td>11E13MO-1402_PO 2020</td>
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**Veranstaltung**

Wearable and Implantable Computing (WIC)

**Event type**

<table>
<thead>
<tr>
<th>Number</th>
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**Organizer**

Institut für Informatik Intelligente Eingebettete Systeme

<table>
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<tbody>
<tr>
<td>Attendance</td>
</tr>
<tr>
<td>Hours of week</td>
</tr>
</tbody>
</table>

**Recommended semester**

<table>
<thead>
<tr>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>nur im Sommersemester</td>
</tr>
</tbody>
</table>

**Pflicht/Wahlpflicht (P/WP)**

**Contents**

Student groups will investigate concrete cases including context recognition, energy-efficient signal processing, and digital design of wearable systems. A wearable device prototype will be realised per student group.

**Examination achievement**

see module details

**Course achievement**

see module details

**Compulsory requirement**

↑
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

**Name of module**

Windenergiesysteme / Wind Energy Systems

**Number of module**

11LE50MO-5256_PO 2020

**Responsible**

Prof. Dr. Moritz Diehl

**Organizer**

Institut für Mikrosystemtechnik Systemtheorie

**Faculty**

Technische Fakultät

**ECTS-Points**

6.0

**Workload**

180 hours

**Recommended semester**

3

**Duration**

1 Semester

**Pflicht/Wahlpflicht (P/WP)**

Wahlpflicht

**Compulsory requirement**

None

**Recommended requirement**

Undergraduate knowledge in physics, mathematics as well as in systems and control.

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windenergiesysteme / Wind Energy Systems</td>
<td>Vorlesung</td>
<td>6.0</td>
<td>3.0</td>
<td>180 hours</td>
<td></td>
</tr>
<tr>
<td>Windenergiesysteme / Wind Energy Systems</td>
<td>Übung</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

**Qualification**

Students understand the physical principles of wind energy and the technology of modern wind energy systems.

**Examination achievement**

Written exam (180 minutes)

**Course achievement**

none
Usability

Compulsory elective module for students of the study program

- M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems
- M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme
- M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systems
- M.Sc. Informatik / Computer Science (PO 2020), in Spezialvorlesung | Specialization Courses

**Important note for M.Sc. Informatik / Computer Science:**

- a specialization lecture in Computer Science (with a graded assessment / Prüfungsleistung)
- as a course in the application area Applied Bioinformatics (as pass/fail course / Studienleistung) (see according module in online module handbook / planner of studies)

Take care during the booking process, as that will define the category in which the course is considered.

**You can't change the category afterwards!** So, you can't change it from PL to SL or vice versa.
## Name of module

Windenergiesysteme / Wind Energy Systems

### Number of module

11LE50MO-5256_PO 2020

### Veranstaltung

Windenergiesysteme / Wind Energy Systems

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vorlesung</td>
<td>11LE50V-5256</td>
</tr>
</tbody>
</table>

### Organizer

Institut für Mikrosystemtechnik Systemtheorie

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>180 hours</td>
</tr>
<tr>
<td>Attendance</td>
<td>52 hours</td>
</tr>
<tr>
<td>Independent study</td>
<td>128 hours</td>
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<tr>
<td>Hours of week</td>
<td>3.0</td>
</tr>
<tr>
<td>Recommended semester</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
</tr>
</tbody>
</table>

### Contents

- Global wind energy resource
- Aerodynamic principles of wind turbines
- Design of modern wind turbines
- Control of modern wind turbines
- The electrical system of wind turbines
- Alternative concepts and high-altitude wind energy

### Examination achievement

See module level

### Course achievement

See module level

### Literature


### Compulsory requirement

### Recommended requirement

Undergraduate knowledge in physics, mathematics as well as in systems and control.
### Name of module
Windenergiesysteme / Wind Energy Systems

### Number of module
11LE50MO-5256_PO 2020

### Veranstaltung
Windenergiesysteme / Wind Energy Systems

### Event type
Übung

### Number
11LE50Ü-5256

### Organizer
Institut für Mikrosystemtechnik Systemtheorie

### ECTS-Points
- 

### Workload
- 

### Attendance
- 

### Independent study
- 

### Hours of week
1.0

### Recommended semester

### Frequency
unregelmäßig

### Pflicht/Wahlpflicht (P/WP)

### Contents
The tutorials deepen the understanding of the material of the lecture.

### Examination achievement
See module level

### Course achievement
See module level

### Compulsory requirement
None
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of node</th>
<th>Number of node</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seminare</td>
<td>11LE13KT-Seminare</td>
</tr>
<tr>
<td>Faculty</td>
<td>Technische Fakultät</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pflicht/Wahlpflicht (P/WP)</th>
<th>Pflicht</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comment</td>
<td>Students have to take 2 Seminars.</td>
</tr>
</tbody>
</table>

Technische Fakultät
Page 295 of 332
Name of module | Number of module
--- | ---
Seminar 1 | 11LE13MO-Seminar 1

Responsible
Prof. Dr. Hannah Bast

Faculty
Technische Fakultät

| ECTS-Points | 3.0 |
| Workload | 90 Stunden | hours |
| Recommended semester | 1 |
| Duration | |
| Pflicht/Wahlpflicht (P/WP) | Pflicht |
| Frequency | in jedem Semester |

Compulsory requirement
keine | none

Recommended requirement
allgemeine mathematische Grundkenntnisse, praktische und theoretische Grundlagen der Informatik, ggf. themenspezifische Vorkenntnisse für den gewählten Themenbereich | general mathematical knowledge, practical and theoretical foundations in Computer Science, possibly subject-specific knowledge for the chosen topics

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>VG Seminar 1 M</td>
<td>Veranstaltung</td>
<td></td>
<td>2.0</td>
<td>90 Stunden</td>
<td>hours</td>
</tr>
</tbody>
</table>

Qualification

Sie erweitern ihre Kenntnisse in den Regeln und Techniken des wissenschaftlichen Arbeitens (z.B. korrektes Zitieren), insbesondere im Hinblick auf den redlichen Umgang in der Wissenschaft; diese Kenntnisse werden für das Verfassen der Masterarbeit benötigt.
Das Anfertigen und Halten einer eigenen Präsentation im Rahmen des Seminars bereitet direkt auf die Präsentation der Masterarbeit vor.

The students get an in-depth insight into scientific work in a special field of computer science. On the basis of selected topics from the various research and work areas of the professors and work groups, the students deepen their knowledge of how to read scientific texts, carry out background research, present scientific results and take part in scientific and technical discussions.
They expand their knowledge of the rules and techniques of scientific work (e.g. correct quoting), especially regarding intellectual honesty; this knowledge is required for writing the Master thesis.
Preparing and holding your own presentation as part of the seminar prepares you directly for the presentation of the Master thesis.

**Examination achievement**

The examination consists of the preparation and implementation of a scientific presentation.

**Course achievement**

As a rule, the course work consists of the following components:
- regular attendance in the seminar meetings
- preparation of 3-4 questions on seminar topics of other participants
- written summary with citation of the references

**Recommendation**

Informationen zum Belegverfahren für Seminare: | Information about booking procedure for seminars:
https://www.tf.uni-freiburg.de/en/studies-and-teaching/a-to-z-study-faq

**Usability**

Compulsory module for students of the study program
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Sc. in Informatik / Computer Science (PO 2020)

Compulsory elective module for students of the study program
- Master of Education Erweiterungsfach Informatik (PO 2021)
- M.Sc. Embedded Systems Engineering (PO 2021)
### Name of module

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seminar 1</td>
<td>11LE13MO-Seminar 1</td>
</tr>
</tbody>
</table>

### Veranstaltungsgruppe

<table>
<thead>
<tr>
<th>Veranstaltungsgruppe</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>VG Seminar 1 M</td>
<td></td>
</tr>
</tbody>
</table>

### Event type

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Veranstaltung</td>
<td>11LE13VG-Seminar</td>
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</tbody>
</table>

### ECTS-Points

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>Workload</th>
<th>Attendance</th>
<th>Independent study</th>
<th>Hours of week</th>
<th>Recommended semester</th>
<th>Frequency</th>
<th>Pflicht/Wahlpflicht (P/WP)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90 Stunden</td>
<td>30</td>
<td>60</td>
<td>2.0</td>
<td></td>
<td>unregelmäßig</td>
<td></td>
</tr>
</tbody>
</table>

### Contents

Various topics (changing each semester) from the research and teaching areas of the work groups/chairs at the Department of Computer Science

### Examination achievement

See module level

### Course achievement

See module level

### Literature

background literature provided by the lecturers

### Compulsory requirement

keine | none

### Recommended requirement

allgemeine mathematische Grundkenntnisse, praktische und theoretische Grundlagen der Informatik, ggf. themenspezifische Vorkenntnisse für den gewählten Themenbereich | general mathematical knowledge, practical and theoretical foundations in Computer Science, possibly subject-specific knowledge for the chosen topics

### Teaching method

Seminars can be held in a weekly fashion or as a compact course (during/at the end of lecture time)
**Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)**

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seminar 2</td>
<td>11LE13MO-Seminar 2</td>
</tr>
</tbody>
</table>

**Responsible**

Prof. Dr. Hannah Bast

**Faculty**

Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>90 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>1</td>
</tr>
<tr>
<td>Duration</td>
<td></td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Pflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>in jedem Semester</td>
</tr>
</tbody>
</table>

**Compulsory requirement**

keine | none

**Recommended requirement**

allgemeine mathematische Grundkenntnisse, praktische und theoretische Grundlagen der Informatik, ggf. themenspezifische Vorkenntnisse für den gewählten Themenbereich | general mathematical knowledge, practical and theoretical foundations in Computer Science, possibly subject-specific knowledge for the chosen topics

**Assigned Courses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seminar 2</td>
<td>Veranstaltung</td>
<td></td>
<td>2.0</td>
<td>90 Stunden</td>
<td>90 Stunden</td>
</tr>
</tbody>
</table>

**Qualification**


Sie erweitern ihre Kenntnisse in den Regeln und Techniken des wissenschaftlichen Arbeitens (z.B. korrektes Zitieren), insbesondere im Hinblick auf den redlichen Umgang in der Wissenschaft; diese Kenntnisse werden für das Verfassen der Masterarbeit benötigt.

Das Anfertigen und Halten einer eigenen Präsentation im Rahmen des Seminars bereitet direkt auf die Präsentation der Masterarbeit vor.

The students get an in-depth insight into scientific work in a special field of computer science. On the basis of selected topics from the various research and work areas of the professors and work groups, the students deepen their knowledge of how to read scientific texts, carry out background research, present scientific results and take part in scientific and technical discussions.

They expand their knowledge of the rules and techniques of scientific work (e.g. correct quoting), especially regarding intellectual honesty; this knowledge is required for writing the Master thesis.
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Preparing and holding your own presentation as part of the seminar prepares you directly for the presentation of the Master thesis.</th>
</tr>
</thead>
</table>

**Examination achievement**

The examination consists of the preparation and implementation of a scientific presentation.

**Course achievement**

As a rule, the course work consists of the following components:
- regular attendance in the seminar meetings
- preparation of 3-4 questions on seminar topics of other participants
- written summary with citation of the references

**Recommendation**

Informationen zum Belegverfahren für Seminare: | Information about booking procedure for seminars:
https://www.tf.uni-freiburg.de/en/studies-and-teaching/a-to-z-study-faq

**Usability**

Compulsory module for students of the study program
- B.Sc. in Informatik (PO 2018)
- polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018)
- M.Sc. in Informatik / Computer Science (PO 2020)

Compulsory elective module for students of the study program
- Master of Education Erweiterungsfach Informatik (PO 2021)
- M.Sc. Embedded Systems Engineering (PO 2021)
### Name of module | Number of module
---|---
Seminar 2 | 11LE13MO-Seminar 2

### Veranstaltungsgruppe

<table>
<thead>
<tr>
<th>Event type</th>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>Veranstaltung</td>
<td>11LE13VG-Seminar</td>
</tr>
</tbody>
</table>

### ECTS-Points

<table>
<thead>
<tr>
<th>Workload</th>
<th>90 Stunden</th>
<th>hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Independent study</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Hours of week</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
<td></td>
</tr>
</tbody>
</table>

### Contents

Various topics (changing each semester) from the research and teaching areas of the work groups/chairs at the Department of Computer Science

### Examination achievement

See module level

### Course achievement

See module level

### Literature

background literature provided by the lecturers

### Compulsory requirement

keine | none

### Recommended requirement

allgemeine mathematische Grundkenntnisse, praktische und theoretische Grundlagen der Informatik, ggf. themenspezifische Vorkenntnisse für den gewählten Themenbereich | general mathematical knowledge, practical and theoretical foundations in Computer Science, possibly subject-specific knowledge for the chosen topics

### Teaching method

Seminars can be held in a weekly fashion or as a compact course (during/at the end of lecture time)
### Praktikum

<table>
<thead>
<tr>
<th>Name of node</th>
<th>Number of node</th>
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</thead>
<tbody>
<tr>
<td>Praktikum</td>
<td>11LE13KT-Praktikum</td>
</tr>
</tbody>
</table>

#### Faculty

Technische Fakultät

#### Pflicht/Wahlpflicht (P/WP)

<table>
<thead>
<tr>
<th>Pflicht/Wahlpflicht (P/WP)</th>
<th>Pflicht</th>
</tr>
</thead>
</table>

#### Comment

Students have to take 1 lab course.
<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Praktikum</td>
<td>11LE13MO-7110 PO 2020</td>
</tr>
</tbody>
</table>

**Responsible**

Prof. Dr. Hannah Bast

**Faculty**

Technische Fakultät

**ECTS-Points**

6.0

**Workload**

180 Stunden | hours

**Recommended semester**

2

**Duration**

1 Semester

**Pflicht/Wahlpflicht (P/WP)**

Pflicht

**Frequency**

in jedem Semester

### Compulsory requirement

keine | none

### Recommended requirement

allgemeine praktische und theoretische Grundlagen der Informatik, Programmierkenntnisse, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general practical and theoretical foundations in Computer Science, programming skills, subject-specific knowledge for the chosen topics

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Praktikum Informatik1</td>
<td>Veranstaltung</td>
<td></td>
<td></td>
<td></td>
<td>180 Stunden</td>
</tr>
</tbody>
</table>

### Qualification

While working with other students or members of the work groups/chairs at the Department of Computer Science on one of many topics they can choose from following their field of interest, students learn to complete given tasks taking into account the given technical conditions, conduct experiments and record and analyze the results in appropriate scientific manner and report on their work.
### Examination achievement

| keine | none |

#### Für Studierende im M.Ed. Informatik:

*Je nach Themenstellung:*
- Bearbeitung der gestellten Aufgaben und Experimente
- Erstellen von Software oder Demonstratoren
- *schriftlicher Bericht: Praktikumsbericht oder Protokoll oder eine (nach den wissenschaftlichen Maßstäben) ausreichenden Dokumentation*
- mündliche Präsentation (in der Regel 20 - 30 Minuten)

Bei mehreren Prüfungsteilen errechnet sich die Note nach dem arithmetischen Mittel der Teilnoten.

### Course achievement

As a rule, the course work consists of the following components:
- regular attendance of the practical parts of the course as well as (team) meetings and discussions with the supervisor
- completing assigned tasks and experiments
- creation of software or demonstrators
- written report: lab report or protocol or sufficient documentation (according to the scientific standards)
- oral presentation (usually 20 - 30 minutes)

### Recommendation

Language is usually English, but might be negotiable (changed to German)

### Usability

- Compulsory module for students of the study program

- Compulsory elective module for students of the study program
  - M.Sc. Embedded Systems Engineering (ESE) (2021) in the Customized Course Selection

- Wahlpflichtmodul für Studierende des Studiengangs
  - M.Ed. Informatik (PO 2018); Modul "Informatik - Vertiefung 2"
**Name of module | Number of module**

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Praktikum</td>
<td>11LE13MO-7110 PO 2020</td>
</tr>
</tbody>
</table>

**Veranstaltungsgruppe**

<table>
<thead>
<tr>
<th>Veranstaltungsgruppe</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Praktikum Informatik1</td>
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</table>

**Event type | Number**

| Veranstaltung | 11LE13VG-7110-P1 |

**ECTS-Points**

<table>
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<th>Workload</th>
<th>180 Stunden</th>
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<tr>
<td>Attendance</td>
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<td>Independent study</td>
<td>120 Stunden</td>
<td></td>
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</tbody>
</table>

**Recommended semester**

| Hours of week | unregelmäßig |

**Recommended requirement**

| Pflicht/Wahlpflicht (P/WP) |                |

---

**Contents**

Various topics from the research and teaching areas of the work groups/chairs at the Department of Computer Science

**Examination achievement**

Siehe Modulebene | See module level

**Course achievement**

Siehe Modulebene | See module level

**Literature**

Instructions and background literature are provided by the lecturers

**Compulsory requirement**

keine | none

**Recommended requirement**

allgemeine praktische und theoretische Grundlagen der Informatik, Programmierkenntnisse, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general practical and theoretical foundations in Computer Science, programming skills, subject-specific knowledge for the chosen topics
<table>
<thead>
<tr>
<th>Name of node</th>
<th>Number of node</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individuelle Studiengestaltung</td>
<td>11LE13KT-Indiv STG</td>
</tr>
<tr>
<td>Faculty</td>
<td></td>
</tr>
<tr>
<td>Technische Fakultät</td>
<td></td>
</tr>
</tbody>
</table>

| Pflicht/Wahlpflicht (P/WP)       | Pflicht        |

**Comment**

Students have to take 18 ECTS credits by doing courses outside of Computer Science.

They can substitute up to 6 of these credits by
- either doing a language course at SLI
- or taking an additional Computer Science lecture (Advanced Lecture or Specialization Course)

In this case, this course counts as a graded assessment.

The other courses are pass/fail courses.
As part of the Customized Course Selection, one additional computer science lecture (from the category of Advanced Lectures or Specialization Courses) can be selected. This lecture is completed with an examination even though it is part of the Customized Course Selection and is included in the final grade with 6 ECTS credits.

For the corresponding module descriptions, please refer to the previous accounts "Advanced Lectures" and "Specialization Courses".
### Spezialvorlesung innerhalb der Individuellen Studiengestaltung

<table>
<thead>
<tr>
<th>Name of node</th>
<th>Number of node</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spezialvorlesung innerhalb der Individuellen Studiengestaltung</td>
<td>11LE13KT-Indiv STG-Spez-Vorl</td>
</tr>
</tbody>
</table>

**Faculty**

Technische Fakultät

<table>
<thead>
<tr>
<th>Pflicht/Wahlpflicht (P/WP)</th>
<th>Wahlpflicht</th>
</tr>
</thead>
</table>

**Comment**

Im Rahmen der Individuellen Studiengestaltung kann eine weitere Informatik-Vorlesung (aus der Kategorie der Weiterführenden Vorlesungen oder der Spezialvorlesungen) gewählt werden. Diese wird auch innerhalb der Individuellen Studiengestaltung mit einer Prüfungsleistung abgeschlossen und geht mit 6 ECTS-Punkten in die Endnote ein.

Für die entsprechenden Modulbeschreibungen wird auf die vorhergehenden Konten "Weiterführende Vorlesungen" und "Spezialvorlesungen" verwiesen.

As part of the Customized Course Selection, one additional computer science lecture (from the category of Advanced Lectures or Specialization Courses) can be selected. This lecture is completed with an examination even though it is part of the Customized Course Selection and is included in the final grade with 6 ECTS credits.

For the corresponding module descriptions, please refer to the previous accounts "Advanced Lectures" and "Specialization Courses".
<table>
<thead>
<tr>
<th>Name of node</th>
<th>Number of node</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fachfremde Veranstaltungen innerhalb der Individuellen Studiengestaltung</td>
<td>11LE13KT-Indiv STG-FWB</td>
</tr>
<tr>
<td>Faculty</td>
<td></td>
</tr>
<tr>
<td>Technische Fakultät</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Pflicht/Wahlpflicht (P/WP)</th>
<th>Pflicht</th>
</tr>
</thead>
</table>

**Comment**

Eine Übersicht zu den verfügbaren Veranstaltungen für Masterstudierende in Informatik / Computer Science finden Sie hier: |

An Overview of the available courses open for Master students in Informatik / Computer Science can be found here:


Students have to take courses amounting to 18 ECTS credits (or at least 12, if doing an additional Computer Science lecture in the Customized Course Selection) from courses outside of Computer Science.

Courses from other departments of the University can only be chosen from selected subjects. These subjects are listed in the following part; only the courses listed here per subject are open to Computer Science students. Other courses from the listed subjects cannot be chosen.
In "Applied Bioinformatics" you can choose the following courses:
- PM-01 Bioinformatics (6 ECTS, from the study program of "Biology")
- Vertiefende Methoden der Bioinformatik (9 ECTS, from the study program of "Pharmazie")
- Introduction to data driven life sciences (6 ECTS, from Computer Science)

Please note: This can be taken here as a course "outside of CS" (then it is pass/fail (SL) only) or as a specialization course in CS (then it is graded (PL)); the mode is determined by booking in HISinOne in the respective area and can NOT be changed afterwards!

Please refer to the subjects for further information and module descriptions.
### Comment

In "Kognitionswissenschaften" (mostly in German) you can choose the following courses:
- Hauptseminar I (6 ECTS)
- Hauptseminar II (6 ECTS)
- Projektseminar (6 ECTS)

Please refer to the subject for further information and module descriptions.
In "Mathematik" (mostly in German) you can choose the following courses:

- Algebra und Zahlentheorie (9 ECTS)
- Algebraische Topologie (9 ECTS)
- Computational Finance (6 ECTS)
- Differentialgeometrie (9 ECTS)
- Differentialtopologie (9 ECTS)
- Einführung in Theorie und Numerik partieller Differentialgleichungen (9 ECTS)
- Elementare Differentialgeometrie (9 ECTS)
- Funktionalanalysis (9 ECTS)
- Funktionentheorie (9 ECTS)
- Kommutative Algebra und Einführung in die Algebraische Geometrie (9 ECTS)
- Kurven und Flächen (9 ECTS)
- Maschinelles Lernen aus stochastischer Sicht (6 ECTS)
- Mathematische Modellierung (6 ECTS)
- Mathematische Statistik (9 ECTS)
- Mengenlehre – Unabhängigkeitsbeweise (9 ECTS)
- Modelltheorie (9 ECTS)
- Numerik Teil 1 (6 ECTS)
- Numerik Teil 2 (Numerik 1 wird vorausgesetzt) (6 ECTS)
- Optimal Transport (3 ECTS)
- Partielle Differentialgleichungen (9 ECTS)
- Stochastische Prozesse (9 ECTS)
- Topologie (9 ECTS)
- Variationsrechnung (9 ECTS)
- Wahrscheinlichkeitstheorie (9 ECTS)
- Wahrscheinlichkeitstheorie II (9 ECTS)
- Bochner-Räume (6 ECTS)

**NO credits can be earned by the Bachelor courses:** Analysis I, Analysis II, Lineare Algebra I, Lineare Algebra II, Mathematische Logik and Stochastik!

Please refer to the subject for further information and module descriptions.
In "Medizin" (in German only) you can choose the following courses:

Before doing another course, you have to take
- Ausgewählte Themen zur Mikrosystemtechnik in der Medizin (3 ECTS)

Then you can choose:
- Themen der medizinischen Informatik (Master) (3 ECTS) *(stark empfohlen, wenn noch nicht im Bachelor absolviert; kann im Master auch nochmal gemacht werden, da Inhalte z.T. unterschiedlich)*
- Struktur, Funktion und Fehlfunktion des menschlichen Organismus - Teil 3 (5 ECTS) **
- Innere Medizin für Zahnmediziner (3 ECTS) **
- Allgemeine Chirurgie für Zahnmediziner (1,5 ECTS) **
- Allgemeine Pathologie für Zahnmediziner (3 ECTS)
- Pathologisch-histologischer Kurs für Zahnmediziner (1,5 ECTS)
- Humangenetik für Studierende der Molekularen Medizin (1,5 ECTS)
- Geschichte, Theorie und Ethik der Medizin (1,5 ECTS)
- Pharmakologie und Toxikologie für Zahnmediziner Teil 1 (1,5 ECTS)
- Mikrobiologie für Pharmazeuten (3 ECTS)
- Seminar Wissenschaftliches Denken und Handeln (3 ECTS) *(sofern nicht bereits im BSc absolviert)*
- Projekt an einem medizinischen Lehrstuhl (6 ECTS)

** *(die beiden Zahnmedizin-Veranstaltungen große inhaltliche Überschneidungen mit „Struktur, Funktion und Fehlfunktion des menschlichen Organismus – Teil 3“ aufweisen und somit redundant sind, wenn diese Veranstaltung belegt wird)*

Please refer to the subject for further information and module descriptions.
### Name of node | Number of node
---|---
Mikrosystemtechnik | 11LE13KT-FWB-MST

**Faculty**
Technische Fakultät

**Pflicht/Wahlpflicht (P/WP)**  |  Wahlpflicht

**Comment**
Freie Auswahl aus den im Studienplaner in diesem Bereich aufgeführten MST-Veranstaltungen
| Any MSE course(s) from the selection given in this area in the study planner

Please refer to the subject for further information and module descriptions.
### Comment

In "Neuroscience" (in English) you can choose from the following courses:

**Please note:**
At least the two lectures "From membrane to brain" and "Computational Neuroscience" (with exercise) are mandatory for this area. Participation in the practical exercise “Simulation of Biological Neuronal Networks” and/or one of the seminars (“Current Research Topics in Systems Neuroscience” or “Language and Brain, Language Ability, Neurobiological Basis”) is only permitted if both lectures have been completed.

- **From Membrane to Brain (4 ECTS)**
- **Computational Neuroscience (11 ECTS)**
- **Simulation of Biological Neuronal Networks (2 ECTS)**
- **Seminar: Current Research Topics in Systems Neuroscience OR Sprache und Gehirn, Sprachvermögen, neurobiologische Basis (in German) (2 ECTS)**

Please refer to the subject for further information and module descriptions.

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<table>
<thead>
<tr>
<th>Name of node</th>
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</thead>
<tbody>
<tr>
<td>Neuroscience</td>
<td>11LE13KT-FWB Neuroscience</td>
</tr>
<tr>
<td>Faculty</td>
<td>Technische Fakultät</td>
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</table>

<table>
<thead>
<tr>
<th>Pflicht/Wahlpflicht (P/WP)</th>
<th>Wahlpflicht</th>
</tr>
</thead>
</table>
In "Physik" (in German) you can choose the following courses:

- Experimentalphysik I (Mechanik, Gase und Flüssigkeiten) (6 ECTS) *
- Experimentalphysik II (Elektromagnetismus, Optik) (6 ECTS) *
- Experimentalphysik III (Spezielle Relativitätstheorie, Optik, Quantenphysik und Atomphysik) (7 ECTS)
- Theoretische Physik I (Mechanik und Relativitätstheorie) (7 ECTS)
- Theoretische Physik II (Elektromagnetismus und Optik) (7 ECTS)

* sofern noch nicht im Bachelor absolviert

Please refer to the subject for further information and module descriptions.
Achtung: Nur 3 Studierende pro Jahr! Frühzeitige Anmeldung bei der Studienfachberatung Informatik erforderlich!

In "Psychologie" (in German) you can choose the following courses:
- Sozialpsychologie - Vorlesung (5 ECTS)
- Pädagogische Psychologie – Vorlesung (5 ECTS)
- Pädagogische Psychologie – Seminar (3 ECTS)
- Arbeits- und Organisationspsychologie – Vorlesung (5 ECTS)

Please refer to the subject for further information and module descriptions.
In "Sustainable Systems Engineering" (in English) you can choose the following courses:
- Complex Networks (6 ECTS)
- Design and Monitoring of Large Infrastructures (5 ECTS)
- Netzintegration und Regelung / Grid Integration and Control (5 ECTS)
- The science of complex systems - fundamentals and applications (6 ECTS)

Please refer to the subject for further information and module descriptions.
In "Economics / Wirtschaftswissenschaften" (some courses in English, some courses in German) you can choose the following courses:

- Computational Economics: Non-linear Optimization (6 ECTS)
- Computational Finance (6 ECTS)
- Business Analytics (6 ECTS)
- Futures and Options (6 ECTS)
- Gesundheitsmanagement (6 ECTS)
- Gesundheitsmanagement - Fallstudien im Krankenhausmanagement (6 ECTS)
- Electronic Markets (6 ECTS)
- Marketing Management (6 ECTS)
- Personal- und Organisationstheorien (6 ECTS)
- Principles of Finance (6 ECTS) *(10 students per year at most!)*
- Unternehmensbesteuerung (6 ECTS)
- Business Analytics (Seminar) (6 ECTS)
- Advanced Macroeconomics I (6 ECTS)
- Advanced Microeconomics I (6 ECTS)
- Advanced Microeconomics II (6 ECTS)
- Economic Policy and Public Choice (6 ECTS)
- Regulation and Competition Policy (4 ECTS)

Please refer to the subject for further information and module descriptions.
As per the examination regulations, exceptions for courses in subjects usually not available might be granted.

Those exceptions must be requested in advance. The application must be submitted formally (i.e. as a letter), with the reason for the choice of the course stated, to the Computer Science program coordinator. It is assumed that the lecturer of the course and the program coordinator for the relevant subject have given their consent to the participation of the Computer Science student. The dean of studies for Computer Science decides on the application.
Students have to do one study project (18 ECTS credits).

If they want to specialize in the area of Artificial Intelligence (AI) or in Cyber-Physical Systems (CPS), they have to take an according study project with a topic related to the respective area.
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studienprojekt</td>
<td>11LE13MO-9140 Studienprojekt Allgemein</td>
</tr>
</tbody>
</table>

Responsible

Prof. Dr. Hannah Bast

Faculty

Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>18.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>540 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>3</td>
</tr>
<tr>
<td>Duration</td>
<td></td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Pflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>in jedem Semester</td>
</tr>
</tbody>
</table>

Compulsory requirement

keine | none

Recommended requirement

general fundamental mathematical knowledge, practical and theoretical foundations in Computer Science, subject-specific knowledge for the chosen topics

Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studienprojekt Allgemein</td>
<td>Veranstaltung</td>
<td></td>
<td></td>
<td></td>
<td>540 Stunden</td>
</tr>
</tbody>
</table>

Qualification

In this module students get involved in the actual research process of the chosen work group/chair. Depending on their personal field of interest and their expertise in various research and teaching areas offered at the Department of Computer Science, they decide on a specific topic and deepen their knowledge and skills in this area as well as their overall proficiency in academic work and research. They learn to work on the different tasks required for the specific project under given technical specifications, to develop appropriate systems and to work constructively in projects. Students acquire the ability to familiarize themselves with new problems and do independent background research. They will work with modern development environments and adhere to the generally accepted quality standards. During the project, working in a team as well as observing the rules of good scientific work will be expected.
### Examination achievement

The graded assessment is (depending on the topic) either a written research paper (if it is rather a theoretical or fundamentally based topic; length usually maximum 40 pages) or the creation of a software or a demonstrator including a sufficient documentation (according to the scientific standards). Details are agreed upon with the supervisor (usually a person authorized to conduct examinations at the Department of Computer Science) when the topic is assigned.

### Course achievement

As a rule, the course work consists of the following components:
- regular attendance of (team) meetings or discussions with the supervisor
- oral presentation (usually 20 - 30 minutes) with subsequent discussion

### Recommendation

Language is usually English, but might be negotiable (changed to German)

Please learn about the procedure of finding a topic and registering for the project in good time. (For instance, see "A to Z - Study FAQ" under "Studies and Teaching" on our faculty website.)

Students are expected to self-organize the given tasks and do background research.

### Usability

Compulsory module for students of the study program

If a specialization is intended, students have to take the study project in the respective specialization area (AI or CPS).
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studienprojekt</td>
<td>11LE13MO-9140 Studienprojekt Allgemein</td>
</tr>
</tbody>
</table>

**Veranstaltungsgruppe**

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studienprojekt Allgemein</td>
<td>11LE13VG-9140 Studienprojekt-Allgemein</td>
</tr>
</tbody>
</table>

**ECTS-Points**

<table>
<thead>
<tr>
<th>Workload</th>
<th>540 Stunden</th>
<th>hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance</td>
<td>ca. 20 Stunden</td>
<td></td>
</tr>
<tr>
<td>Independent study</td>
<td>ca. 520 Stunden</td>
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<tr>
<td>Hours of week</td>
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<td></td>
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<tr>
<td>Recommended semester</td>
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<tr>
<td>Frequency</td>
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<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
<td></td>
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</tbody>
</table>

**Contents**

Students choose a specific topic (according to their personal interest and present field of expertise) from one of the research and teaching areas offered at the Department of Computer Science. They work independently under a supervisor and connected to the research team on subject specific tasks, gaining experience with scientific work and working with state-of-the-art development environments or lab equipment.

**Examination achievement**

| Siehe Modulebene | See module level |

**Course achievement**

| Siehe Modulebene | See module level |

**Literature**

Depends on topic; provided by the supervisor

**Compulsory requirement**

keine | none

**Recommended requirement**

allgemeine mathematische Grundlagen, praktische und theoretische Grundlagen der Informatik, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general fundamental mathematical knowledge, practical and theoretical foundations in Computer Science, subject-specific knowledge for the chosen topics
## Studienprojekt KI

### Name of module
Studienprojekt KI

### Number of module
11LE13MO-9140KI

### Responsible
Prof. Dr. Hannah Bast

### Faculty
Technische Fakultät

### ECTS-Points
18.0

### Workload
540 Stunden | hours

### Recommended semester
3

### Duration

### Pflicht/Wahlpflicht (P/WP)

### Frequency
in jedem Semester

### Compulsory requirement

keine | none

### Recommended requirement
allgemeine mathematische Grundlagen, praktische und theoretische Grundlagen der Informatik, themenspezifische Vorkenntnisse aus dem Bereich der Künstlichen Intelligenz | general fundamental mathematical knowledge, practical and theoretical foundations in Computer Science, subject-specific knowledge for the field of Artificial Intelligence

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studienprojekt im Bereich KI</td>
<td>Veranstaltung</td>
<td></td>
<td></td>
<td></td>
<td>540 Stunden</td>
</tr>
</tbody>
</table>

### Qualification

In this module students get involved in the actual research process of the chosen work group/chair, specifically in the area of Artificial Intelligence. Depending on their personal field of interest and their expertise in various research and teaching areas connected to AI and offered at the Department of Computer Science, they decide on a specific topic and deepen their knowledge and skills in this area as well as their overall proficiency in academic work and research. They learn to work on the different tasks required for the specific project under given technical specifications, to develop appropriate systems and to work constructively in projects. Students acquire the ability to familiarize themselves with new problems and do independent background research. They will work with modern development environments and adhere to the generally accepted quality standards. During the project, working in a team as well as observing the rules of good scientific work will be expected.
**Examination achievement**

The graded assessment is (depending on the topic) either a written research paper (if it is rather a theoretical or fundamentally based topic; length usually maximum 40 pages) or the creation of a software or a demonstrator including a sufficient documentation (according to the scientific standards). Details are agreed upon with the supervisor (usually a person authorized to conduct examinations at the Department of Computer Science) when the topic is assigned.

**Course achievement**

As a rule, the course work consists of the following components:
- regular attendance of (team) meetings or discussions with the supervisor
- oral presentation (usually 20 - 30 minutes) with subsequent discussion

**Recommendation**

Language is usually English, but might be negotiable (changed to German)

Please learn about the procedure of finding a topic and registering for the project in good time. (For instance, see "A to Z - Study FAQ" under "Studies and Teaching" on our faculty website.)

Students are expected to self-organize the given tasks and do background research.

**Usability**

Compulsory module for students of the study program
- M.Sc. Informatik / Computer Science (2020) for students intending a specialization in AI.

If no specialization is intended, students have to take the general study project "Studienprojekt Allgemein"
**Name of module**

Studienprojekt KI

**Number of module**

11LE13MO-9140KI

---

**Veranstaltungsgruppe**

Studienprojekt im Bereich KI

---

**Event type**

Veranstaltung

**Number**

11LE13VG-9140KI-Studienprojekt-KI

---

**ECTS-Points**

Workload 540 Stunden | hours

Attendance ca. 20 Stunden

Independent study ca. 520 Stunden

---

**Recommended semester**

---

**Frequency**

unregelmäßig

---

**Pflicht/Wahlpflicht (P/WP)**

---

**Contents**

Students choose a specific topic (according to their personal interest and present field of expertise) from one of the research and teaching areas connected to the field of Artificial Intelligence and offered at the Department of Computer Science.

They work independently under a supervisor and connected to the research team on subject specific tasks, gaining experience with scientific work and working with state-of-the-art development environments or lab equipment.

**Examination achievement**

Depending on specific project: written research paper or creation of a software program or demonstrators

**Course achievement**

Active participation (attendance can be required) in (team) discussions or meetings with the supervisor, self-organizing the given tasks, doing background research, presentation of results

**Literature**

Depends on topic; provided by the supervisor

**Compulsory requirement**

keine | none

**Recommended requirement**

allgemeine mathematische Grundlagen, praktische und theoretische Grundlagen der Informatik, themenspezifische Vorkenntnisse aus dem Bereich der Künstlichen Intelligenz | general fundamental mathematical knowledge, practical and theoretical foundations in Computer Science, subject-specific knowledge for the field of Artificial Intelligence
## Studienprojekt CPS

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studienprojekt CPS</td>
<td>11LE13MO-9140 CPS</td>
</tr>
</tbody>
</table>

**Responsible**

Prof. Dr. Hannah Bast

**Faculty**

Technische Fakultät

<table>
<thead>
<tr>
<th>ECTS-Points</th>
<th>18.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>540 Stunden</td>
</tr>
<tr>
<td>Recommended semester</td>
<td>3</td>
</tr>
<tr>
<td>Duration</td>
<td></td>
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<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td>Pflicht</td>
</tr>
<tr>
<td>Frequency</td>
<td>in jedem Semester</td>
</tr>
</tbody>
</table>

**Compulsory requirement**

keine | none

**Recommended requirement**

allgemeine mathematische Grundlagen, praktische und theoretische Grundlagen der Informatik, themenspezifische Vorkenntnisse aus dem Bereich der Cyber-Physical Systems | general fundamental mathematical knowledge, practical and theoretical foundations in Computer Science, subject-specific knowledge for the field of Cyber-Physical Systems

### Assigned Courses

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>P/WP</th>
<th>ECTS</th>
<th>HoW</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studienprojekt im Bereich CPS</td>
<td>Veranstaltung</td>
<td></td>
<td></td>
<td></td>
<td>540 Stunden</td>
</tr>
</tbody>
</table>

**Qualification**

In this module students get involved in the actual research process of the chosen work group/chair, specifically in the area of Cyber-Physical Systems. Depending on their personal field of interest and their expertise in various research and teaching areas connected to CPS and Embedded Systems and offered at the Department of Computer Science, they decide on a specific topic and deepen their knowledge and skills in this area as well as their overall proficiency in academic work and research. They learn to work on the different tasks required for the specific project under given technical specifications, to develop appropriate systems and to work constructively in projects. Students acquire the ability to familiarize themselves with new problems and do independent background research. They will work with modern development environments and adhere to the generally accepted quality standards. During the project, working in a team as well as observing the rules of good scientific work will be expected.
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

<table>
<thead>
<tr>
<th>Examination achievement</th>
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<tr>
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<table>
<thead>
<tr>
<th>Course achievement</th>
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<tbody>
<tr>
<td>As a rule, the course work consists of the following components:</td>
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<tr>
<td>- regular attendance of (team) meetings or discussions with the supervisor</td>
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<tr>
<td>- oral presentation (usually 20 - 30 minutes) with subsequent discussion</td>
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<table>
<thead>
<tr>
<th>Recommendation</th>
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<tbody>
<tr>
<td>Language is usually English, but might be negotiable (changed to German)</td>
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<tr>
<td>Please learn about the procedure of finding a topic and registering for the project in good time. (For instance, see &quot;A to Z - Study FAQ&quot; under &quot;Studies and Teaching&quot; on our faculty website.)</td>
</tr>
<tr>
<td>Students are expected to self-organize the given tasks and do background research.</td>
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<table>
<thead>
<tr>
<th>Usability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compulsory module for students of the study program</td>
</tr>
<tr>
<td>- M.Sc. Informatik / Computer Science (2020) for students intending a specialization in CPS.</td>
</tr>
<tr>
<td>If no specialization is intended, students have to take the general study project &quot;Studienprojekt Allgemein&quot;</td>
</tr>
</tbody>
</table>
Master of Science (M.Sc.) in the subject Informatik/Computer Science - Hauptfach (Examination regulations version 2020)

**Name of module**

<table>
<thead>
<tr>
<th>Name of module</th>
<th>Number of module</th>
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</thead>
<tbody>
<tr>
<td>Studienprojekt CPS</td>
<td>11LE13MO-9140 CPS</td>
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**Veranstaltungsgruppe**

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<th>Veranstaltungsgruppe</th>
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**Event type**

<table>
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</thead>
<tbody>
<tr>
<td></td>
<td>11LE13VG-9140CPS-Studienprojekt-CPS</td>
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</table>

**ECTS-Points**

<table>
<thead>
<tr>
<th>Workload</th>
<th>540 Stunden</th>
<th>hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance</td>
<td>ca. 20 Stunden</td>
<td></td>
</tr>
<tr>
<td>Independent study</td>
<td>ca. 520 Stunden</td>
<td></td>
</tr>
<tr>
<td>Hours of week</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recommended semester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>unregelmäßig</td>
<td></td>
</tr>
<tr>
<td>Pflicht/Wahlpflicht (P/WP)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Contents**

Students choose a specific topic (according to their personal interest and present field of expertise) from one of the research and teaching areas connected to the field of Cyber-Physical Systems/Embedded Systems and offered at the Department of Computer Science. They work independently under a supervisor and connected to the research team on subject specific tasks, gaining experience with scientific work and working with state-of-the-art development environments or lab equipment.

**Examination achievement**

Depending on specific project: written research paper or creation of a software program or demonstrators

**Course achievement**

Active participation (attendance can be required) in (team) discussions or meetings with the supervisor, self-organizing the given tasks, doing background research, presentation of results

**Literature**

Depends on topic; provided by the supervisor

**Compulsory requirement**

keine | none

**Recommended requirement**

allgemeine mathematische Grundlagen, praktische und theoretische Grundlagen der Informatik, themenspezifische Vorkenntnisse aus dem Bereich der Cyber-Physical Systems | general fundamental mathematical knowledge, practical and theoretical foundations in Computer Science, subject-specific knowledge for the field of Cyber-Physical Systems
Epilogue

Modules in the context of the study areas

The **Advanced Lectures (6 or 12 ECTS)** encompass the following seven specific lectures: Software Engineering, Foundations of Artificial Intelligence, Image Processing and Computer Graphics, Algorithms Theory, Databases and Information Systems, Machine Learning, and Computer Architecture. These lectures serve as foundations for the thematically related specialization courses as they provide the basic concepts and introductory knowledge in the respective fields. If students are interested in a certain area as their personal field of expertise, while not mandatory as prerequisites it is strongly recommended to complete the according Advanced Lecture before deepening their knowledge in specialization courses, especially if they have no previous knowledge or qualifications in the respective area.

**Specialization courses (36 or 30 ECTS)** generally represent the research and teaching areas of the professors at the Department of Computer Science in Freiburg. There is a big variety of different topics covered by about 50 Specialization Courses, roughly summarized in the following subject areas:

- Algorithms / Bioinformatics
- Computer Architecture / Operating Systems / Embedded Systems
- Software / Programming Languages
- Artificial Intelligence / Robotics / Machine Learning
- Computer vision / Computer graphics
- Network / communication
- Data bases

A special subset of the specialization courses is provided in relation to the two specialization areas: Artificial Intelligence and Cyber-Physical Systems. Students planning to specialize in one of these areas have to take at least 4 related courses. Generally, students can select any specialization course if they are confident to bring the required basics. This way, they acquire an individually chosen skill set to form their personal competency profile.

In the two **Seminars (6 ECTS)** students improve their research skills and develop further scientific qualifications relevant for a future academic career. The acquired interdisciplinary skills are also beneficial for professional qualifications. Topics vary every semester, as lecturers like to keep the content of the seminars up-to-date with their current research.

The **Lab Course (6 ECTS)** can be chosen from different thematic backgrounds, to complement the so far created skill profile of the students. With a hands-on approach, it provides practical experience and transfers the previously mostly theoretical concepts and methods into applications for real-life problems.

In the **Study Project (18 ECTS)** students work supervised, but independently on a current research topic in one of the workgroups / chairs of the department. This module is very similar to the Thesis, in regards to the expected skills and knowledge as well as technical and organizational aspects. As it has to be completed before the Thesis can be started, it can be used as ground work, building upon the results and experience already gained. As the formal requirements are less strict and more flexible, it can be seen as a trial run for the Thesis, reducing performance pressure by having familiarized with some steps already.
The **Customized Course Selection (18 ECTS)** serves to further develop a personal profile and offers different choices. While students are expected to broaden their view by gaining insight into one or more subjects outside the area of computer science, they can also take one additional computer science lecture here. Anyways, as computer scientists often work in interdisciplinary groups with experts from other subjects, it is beneficial to have some basic knowledge and qualifications in a possible application area like Bioinformatics, Economics, Microsystems or Sustainable Systems Engineering, Medical Science or Neuroscience. So taking some courses from subjects outside of computer science is mandatory. Students can either choose to concentrate on one subject and taking multiple courses there or to mix basic courses from different subjects to create an individual profile.