Faculty of Engineering

Module description

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

universität freiburg

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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

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B. Overview of Study program and teaching unit

Subject	Informatik / Computer Science
Degree	Master of Science (M.Sc.)
Scope of ECTS credit points	120
Study duration	4 Semesters / 2 years

Study format	Full-time
Type of study program	Consecutive and research oriented
Regular study duration	4 Semesters
University	Albert-Ludwigs-Universität Freiburg / University of Freiburg
Faculty	Faculty of Engineering
Department	Department of Computer Science
Homepage	https://www.tf.uni-freiburg.de/en/study-programs/computer-science
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.
Language(s)	English (some elective courses in application areas in German)
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 April 2025 / 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
- 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 (see section "Curriculum" (resp. Studieninhalt & -plan in German) just before the graph).
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 is 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 the 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.

Name of module	Number of module
Master module	11LE13MO-8000-MSc-679-2020
Responsible	
Prof. Dr. Hannah Bast	
Faculty	
Faculty of Engineering	

ECTS-Points	30.0
Workload	900 Stunden | hours
Hours of week	
Recommended semester	4
Duration	1 semester / 6 months
Compulsory/Elective (C/E)	Compulsory
Frequency	each term

Compulsory requirement
Erfolgreicher Abschluss von Modulen mit einem Umfang von mindestens 72 ECTS-Punkten und erfolgreiches Absolvieren des Moduls Studienprojekt im Rahmen des Studiengangs Master of Science im Fach Informatik/Computer Science. | Successful completion of modules with a scope of at least 72 ECTS credits and successful completion of the study project module as part of the Master of Science degree in computer science.
Recommended requirement
Vertiefte Kenntnisse in mathematischen Grundlagen, in praktischen und theoretischen Informatikbereichen und insbesondere im Themenbereich, in dem die Arbeit erstellt wird | In-depth knowledge of mathematical fundamentals, in practical and theoretical IT areas and especially in the subject area in which the thesis will be written

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload

Contents
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
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
Active participation (attendance can be required) in meetings with the supervisor, self-organizing the given tasks, doing background research
Literature
Abhängig vom Thema | Depending on topic
Usability
Compulsory Module for students of the study pogram ■ M.Sc. in Informatik / Computer Science (PO 2020)

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Name of node	**Number of node**
Advanced Lectures	11LE13KT-Weiterf Vorlesung
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory
ECTS-Points	12.0

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.

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Name of module	**Number of module**
Algorithms Theory	11LE13MO-2010_PO 2020
Responsible	
Prof. Dr. Hannah Bast Prof. Dr. Fabian Kuhn	
Organizer	
Department of Computer Science, Algorithms and Complexity	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

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					
Name	Type	C/E	ECTS	HoW	Workload
Algorithms Theory	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Algorithms Theory - Exercises	excercise course	Core elective		1.0	

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

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Name of module	Number of module
Algorithms Theory	11LE13MO-2010_PO 2020
course	
Algorithms Theory	
Event type	Number
lecture course	11LE13V-2010
Organizer	
Department of Computer Science, Algorithms and Data Structures Department of Computer Science, Algorithms and Complexity	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	47 Stunden | hours
Independent study	118 Stunden | hours
Hours of week	3.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

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
Literature
■ Jon Kleinberg and Éva Tardos: Algorithm Design, Addison Wesley ■ Thomas H. Cormen, Charles E. Leiserson, Robert L. Rivest, and Cliford Stein: Introduction to Algorithms, MIT Press ■ 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

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Name of module	**Number of module**
Algorithms Theory	11LE13MO-2010_PO 2020
course	
Algorithms Theory - Exercises	
Event type	Number
excercise course	11LE13Ü-2010
Organizer	
Department of Computer Science, Algorithms and Data Structures Department of Computer Science, Algorithms and Complexity	

ECTS-Points	
Attendance	15 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement
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.

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Name of module	**Number of module**
Datenbanken und Informationssysteme / Data Bases and Information Systems	11LE13MO-2060_PO 2020
Responsible	
Prof. Dr. Hannah Bast Prof. Dr. Joschka Bödecker	
Organizer	
Department of Computer Science, Algorithms and Data Structures Department of Computer Science, Databases and Information Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

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					
Name	Type	C/E	ECTS	HoW	Workload
Datenbanken und Informationssysteme / Data Bases and Information Systems - Lecture	lecture course	Compulsory	6.0	2.0	180 Stunden | hours
Datenbanken und Informationssysteme / Data Bases and Information Systems - Exercises	excercise course	Compulsory		2.0	

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)

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Name of module	Number of module
Datenbanken und Informationssysteme / Data Bases and Information Systems	11LE13MO-2060_PO 2020
course	
Datenbanken und Informationssysteme / Data Bases and Information Systems - Lecture	
Event type	Number
lecture course	11LE13V-2060
Organizer	
Department of Computer Science, Algorithms and Data Structures Department of Computer Science, Databases and Information Systems	

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	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Languages	german, english

Contents

Aufgabe von Datenbanken ist die Verwaltung großer, dauerhafter Datenbestände in der Weise, dass eine Menge von Benutzern diese Daten unabhängig voneinander, effizient, bequem und sicher verarbeiten können.
Der Stoff der Vorlesung wird in Übungen und einem parallel laufenden Praktikum anhand verschiedener Datenbanksysteme konkretisiert.
Es werden im einzelnen die folgenden Aspekte behandelt:

- Einführung in Datenbanken
- Datenbankentwurf und Datenmodelle
- Datenmanipulationssprachen
- Entwurfstheorie
- Datenintegrität
- Transaktionsverwaltung
- Physische Datenorganisation und aktuelle Entwicklungen.

|
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 theoretiscal 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
- Physical data organization and current developments.

Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Literature
■ G. Lausen: Datenbanken - Grundlagen und XML-Technologien, Elsevier Spektrum Akademischer Verlag, 2005. ■ A. Heuer, G. Saake: Datenbanken - Konzepte und Sprachen, International Thomson Publishing, 2. Auflage, 2000. ■ A. Kemper, A. Eickler: Datenbanksysteme - Eine Einführung, Oldenbourg, 4. Auflage, 2001. ■ G. Vossen: Datenmodelle, Datenbanksprachen und Datenbank-Management-Systeme, Oldenbourg, 4. Auflage, 2000.
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	**Number of module**
Datenbanken und Informationssysteme / Data Bases and Information Systems	11LE13MO-2060_PO 2020
course	
Datenbanken und Informationssysteme / Data Bases and Information Systems - Exercises	
Event type	Number
excercise course	11LE13Ü-2060
Organizer	
Department of Computer Science, Databases and Information Systems	

ECTS-Points	
Attendance	30 Stunden | hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Languages	german, english

Contents
Die Übungen vertiefen den in der Vorlesung behandelten Stoff in Theorie und Praxis. Die Übungsblätter enthalten auch am Computer zu lösende Aufgaben. Hierzu ist ein Vertrautmachen mit der benötigten Software erforderlich. | 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.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	Number of module
Foundations of Artificial Intelligence	11LE13MO-2040_PO 2020
Responsible	
Prof. Dr. Joschka Bödecker Prof. Dr. Frank Roman Hutter	
Organizer	
Department of Computer Science, Computer Science, Foundations of Artificial Intelligence Department of Computer Science, Autonomous Intelligent Systems Department of Computer Science, Professorship in Neurorobotics Department of Computer Science, Professorship in Machine Learning	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
keine | none Grundlagenkenntnisse in mathematischer Logik können hilfreich sein | asic knowledge about formal logic can be helpful

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Foundations of Artificial Intelligence - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Foundations of Artificial Intelligence - Exercises	excercise course	Core elective		1.0	

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

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Name of module	Number of module
Foundations of Artificial Intelligence	11LE13MO-2040_PO 2020
course	
Foundations of Artificial Intelligence - Lecture	
Event type	Number
lecture course	11LE13V-2040
Organizer	
Department of Computer Science, Computer Science, Foundations of Artificial Intelligence Department of Computer Science, Autonomous Intelligent Systems Department of Computer Science, Professorship in Neurorobotics Department of Computer Science, Professorship in Machine Learning	

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	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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

Recommended requirement
keine | none Grundlagenkenntnisse in mathematischer Logik können hilfreich sein | Basic knowledge about formal logic can be helpful

↑

Name of module	**Number of module**
Foundations of Artificial Intelligence	11LE13MO-2040_PO 2020
course	
Foundations of Artificial Intelligence - Exercises	
Event type	Number
excercise course	11LE13Ü-2040
Organizer	
Department of Computer Science, Computer Science, Foundations of Artificial Intelligence Department of Computer Science, Autonomous Intelligent Systems Department of Computer Science, Professorship in Neurorobotics Department of Computer Science, Professorship in Machine Learning	

ECTS-Points	
Attendance	13 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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	**Number of module**
Image Processing and Computer Graphics	11LE13MO-2050_PO 2020
Responsible	
Prof. Dr. Thomas Brox Prof. Dr.-Ing. Matthias Teschner	
Organizer	
Department of Computer Science, Computer Graphics Department of Computer Science, Pattern Recognition and Image Processing	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Fundamental mathematical knowledge and programming skills in C/C++

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Image Processing and Computer Graphics - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Image Processing and Computer Graphics - Exercise	excercise course	Core elective		1.0	

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

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Name of module	Number of module
Image Processing and Computer Graphics	11LE13MO-2050_PO 2020
course	
Image Processing and Computer Graphics - Lecture	
Event type	Number
lecture course	11LE13V-2050
Organizer	
Department of Computer Science, Computer Graphics Department of Computer Science, Pattern Recognition and Image Processing	

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	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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++

↑

Name of module	**Number of module**
Image Processing and Computer Graphics	11LE13MO-2050_PO 2020
course	
Image Processing and Computer Graphics - Exercise	
Event type	Number
excercise course	11LE13Ü-2050
Organizer	
Department of Computer Science, Computer Graphics Department of Computer Science, Pattern Recognition and Image Processing	

ECTS-Points	
Attendance	13 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	Number of module
Machine Learning	11LE13MO-1153_PO 2020
Responsible	
Prof. Dr. Joschka Bödecker Prof. Dr. Frank Roman Hutter	
Organizer	
Department of Computer Science, Professorship in Neurorobotics Department of Computer Science, Professorship in Machine Learning	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
Knowledge in Grundlagen der Künstlichen Intelligenz / Foundations of Artifical Intelligence

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Maschinelles Lernen / Machine Learning - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Maschinelles Lernen / Machine Learning - Exercises	excercise course	Core elective		1.0	

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.

Examination achievement
written or oral examination
Course achievement
To prepare for the exam, there can be a mock exam (written or oral).
Examination weight
■ Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2009: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade. ■ Bachelor of Science in Embedded Systems Engineering, Academic regulations of 2011: The grade of the module is triple-weighted according to the number of its ECTS-points in the calculation of the overall grade. ■ Master of Science in Embedded Systems Engineering, Academic regulations of 2012: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. ■ Master of Science in Informatik, Academic regulations of 2005: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade. ■ Master of Science in Informatik, Academic regulations of 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Usability
Elective Module for students of the study program ■ Bachelor of Science in Embedded Systems Engineering ■ Bachelor of Science in Informatik ■ Lehramt an Gymnasien in Informatik, major subject ■ Lehramt an Gymnasien in Informatik, additional major subject ■ Lehramt an Gymnasien in Informatik, major subject in combination with Visual Arts or Music ■ Master of Science in Embedded Systems Engineering - Robotics and Computer Vision - Verteilte Systeme - Personal Profile ■ Master of Science in Informatik - Graphische und Bildverarbeitende Systeme - Künstliche Ingelligenz und Robotic - Kognitive technische Systeme - Information Systems

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Name of module	**Number of module**
Machine Learning	11LE13MO-1153_PO 2020
course	
Maschinelles Lernen / Machine Learning - Lecture	
Event type	Number
lecture course	11LE13V-1153
Organizer	
Department of Computer Science, Professorship in Machine Learning	

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	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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
Goodfellow, Bengio and Courville: Deep Learning
Michael Nielsen: Neural Networks and Deep Learning

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

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 assigments. 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.
Teaching method
For in-class lectures: Despite the large lecture rooms, a teacher-centered style shall be enriched as much as possible by measures like: ■ interactive question and answer rounds ■ discussions in sub-groups, reporting to the large group ■ cross-teaching ■ problem-oriented teaching e.g. via data analysis competition ■ repetition of important concepts in slightly altered contexts. **For virtual lectures:** ■ flipped classroom teaching with videos provided ■ Q&A sessions to discuss the videos' content ■ Cross-teaching via Ilias forum ■ problem-oriented teaching e.g. via data analysis competition ■ repetition of important concepts in slightly altered contexts.

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Name of module	**Number of module**
Machine Learning	11LE13MO-1153_PO 2020
course	
Maschinelles Lernen / Machine Learning - Exercises	
Event type	Number
excercise course	11LE13Ü-1153
Organizer	
Department of Computer Science, Professorship in Machine Learning	

ECTS-Points	
Attendance	15 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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	Number of module
Rechnerarchitektur / Computer Architecture	11LE13MO-2020_PO 2020
Responsible	
Prof. Dr. Armin Biere Prof. Dr. Christoph Scholl	
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

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

Name	Type	C/E	ECTS	HoW	Workload
Rechnerarchitektur / Computer Architecture - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Rechnerarchitektur / Computer Architecture - Exercises	excercise course	Core elective		1.0	

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.
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 reached at least 50% of points per exercise sheet.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Weiterführende Vorlesung | Advanced Lectures ■ M.Sc. Embedded Systems Engineering (ESE) (2021) 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 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)

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Name of module	**Number of module**
Rechnerarchitektur / Computer Architecture	11LE13MO-2020_PO 2020
course	
Rechnerarchitektur / Computer Architecture - Lecture	
Event type	Number
lecture course	11LE13V-2020
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	

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	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

An introduction to fundamental questions, methods and techniques of computer design and computer architecture is given. The following topics are included:
Instructions, Logic Design, Digital Circuit Verification, Testing, Placement & Routing, Single-Cycle Datapath & Control, Pipelining and Pipelining Hazards, Parallelism, Exception and Interrupts

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:
- J.Teich: Digitale Hardware/Software-Systeme, Springer Verlag, 1997.
- Becker, Bernd and Drechsler, Rolf and Molitor, Paul, „Technische Informatik – Eine Einführung“, Pearson Studium.
- Tanenbaum: Structured Computer Organization, Prentice Hall, 3rd Edition, 1990.

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 ++

↑

Name of module	**Number of module**
Rechnerarchitektur / Computer Architecture	11LE13MO-2020_PO 2020
course	
Rechnerarchitektur / Computer Architecture - Exercises	
Event type	Number
excercise course	11LE13Ü-2020
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	

ECTS-Points	
Attendance	15 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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	Number of module
Softwaretechnik / Software Engineering	11LE13MO-2030_PO 2020
Responsible	
Prof. Dr. Andreas Podelski	
Organizer	
Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge about practical Computer Science concepts, algorithms and datastructure, Programming Skills

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Softwaretechnik / Software Engineering - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Softwaretechnik / Software Engineering - Exercises	excercise course	Core elective		1.0	

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

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Name of module	Number of module
Softwaretechnik / Software Engineering	11LE13MO-2030_PO 2020
course	
Softwaretechnik / Software Engineering - Lecture	
Event type	Number
lecture course	11LE13V-2030
Organizer	
Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	40 Stunden | hours
Independent study	127 Stunden | hours
Hours of week	3.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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)

↑

Name of module	Number of module
Softwaretechnik / Software Engineering	11LE13MO-2030_PO 2020
course	
Softwaretechnik / Software Engineering - Exercises	
Event type	Number
excercise course	11LE13Ü-2030
Organizer	
Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering	

ECTS-Points	
Attendance	13 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
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

↑

Name of node	**Number of node**
Specialization Course	11LE13KT-Spez Vorlesung
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory
ECTS-Points	36.0

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.

↑

Name of module	**Number of module**
Advanced Algorithms	11LE13MO-1326_PO 2020
Responsible	
Prof. Dr. Fabian Kuhn	
Organizer	
Department of Computer Science, Algorithms and Complexity	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

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					
Name	Type	C/E	ECTS	HoW	Workload
Advanced Algorithms	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Advanced Algorithms	excercise course	Core elective		2.0	

Qualification
Students have advanced knowlegde 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
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**
Advanced Algorithms	11LE13MO-1326_PO 2020
course	
Advanced Algorithms	
Event type	Number
lecture course	11LE13V-1326
Organizer	
Department of Computer Science, Algorithms and Complexity	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	28
Independent study	124
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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 learningk - 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.

↑

Name of module	**Number of module**
Advanced Algorithms	11LE13MO-1326_PO 2020
course	
Advanced Algorithms	
Event type	Number
excercise course	11LE13Ü-1326
Organizer	
Department of Computer Science, Algorithms and Complexity	

ECTS-Points	
Attendance	28
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	**Number of module**
Advanced Computer Graphics	11LE13MO-1106_PO 2020
Responsible	
Prof. Dr.-Ing. Matthias Teschner	
Organizer	
Department of Computer Science, Computer Graphics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

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					
Name	Type	C/E	ECTS	HoW	Workload
Fortgeschrittene Computergraphik / Advanced Computer Graphics - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Fortgeschrittene Computergraphik / Advanced Computer Graphics - Exercises	excercise course	Core elective		2.0	

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 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**
Advanced Computer Graphics	11LE13MO-1106_PO 2020
course	
Fortgeschrittene Computergraphik / Advanced Computer Graphics - Lecture	
Event type	Number
lecture course	11LE13V-1106
Organizer	
Department of Computer Science, Computer Graphics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	30 Stunden
Independent study	90 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature

- Dutre, Bala, Bekaert: Advanced Global Illumination, A K Peters, 2006
- Pharr, Humphreys: Physically Based Rendering, Elsevier, 2010
- Shirley, Keith Morley: Realistic Ray Tracing, A K Peters, 2003
- Suffern: Ray Tracing From The Ground Up, A K Peters, 2007
- Foley, vanDam, Feiner, Hughes: Computer Graphics - Principles and Practice -, Addison Wesley, ISBN 0-201-84840-6
- Tomas Moller and Eric Haines: Real-Time Rendering, A. K. Peters Limited, 1999, ISBN 1-56881-182-9
- David F. Rogers: Procedural Elements for Computer Graphics, McGraw-Hill, 1998, ISBN 0-07-053548-5
- OpenGL Programming Guide, Second Edition, Addison-Wesley, 1997, ISBN 0-201-461138-2

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

↑

Name of module	**Number of module**
Advanced Computer Graphics	11LE13MO-1106_PO 2020
course	
Fortgeschrittene Computergraphik / Advanced Computer Graphics - Exercises	
Event type	Number
excercise course	11LE13Ü-1106
Organizer	
Department of Computer Science, Computer Graphics	

ECTS-Points	
Attendance	30 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Practical development of ray tracing components based on concepts from lectures
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Advanced Deep Learning	11LE13MO-1146_PO 2020
Responsible	
Prof. Dr. Abhinav Valada	
Organizer	
Department of Computer Science, Autonomous Intelligent Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
none
Recommended requirement
Fundamentals of Deep Learning Machine Learning

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Advanced Deep Learning	lecture course	Core elective	6.0	2.0	180 hours
Advanced Deep Learning	excercise course	Core elective		2.0	

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

↑

Name of module	**Number of module**
Advanced Deep Learning	11LE13MO-1146_PO 2020
course	
Advanced Deep Learning	
Event type	Number
lecture course	11LE13V-1146_PO 2020
Organizer	
Department of Computer Science, Autonomous Intelligent Systems	

ECTS-Points	6.0
Workload	180 hours
Attendance	32 Stunden
Independent study	116 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	**Number of module**
Advanced Deep Learning	11LE13MO-1146_PO 2020
course	
Advanced Deep Learning	
Event type	Number
excercise course	11LE13Ü-1146_PO 2020
Organizer	
Department of Computer Science, Autonomous Intelligent Systems	

ECTS-Points	
Attendance	32 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Students learn to apply some of the techniques from the lecture.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	Number of module
Algorithms for Wireless Communication	11LE13MO-1157_PO 2020
Responsible	
Prof. Dr. Christian Schindelhauer	
Organizer	
Department of Computer Science, Computer Networks and Telematics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge about Distributed Systems, Computer Networks, Algorithms and Data Structures

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Algorithms for Wireless Communication	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Algorithms for Wireless Communication	excercise course	Core elective		2.0	

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
course	
Algorithms for Wireless Communication	
Event type	Number
lecture course	11LE13V-1157_PO 2020
Organizer	
Department of Computer Science, Computer Networks and Telematics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	32 Stunden
Independent study	116 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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 accoustic 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.

↑

Name of module	**Number of module**
Algorithms for Wireless Communication	11LE13MO-1157_PO 2020
course	
Algorithms for Wireless Communication	
Event type	Number
excercise course	11LE13Ü-1157_PO 2020
Organizer	
Department of Computer Science, Computer Networks and Telematics	

ECTS-Points	
Attendance	32 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Languages	german, english

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	**Number of module**
Automated Machine Learning	11LE13MO-1415_PO 2020
Responsible	
Prof. Dr. Frank Roman Hutter	
Organizer	
Department of Computer Science, Professorship in Machine Learning	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

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

Name	Type	C/E	ECTS	HoW	Workload
Automated Machine Learning	lecture course	Core elective	6.0	2.0	180 hours
Automated Machine Learning	excercise course	Core elective		2.0	

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.
Examination achievement
oral examination (usually 30 or 45 minutes)
Course achievement
Doing a project (workload about 80h)
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 **and** 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
Automated Machine Learning	11LE13MO-1415_PO 2020
course	
Automated Machine Learning	
Event type	Number
lecture course	11LE13V-1415
Organizer	
Department of Computer Science, Professorship in Machine Learning	

ECTS-Points	6.0
Workload	180 hours
Attendance	30
Independent study	90
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
* Design of configuration spaces for automated machine learning * Hyperparameter Optimization with Bayesian Optimization * Neural architecture search with Reinforcement learning, Bayesian Optimization and Evoluationary 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

↑

Name of module	**Number of module**
Automated Machine Learning	11LE13MO-1415_PO 2020
course	
Automated Machine Learning	
Event type	Number
excercise course	11LE13Ü-1415
Organizer	
Department of Computer Science, Professorship in Machine Learning	

ECTS-Points	
Attendance	30
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Die Übungen orientieren sich an den Vorlesungen. In den praktisch angelegten Übungen werden die Inhalte der Vorlesung praktisch selbstständig umgesetzt. Am Ende gibt es ein großes Projekt (80h), in dem die Studierenden die Inhalte eigenständig auf ein neues Problem anwenden. Dieses Projekt wird im ersten Teil der mündlichen Prüfung vorgestellt. 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	**Number of module**
Bioinformatics I	11LE13MO-1309_PO 2020
Responsible	
Prof. Dr. Rolf Backofen	
Organizer	
Department of Computer Science, Bioinformatics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

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

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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					
Name	Type	C/E	ECTS	HoW	Workload
Bioinformatik I / Bioinformatics I - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Bioinformatik I / Bioinformatics I - Exercises	excercise course	Core elective		2.0	

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. M.Sc. Embedded Systems Engineering **and** Part of the specialization Biomedical Engineering (BE) in 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**
Bioinformatics I	11LE13MO-1309_PO 2020
course	
Bioinformatik I / Bioinformatics I - Lecture	
Event type	Number
lecture course	11LE13V-1309
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	30
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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

Recommended requirement

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

↑

Name of module	**Number of module**
Bioinformatics I	11LE13MO-1309_PO 2020
course	
Bioinformatik I / Bioinformatics I - Exercises	
Event type	Number
excercise course	11LE13Ü-1309
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	
Attendance	28 Stunden
Independent study	124 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Participating in the 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.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	Number of module
Bioinformatics II	11LE13MO-1310_PO 2020
Responsible	
Prof. Dr. Rolf Backofen	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

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					
Name	Type	C/E	ECTS	HoW	Workload
Bioinformatik II / Bioinformatics II - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Bioinformatik II / Bioinformatics II - Exercises	excercise course	Core elective		2.0	

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.

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 (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. M.Sc. Embedded Systems Engineering **and** Part of the specialization Biomedical Engineering (BE) in M.Sc. 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
Bioinformatics II	11LE13MO-1310_PO 2020
course	
Bioinformatik II / Bioinformatics II - Lecture	
Event type	Number
lecture course	11LE13V-1310
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	32 Stunden
Independent study	116 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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

Literature
- Clote, Backofen: Computational Molecular Biologie, An Introduction. Wiley & Sons. ISBN-10: 0471872520 ISBN-13: 978-0471872528 - Durbin et al.: Biological Sequence Analysis. Cambridge University Press. ISBN-10: 0521629713 ISBN-13: 978-0521629713 - 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

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Name of module	**Number of module**
Bioinformatics II	11LE13MO-1310_PO 2020
course	
Bioinformatik II / Bioinformatics II - Exercises	
Event type	Number
excercise course	11LE13Ü-1310
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	
Attendance	32 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	**Number of module**
Blockchain and Cryptocurrencies	11LE13MO-1235_PO 2020
Responsible	
Prof. Dr. Peter Thiemann	
Organizer	
Department of Computer Science, Programming Languages	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Blockchain and Cryptocurrencies	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Blockchain and Cryptocurrencies	excercise course	Core elective		2.0	

Qualification
Students know the concepts of how blockchains work. They have insight in application scenarios, especially regarding the monetary background,Bitcoin and other crypto currencies. 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 impliciations and risks.

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

↑

Name of module	**Number of module**
Blockchain and Cryptocurrencies	11LE13MO-1235_PO 2020
course	
Blockchain and Cryptocurrencies	
Event type	Number
lecture course	11LE13V-1235
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	28
Independent study	124
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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 impliciations and risks
Examination achievement
See module level
Course achievement
See module level
Literature
■ Fabian Schär, Aleksander Berentsen. Bitcoin, Blockchain und Kryptoassets: Eine umfassende Einführung. Books on Demand. 2017 ■ Narayanan et al. Bitcoin and Cryptocurrency Technologies. Princeton University Press. 2016.
Compulsory requirement
keine | none
Recommended requirement
keine | none

↑

Name of module	**Number of module**
Blockchain and Cryptocurrencies	11LE13MO-1235_PO 2020
course	
Blockchain and Cryptocurrencies	
Event type	Number
excercise course	11LE13Ü-1235

ECTS-Points	
Attendance	28
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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	
Department of Computer Science, Programming Languages	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Compilerbau / Compiler Construction	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Compilerbau / Compiler Construction	excercise course	Core elective		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	Number of module
Compilerbau / Compiler Construction	11LE13MO-1208_PO 2020
course	
Compilerbau / Compiler Construction	
Event type	Number
lecture course	11LE13V-1208
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	28 Stunden | hours
Independent study	152 Stunden | hours
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Languages	german, english

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
■ Andrew Appel with Jens Palsberg, Modern Compiler Implementation in Java, 2nd edition. Cambridge University Press (2002) ■ Alfred V. Aho, Monica S. Lam, Ravi Sethi, and Jeffrey D. Ullman. Compilers, Principles, Techniques, and Tools (2nd Edition). Prentice Hall, 2006. ■ Reinhard Wilhelm and Dieter Maurer. Übersetzerbau -- Theorie, Konstruktion, Generierung -- 2. Auflage. Lehrbuch. Springer-Verlag, Berlin, Heidelberg, 1996
Compulsory requirement
keine | none
Recommended requirement
keine | none

↑

Name of module	**Number of module**
Compilerbau / Compiler Construction	11LE13MO-1208_PO 2020
course	
Compilerbau / Compiler Construction	
Event type	Number
excercise course	11LE13Ü-1208
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	
Attendance	28 Stunden | hours
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
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.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	Number of module
Computer Vision	11LE13MO-1123_PO 2020
Responsible	
Prof. Dr. Thomas Brox	
Organizer	
Department of Computer Science, Pattern Recognition and Image Processing	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

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					
Name	Type	C/E	ECTS	HoW	Workload
Computer Vision - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Computer Vision - Exercises	excercise course	Core elective		2.0	

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.
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 ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
Computer Vision	11LE13MO-1123_PO 2020
course	
Computer Vision - Lecture	
Event type	Number
lecture course	11LE13V-1123
Organizer	
Department of Computer Science, Pattern Recognition and Image Processing	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	32 Stunden
Independent study	148 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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"

↑

Name of module	**Number of module**
Computer Vision	11LE13MO-1123_PO 2020
course	
Computer Vision - Exercises	
Event type	Number
excercise course	11LE13Ü-1123
Organizer	
Department of Computer Science, Pattern Recognition and Image Processing	

ECTS-Points	
Attendance	30 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	**Number of module**
Concurrency, Theory and Practice	11LE13MO-1225_PO 2020
Responsible	
Prof. Dr. Peter Thiemann	
Organizer	
Department of Computer Science, Programming Languages	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine
Recommended requirement
keie

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Concurrency, Theory and Practice	lecture course	Core elective	6.0	2.0	180 Stunden/hours
Concurrency, Theory and Practice	excercise course	Core elective		2.0	

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)

↑

Name of module	**Number of module**
Concurrency, Theory and Practice	11LE13MO-1225_PO 2020
course	
Concurrency, Theory and Practice	
Event type	Number
lecture course	11LE13V-1225
Organizer	
Department of Computer Science, Programming Languages	

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	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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	**Number of module**
Concurrency, Theory and Practice	11LE13MO-1225_PO 2020
course	
Concurrency, Theory and Practice	
Event type	Number
excercise course	11LE13Ü-1225
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	
Attendance	32 Stunden/hours
Hours of week	2.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Extension, consolidation, and practical exploration of lecture contents
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	Number of module
Cyber-Physikalische Systeme - Diskrete Modelle / Cyber-Physical Systems – Discrete Models	11LE13MO-2070_PO 2020
Responsible	
Prof. Dr. Andreas Podelski	
Organizer	
Department of Computer Science, Software Engineering	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

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					
Name	Type	C/E	ECTS	HoW	Workload
Cyber-Physikalische Systeme – Diskrete Modelle / Cyber-Physical Systems – Discrete Models - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Cyber-Physikalische Systeme – Diskrete Modelle / Cyber-Physical Systems – Discrete Models - Exercises	excercise course	Core elective		1.0	

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 ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Essential Lectures in Computer Science 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)

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Name of module	Number of module
Cyber-Physikalische Systeme - Diskrete Modelle / Cyber-Physical Systems – Discrete Models	11LE13MO-2070_PO 2020
course	
Cyber-Physikalische Systeme – Diskrete Modelle / Cyber-Physical Systems – Discrete Models - Lecture	
Event type	Number
lecture course	11LE13V-2070
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering Department of Computer Science, Operating Systems	

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	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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 BDDbased 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
■ Christel Baier, Joost-Pieter Katoen, Principles of Model Checking, MIT, 2008, ISBN 9780262026499 ■ B. Berard, M. Bidoit, A. Finkel, F. Laroussinie, Systems and Software Verification, Springer, 2001, ISBN 3642074782 ■ E. Clarke, O. Grumberg, D. Peled, "Model Checking", MIT Press 1999 ■ Kropf, Thomas, "Introduction to Formal Hardware Verification", Springer, 1999, ISBN 3-540-65445-3
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

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Name of module	**Number of module**
Cyber-Physikalische Systeme - Diskrete Modelle / Cyber-Physical Systems – Discrete Models	11LE13MO-2070_PO 2020
course	
Cyber-Physikalische Systeme – Diskrete Modelle / Cyber-Physical Systems – Discrete Models - Exercises	
Event type	Number
excercise course	11LE13Ü-2070
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering Department of Computer Science, Operating Systems	

ECTS-Points	
Attendance	15 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	Number of module
Cyber-Physical Systems – Program Verification	11LE13MO-1207_v2_PO 2020
Responsible	
Prof. Dr. Andreas Podelski	
Organizer	
Department of Computer Science, Software Engineering	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

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					
Name	Type	C/E	ECTS	HoW	Workload
Cyber-Physische Systeme - Programmverifikation / Cyber-Physical Systems – Program Verification	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Cyber-Physische Systeme - Programmverifikation / Cyber-Physical Systems – Program Verification	excercise course	Core elective		2.0	

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.

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 ■ 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)

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Name of module	Number of module
Cyber-Physical Systems – Program Verification	11LE13MO-1207_v2_PO 2020
course	
Cyber-Physische Systeme - Programmverifikation / Cyber-Physical Systems – Program Verification	
Event type	Number
lecture course	11LE13V-1207_v2
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering Department of Computer Science, Operating Systems	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	26 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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 rulesin 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 Almeida, J.B., Frade, M.J., Pinto, J.S., Melo de Sousa, S. - Rigorous Software Development - An Introduction to Program Verification
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).

↑

Name of module	**Number of module**
Cyber-Physical Systems – Program Verification	11LE13MO-1207_v2_PO 2020
course	
Cyber-Physische Systeme - Programmverifikation / Cyber-Physical Systems – Program Verification	
Event type	Number
excercise course	11LE13Ü-1207_v2
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering Department of Computer Science, Operating Systems	

ECTS-Points	
Attendance	26 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Debugging and Fuzzing	11LE13MO-1158_PO 2020
Responsible	
Prof. Dr. Armin Biere	
Organizer	
Department of Computer Science, Computer Architecture	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

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					
Name	Type	C/E	ECTS	HoW	Workload
Debugging and Fuzzing	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Debugging and Fuzzing	excercise course	Core elective		2.0	

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

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Name of module	Number of module
Debugging and Fuzzing	11LE13MO-1158_PO 2020
course	
Debugging and Fuzzing	
Event type	Number
lecture course	11LE13V-1158_PO 2020
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	30
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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 recommende: Advanced Programming Skills (in C, C++, Java, or Python) Software Engineering, Algorithms and Data-Structures

↑

Name of module	**Number of module**
Debugging and Fuzzing	11LE13MO-1158_PO 2020
course	
Debugging and Fuzzing	
Event type	Number
excercise course	11LE13Ü-1158_PO 2020
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	
Attendance	30
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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	**Number of module**
Digital Health (DH)	11LE13MO-1160_PO 2020
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

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

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Digital Health (DH)	lecture course	Core elective	6.0	2.0	180 hours
Digital Health (DH)	excercise course	Compulsory		2.0	

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.
Course achievement
written composition Reports on exercises to be submitted
Literature
Up-to-date literature recommendations are provided during the lectures.
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 Biomedical Engineering ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung 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

↑

Name of module	**Number of module**
Digital Health (DH)	11LE13MO-1160_PO 2020
course	
Digital Health (DH)	
Event type	Number
lecture course	11LE13V-1160_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	6.0
Workload	180 hours
Attendance	32 hours
Independent study	116 hours
Hours of week	2.0
Recommended semester	1
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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

Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

↑

Name of module	**Number of module**
Digital Health (DH)	11LE13MO-1160_PO 2020
course	
Digital Health (DH)	
Event type	Number
excercise course	11LE13Ü-1160_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	32 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Language	english

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

↑

Name of module	**Number of module**
Echtzeitbetriebssysteme und Worst-Case-Execution-Times / Real-Time Operating Systems and Worst-Case Execution Times	11LE13MO-1240_PO 2020
Responsible	
Prof. Dr. Christoph Scholl	
Organizer	
Department of Computer Science, Operating Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Knowledge in computer architecture / Computer Architecture and software technology / Software Enginee-ring

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Echtzeitbetriebssysteme und Worst-Case-Execution-Times / Real-Time Operating Systems and Worst-Case Execution Times	lecture course	Core elective	6.0	3.0	180 hours
Echtzeitbetriebssysteme and Worst-Case-Execution-Times/ Real-Time Operating Systems and Worst-Case Execution Times	excercise course	Core elective		1.0	

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.

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
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	**Number of module**
Echtzeitbetriebssysteme und Worst-Case-Execution-Times / Real-Time Operating Systems and Worst-Case Execution Times	11LE13MO-1240_PO 2020
course	
Echtzeitbetriebssysteme und Worst-Case-Execution-Times / Real-Time Operating Systems and Worst-Case Execution Times	
Event type	Number
lecture course	11LE13V-1240
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	

ECTS-Points	6.0
Workload	180 hours
Attendance	64 Stunden | hours
Independent study	116 Stunden | hours
Hours of week	3.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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 Enginee-ring

↑

Name of module	**Number of module**
Echtzeitbetriebssysteme und Worst-Case-Execution-Times / Real-Time Operating Systems and Worst-Case Execution Times	11LE13MO-1240_PO 2020
course	
Echtzeitbetriebssysteme and Worst-Case-Execution-Times/ Real-Time Operating Systems and Worst-Case Execution Times	
Event type	Number
excercise course	11LE13Ü-1240
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	
Attendance	16 Stunden | hours
Hours of week	1.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	**Number of module**
Einführung in die Kryptographie / Introduction to Cryptography	11LE13MO-1401_PO 2020
Responsible	
Prof. Dr. Christian Schindelhauer	
Organizer	
Department of Computer Science, Computer Networks and Telematics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Einführung in die Kryptographie/Introduction to Cryptography- Lecture	lecture course	Core elective		2.0	180 Stunden | hours
Einführung in die Kryptographie/Introduction to Cryptography-Exercise	excercise course	Core elective		2.0	

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).

Course achievement
keine | none
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 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**
Einführung in die Kryptographie / Introduction to Cryptography	11LE13MO-1401_PO 2020
course	
Einführung in die Kryptographie/Introduction to Cryptography- Lecture	
Event type	Number
lecture course	11LE13V-1401
Organizer	
Department of Computer Science, Computer Networks and Telematics-VB	

ECTS-Points	
Workload	180 Stunden | hours
Attendance	32 Stunden
Independent study	116 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

Vorlesungsthemen:

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

|

Lecture topics

- Symmetric-Key Cryptography
- Public-Key-Cryptography
- Cryptographic Protocols
- One-Way-Functions
- One-Time Pads
- Quantum Cryptography

Examination achievement

Siehe Modulebene | See module level

Course achievement

Siehe Modulebene | See module level

Literature

- Introduction to Cryptography, Principles and Applications, Hans Delfs, Helmut Knebel, Springer 2015
- Einführung in die Kryptographie, Johannes Buchmann, Springer, 2009

Compulsory requirement
keine | none
Recommended requirement
keine | none

↑

Name of module	**Number of module**
Einführung in die Kryptographie / Introduction to Cryptography	11LE13MO-1401_PO 2020
course	
Einführung in die Kryptographie/Introduction to Cryptography-Exercise	
Event type	Number
excercise course	11LE13Ü-1401
Organizer	
Department of Computer Science, Computer Networks and Telematics-VB	

ECTS-Points	
Attendance	32 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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	**Number of module**
Einführung in Embedded Systems / Introduction to Embedded Systems	11LE13MO-910_PO 2020
Responsible	
Prof. Dr. Oliver Amft Prof. Dr. Christoph Scholl	
Organizer	
Department of Computer Science, Operating Systems Department of Computer Science, Professorship in Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

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					
Name	Type	C/E	ECTS	HoW	Workload
Einführung in Embedded Systems / Introduction to Embedded Systems - Lecture	lecture course	Compulsory	6.0	3.0	180 Stunden | hours
Einführung in Embedded Systems / Introduction to Embedded Systems - Exercises	excercise course	Compulsory		1.0	

Qualification
Die Studierenden verstehen die spezifischen Eigenschaften eingebetteter Systeme, ihre Architektur und Komponenten, ihre Hardware- und Softwareschnittstelle, die Kommunikation zwischen Komponenten, grundlegende Analog-Digital-Analog-Umwandlungsmethoden, stromsparende Designs und Spezifikationstechniken. Sie sind in der Lage eingebettete Systeme mit VHDL, Zustandsdiagrammen und Petri-Netzen zu spezifizieren sowie Eigenschaften des modellierten Systems anzugeben und zu diskutieren und grundlegende Programme in C für eine eingebettete Plattform zu schreiben. | 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 con-

version 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) ■ polyvalenter 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

↑

Name of module	Number of module
Einführung in Embedded Systems / Introduction to Embedded Systems	11LE13MO-910_PO 2020
course	
Einführung in Embedded Systems / Introduction to Embedded Systems - Lecture	
Event type	Number
lecture course	11LE13V-910
Organizer	
Department of Computer Science, Operating Systems Department of Computer Science, Professorship in Embedded Systems	

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	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Languages	german, english

Contents
Eingebettete Systeme gelten als die Schlüsselanwendung der Informationstechnologie in den kommenden Jahren und sind, wie der Name bereits andeutet, Systeme, bei denen Informationsverarbeitung in eine Umgebung eingebettet ist und dort komplexe Regelungs-, Steuerungs- oder Datenverarbeitungsaufgaben übernimmt. Die Vorlesung beschäftigt sich mit grundlegenden Konzepten für Modellierung und Entwurf Eingebetteter Systeme. Sie behandelt u.a. Spezifikationssprachen und Methoden für Eingebettete Systeme (wie z.B. Statecharts, Petrinetze, VHDL), Abbildung von Spezifikationen auf Prozesse, Hardware Eingebetteter Systeme sowie Hardware-/Software-Codesign. Es wird auf die Bauelemente eines Eingebetteten Systems eingegangen (z.B. Prozessoren, AD-/DA-Wandler, Sensoren, Sensorschnittstellen, Speicher) und es werden Methoden zum Entwurf und zur Optimierung der zugehörigen Schaltungen bezüglich Geschwindigkeit, Energieverbrauch und Testbarkeit vorgestellt. | 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.
Examination achievement
Siehe Modulebene | See module level

Course achievement
Siehe Modulebene | See module level
Literature
1. Marwedel, P.: Embedded System Design. Springer-Verlag New York, Inc., 2006. 2. Marwedel, P. ; Wehmayer, L.: Eingebettete Systeme. Springer-Verlag Berlin, 2007. 3. Ritter, J. ; Molitor, P.: VHDL - Eine Einführung. Pearson Studium, 2004. 4. Chang, K. C.: Digital Design and Modeling with VHDL and Synthesis. IEEE Computer Society Press, 1996. 5. Teich, J. ; Haubelt, C.: Digitale Hardware/Software-Systeme. Berlin : Springer-Verlag Berlin, 2007. 6. Baker, R. J.; Li, H. W.; Boyce, D. E.: CMOS Circuit Design, Layout, and Simulation. IEEE Press Series on Microelectronic Systems, 1998. 7. Rabaey, J. M.; Chandrakasan, A. P.; Nikolic, B.: Digital Integrated Circuits. Prentice-Hall, 2003. 8. Tietze, U.; Schenk, C.: Halbleiter Schaltungstechnik. Springer-Verlag, 2002. 9. Weste, N.; Eshraghian, K.: Principles of CMOS VLSI Design; A Systems Perspective. Addison-Wesley, 1993.
Compulsory requirement
keine | none
Recommended requirement
Grundkennnisse 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 ++

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Name of module	Number of module
Einführung in Embedded Systems / Introduction to Embedded Systems	11LE13MO-910_PO 2020
course	
Einführung in Embedded Systems / Introduction to Embedded Systems - Exercises	
Event type	Number
excercise course	11LE13Ü-910
Organizer	
Department of Computer Science, Operating Systems Department of Computer Science, Professorship in Embedded Systems	

ECTS-Points	
Attendance	15 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Compulsory
Languages	german, english

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

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404_PO 2020
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Embedded Computing Entrepreneurship (2ES)	lecture course	Core elective	6.0	1.0	180 Stunden / Hours
Embedded Computing Entrepreneurship (2ES)	seminar	Core elective		1.0	
Embedded Computing Entrepreneurship (2ES)	excercise course	Core elective		2.0	

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

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Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404_PO 2020
course	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
lecture course	11LE13V-1404_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Attendance	16 Stunden / Hours
Independent study	116 Stunden / Hours
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404_PO 2020
course	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
seminar	11LE13S-1404_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	16 Stunden / Hours
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404_PO 2020
course	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
excercise course	11LE13Ü-1404_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	32 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective

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

↑

Name of module	**Number of module**
Foundations of Deep Learning	11LE13MO-1145_PO 2020
Responsible	
Prof. Dr. Frank Roman Hutter	
Organizer	
Department of Computer Science, Professorship in Machine Learning	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
none
Recommended requirement
Knowledge of linear algebra and machine learning

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Foundations of Deep Learning	lecture course	Core elective	6.0	3.0	180 Stunden
Foundations of Deep Learning	excercise course	Core elective			

Qualification
Foundations of Deep Learning, as covered in the book "Deep Learning" by Goodfellow, Bengio, and Courville.
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)

↑

Name of module	Number of module
Foundations of Deep Learning	11LE13MO-1145_PO 2020
course	
Foundations of Deep Learning	
Event type	Number
lecture course	11LE13V-1145
Organizer	
Department of Computer Science, Professorship in Machine Learning	

ECTS-Points	6.0
Workload	180 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In this course, we will cover the Foundations of Deep Learning, primarily using the book "Deep Learning" by Goodfellow, Bengio, and Courville.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement
Recommended requirement
Knowledge of linear algebra and machine learning

↑

Name of module	**Number of module**
Foundations of Deep Learning	11LE13MO-1145_PO 2020
course	
Foundations of Deep Learning	
Event type	Number
excercise course	11LE13Ü-1145
Organizer	
Department of Computer Science, Professorship in Machine Learning	

ECTS-Points	
Hours of week	
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Funktionale Programmierung / Functional Programming	11LE13MO-1510_PO 2020
Responsible	
Prof. Dr. Peter Thiemann	
Organizer	
Department of Computer Science, Programming Languages	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

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					
Name	Type	C/E	ECTS	HoW	Workload
Funktionale Programmierung / Functional Programming - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden
Funktionale Programmierung / Functional Programming - Exercises	excercise course	Core elective		1.0	

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)

↑

Name of module	**Number of module**
Funktionale Programmierung / Functional Programming	11LE13MO-1510_PO 2020
course	
Funktionale Programmierung / Functional Programming - Lecture	
Event type	Number
lecture course	11LE13V-1510
Organizer	
Department of Computer Science, Programming Languages Department of Computer Science, Software Engineering	

ECTS-Points	6.0
Workload	180 Stunden
Attendance	39 Stunden
Independent study	128 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

In diesem Kurs werden grundlegende bis fortgeschrittene Konzepte der funktionalen Programmierung anhand der Programmiersprache Haskell vermittelt.
Behandelte Themen:

- Definition von Funktionen, Patternmatching und Funktionen höherer Ordnung
- Typen und Typklassen
- Algebraische Datentypen
- Funktionale Datenstrukturen
- Applicative Parser
- Monaden und Monadentransformer
- Arrows
- Verifikation von funktionalen Programmen
- Monadische Ein/Ausgabe und Stream Ein/Ausgabe

|
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 datatypes
- Functional datastructures
- I/O, monads, and monad transformers
- Parsers and applicatives
- Arrows
- Verification of functional programs
- Generic programming with algebras

Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Literature
Grundlage für das erste Drittel der Vorlesung ist das Lehrbuch Programming in Haskell von Graham Hutton, welches auch in der TF-Bibliothek steht. Stephen Diehl's WHAT I WISH I KNEW WHEN LEARNING HASKELL | 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
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

↑

Name of module	**Number of module**
Funktionale Programmierung / Functional Programming	11LE13MO-1510_PO 2020
course	
Funktionale Programmierung / Functional Programming - Exercises	
Event type	Number
excercise course	11LE13Ü-1510
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	
Attendance	13 Stunden
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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 | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Grundlagen von Programmiersprachen / Essentials of Programming Languages	11LE13MO-1222_PO 2020
Responsible	
Prof. Dr. Peter Thiemann	
Organizer	
Department of Computer Science, Programming Languages	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

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					
Name	Type	C/E	ECTS	HoW	Workload
Grundlagen von Programmiersprachen / Essentials of Programming Languages - Lecture	lecture course	Core elective		3.0	180 Stunden | hours
Grundlagen von Programmiersprachen / Essentials of Programming Languages - Exercises	excercise course	Core elective		1.0	

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.

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

↑

Name of module	Number of module
Grundlagen von Programmiersprachen / Essentials of Programming Languages	11LE13MO-1222_PO 2020
course	
Grundlagen von Programmiersprachen / Essentials of Programming Languages - Lecture	
Event type	Number
lecture course	11LE13V-1222
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	
Workload	180 Stunden | hours
Attendance	42 Stunden | hours
Independent study	124 Stunden | hours
Hours of week	3.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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	**Number of module**
Grundlagen von Programmiersprachen / Essentials of Programming Languages	11LE13MO-1222_PO 2020
course	
Grundlagen von Programmiersprachen / Essentials of Programming Languages - Exercises	
Event type	Number
excercise course	11LE13Ü-1222
Organizer	
Department of Computer Science, Programming Languages	

ECTS-Points	
Attendance	14 Stunden | hours
Hours of week	1.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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	**Number of module**
Hardware Security and Trust	11LE13MO-1227_PO 2020
Responsible	
Prof. Dr. Christoph Scholl	
Organizer	
Department of Computer Science, Operating Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

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					
Name	Type	C/E	ECTS	HoW	Workload
Hardware Security and Trust - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Hardware Security and Trust - Exercise	excercise course	Core elective		1.0	

Qualification
Studierende kennen die Grundlagen in Bezug auf Kryptographie, Authentifizierung, Secret Sharing, VLSI Entwurf, Test, Zuverlässigkeit und Verifikation. Darauf aufbauend haben Sie einen Überblick über den aktuellen Stand der Forschung im Bereich "Hardware Security and Trust". Sie wissen Bescheid über verschiedene potentielle Angriffstechniken und kennen Möglichkeiten, diese Gefahren abzuwehren oder zu minimieren. 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	Number of module
Hardware Security and Trust	11LE13MO-1227_PO 2020
course	
Hardware Security and Trust - Lecture	
Event type	Number
lecture course	11LE13V-1227
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	48 Stunden
Independent study	116 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
Die Konvergenz von IT-Systemen, Datennetzwerken und allgegenwärtigen eingebetteten Geräten in sogenannten Cyber Physical Systems hat zum Entstehen neuer Sicherheitsbedrohungen und -anforderungen im Zusammenhang mit der System-Hardware geführt. Die Manipulation von Hardware-Komponenten, die Sicherheitsfunktionen implementieren, kann die Systemintegrität beeinträchtigen, unautorisierten Zugang zu geschützten Daten ermöglichen und geistiges Eigentum (Intellectual Property) gefährden. Diese Gefährdungen zu adressieren, ist wesentlich, wenn verhindert werden soll, dass Hardware zur Schwachstelle des gesamten Systems wird. Zumindest ein Grundlagenwissen in "Hardware Security and Trust" ist wichtig für jeden Systemingenieur. 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, 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
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	Number of module
Hardware Security and Trust	11LE13MO-1227_PO 2020
course	
Hardware Security and Trust - Exercise	
Event type	Number
excercise course	11LE13Ü-1227
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	

ECTS-Points	
Attendance	16 Stunden
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
Übungen vertiefen Methoden und Algorithmen, die in der Vorlesung eingeführt wurden, anhand von praktischen Beispielen. | Exercises expand on the methods and algorithms that were introduced in the lecture using practical examples.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
High-throughput data analysis with Galaxy	11LE13MO-1350_PO 2020
Responsible	
Prof. Dr. Rolf Backofen	
Organizer	
Department of Computer Science, Bioinformatics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden/hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	each term

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					
Name	Type	C/E	ECTS	HoW	Workload
High-throughput data analysis with Galaxy	lecture course	Core elective	6.0	1.0	180 Stunden | hours
High-throughput data analysis with Galaxy	excercise course	Core elective		3.0	

Qualification
In biological and medical research big data analysis is urgently needed for understandig 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
- are able to visualize the results
- know major resources of biologcal reference data
- can use Galaxy for data analyis

Examination achievement
Klausur / written exam

Course achievement
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

Pass/fail only compulsory elective module for students of the study program
- M.Sc. Microsystems Engineering (MSE) (2021) in Cuostomized Course Selection: Courses offered by other departmens of the University of Freiburg
- M.Sc. Mikrosystemtechnik (MST) (2021) in Individuelle Ergänzung Lehrangebot Uni Freiburg

↑

Name of module	**Number of module**
High-throughput data analysis with Galaxy	11LE13MO-1350_PO 2020
course	
High-throughput data analysis with Galaxy	
Event type	Number
lecture course	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	each term
Compulsory/Elective (C/E)	Core elective
Language	english

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	**Number of module**
High-throughput data analysis with Galaxy	11LE13MO-1350_PO 2020
course	
High-throughput data analysis with Galaxy	
Event type	Number
excercise course	11LE13Ü-1350_PO 2020
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	
Attendance	30 Stunden / hours
Hours of week	3.0
Recommended semester	2
Frequency	each term
Compulsory/Elective (C/E)	Core elective
Language	english

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: Distributed-memory parallelization on GPUs and accelerators	11LE50MO-5284 ESE PO 2021
Responsible	
Prof. Dr. Lars Pastewka	
Organizer	
Department of Microsystems Engineering, Simulation	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden/hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
None
Recommended requirement
Experience with programing in C++ or Fortran or Python; knowledge of common hardware architectures will be useful

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Höchstleistungsrechnen: Parallelisierung auf verteilten GPUs und Acceleratoren / High-performance computing: Distributed-memory parallelization on GPUs and accelarators	lecture course	Core elective	6.0	2.0	180 hours
Höchstleistungsrechnen: Parallelisierung auf verteilten GPUs und Acceleratoren / High-performance computing: Distributed-memory parallelization on GPUs and accelarators	excercise course	Core elective		2.0	

Qualification
After completing this class, the student will be able to… * …understand the difference between vectorization, shared-memory and distributed-memory parallelization * …write vectorized code for GPUs or accelerators using a hardware abstraction layer (such as Kokkos, Fortran, JAX or others) * …write distributed-memory code using the Message Passing Interface (MPI)

* …understand the foundations of the Lattice Boltzmann Method and how to parallelize it
Examination achievement
mündlicher Vortrag / oral examination Erstellung von Demonstratoren oder Software / Development of demonstrators or software
Course achievement
keine / none
Usability
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

↑

Name of module	Number of module
High-performance computing: Distributed-memory parallelization on GPUs and accelerators	11LE50MO-5284 ESE PO 2021
course	
Höchstleistungsrechnen: Parallelisierung auf verteilten GPUs und Acceleratoren / High-performance computing: Distributed-memory parallelization on GPUs and accelarators	
Event type	Number
lecture course	11LE50V-5284 PO 2021
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	6.0
Workload	180 hours
Attendance	60 on site
Independent study	120 self study
Hours of week	2.0
Recommended semester	2
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
* Hardware architectures * Vectorization, shared-memory and distributed memory parallelization * Low-level interfaces to GPUs and accelerators: CUDA, HIP * Abstraction layers for GPUs and accelerators: Kokkos, SYCL, Fortran and Python * Message Passing Interface (MPI) * Fluid Dynamics * Lattice Boltzmann Method * Domain decomposition
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement
None
Recommended requirement
Experience with programing in C++ or Fortran or Python; knowledge of common hardware architectures will be useful

↑

Name of module	**Number of module**
High-performance computing: Distributed-memory parallelization on GPUs and accelerators	11LE50MO-5284 ESE PO 2021
course	
Höchstleistungsrechnen: Parallelisierung auf verteilten GPUs und Acceleratoren / High-performance computing: Distributed-memory parallelization on GPUs and accelarators	
Event type	Number
excercise course	11LE50Ü-5284 PO 2021
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	
Hours of week	2.0
Recommended semester	2
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Languages	german, english

Contents
Throughout the term, the students will implement a parallel Lattice Boltzmann solver that can run on heterogeneous architectures. Students will be divided in groups that use different programming languages and programming models.
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	
Department of Microsystems Engineering, Simulation	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
None
Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Höchstleistungsrechnen mit Python / High-Performance Computing with Python	lecture course	Core elective	6.0	2.0	180 Stunden
Höchstleistungsrechnen mit Python / High-Performance Computing with Python - Project	excercise course	Core elective		2.0	

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 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 exam- regulations) can complete this elective module in the technical concentration area *Sustainable Materials Engineering* or *Interdisciplinary Profile - Modules <u>related to</u> the Subject Area.*

↑

Name of module	**Number of module**
High-Performance Computing: Fluid Mechanics with Python	11LE50MO-5285
course	
Höchstleistungsrechnen mit Python / High-Performance Computing with Python	
Event type	Number
lecture course	11LE50V-5285
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	6.0
Workload	180 Stunden
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective

Contents

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

Examination achievement

See module level

Course achievement

See module level

Literature

A. Scopatz, K.D. Huff, "Effective Computation in Physics" (O'Reilly 2015)
W.A. Wolf-Gladrow, "Lattice-Gas Cellular Automata and Lattice Boltzmann Models" (Springer 2000)

T. Krüger, H. Kusumaatmaja, A. Kuzmin, O. Shardt, G. Silva, E.M. Viggen, "The Lattice Boltzmann Method" (Springer 2017)
Compulsory requirement
None
Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

↑

Name of module	**Number of module**
High-Performance Computing: Fluid Mechanics with Python	11LE50MO-5285
course	
Höchstleistungsrechnen mit Python / High-Performance Computing with Python - Project	
Event type	Number
excercise course	11LE50Ü-5285
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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	**Number of module**
High-Performance Computing: Molecular Dynamics with C++	11LE50MO-5288 PO 2021
Responsible	
Prof. Dr. Lars Pastewka	
Organizer	
Department of Microsystems Engineering, Simulation	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
None
Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
High-Performance Computing: Molecular Dynamics with C++	lecture course	Core elective	6.0	2.0	180 hours
Molekularstatik und Molekulardynamik / Molecular Statics and Molecular Dynamics Veranstaltung_2	excercise course	Core elective		2.0	-

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 excercise sheets have been successfully completed.

Usability
■ 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
course	
High-Performance Computing: Molecular Dynamics with C++	
Event type	Number
lecture course	11LE50V-5286
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	6.0
Workload	180 hours
Attendance	56 Stunden
Independent study	124 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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
Understanding Molecular Simulation: From Algorithms to Applications, Daan Frenkel and Berend Smit (Academic Press, 2001) Computer simulation of liquids, M. P. Allen and Dominic J. Tildesley (Clarendon Press, Oxford, 1996)
Compulsory requirement
None
Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

↑

Name of module	**Number of module**
High-Performance Computing: Molecular Dynamics with C++	11LE50MO-5288 PO 2021
course	
Molekularstatik und Molekulardynamik / Molecular Statics and Molecular Dynamics Veranstaltung_2	
Event type	Number
excercise course	11LE50Ü-5286
Organizer	
Department of Microsystems Engineering, Simulation	

ECTS-Points	
Workload	-
Attendance	-
Independent study	-
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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.)

↑

Name of module	**Number of module**
Information Retrieval	11LE13MO-1304_PO 2020
Responsible	
Prof. Dr. Hannah Bast	
Organizer	
Department of Computer Science, Algorithms and Data Structures	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Grundlagen zu Algorithmen und Datenstrukturen, Programmierkenntnisse (C++ / C) | Fundamental knowledge about algorithms and data structures, programming skills (C++ / C)

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Suchmaschinen / Information Retrieval - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Suchmaschinen / Information Retrieval - Exercises	excercise course	Core elective		2.0	

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)

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. 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) ■ 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
Information Retrieval	11LE13MO-1304_PO 2020
course	
Suchmaschinen / Information Retrieval - Lecture	
Event type	Number
lecture course	11LE13V-1304
Organizer	
Department of Computer Science, Algorithms and Data Structures	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	30 Stunden
Independent study	120 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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. Netzwerkkommunikation und Benutzerschnittstellen: Webserver, Socket-Kommunikation, AJAX-Programmierung. | 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 Standartbuch 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 .

Compulsory requirement
keine | none

Recommended requirement
Grundlagen zu Algorithmen und Datenstrukturen, Programmierkenntnisse (C++ / C) | Fundamental knowledge about algorithms and data structures, programming skills (C++ / C)

↑

Name of module	Number of module
Information Retrieval	11LE13MO-1304_PO 2020
course	
Suchmaschinen / Information Retrieval - Exercises	
Event type	Number
excercise course	11LE13Ü-1304
Organizer	
Department of Computer Science, Algorithms and Data Structures	

ECTS-Points	
Attendance	30 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	**Number of module**
Interactive Proof Systems and Cryptographic Protocols	11LE13MO-1351_PO 2020
Responsible	
Prof. Dr. Christian Schindelhauer	
Organizer	
Department of Computer Science, Computer Networks and Telematics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden
Hours of week	4.0
Attendance	32 Studen
Independent study	116 Stunden
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine / none
Recommended requirement
Introduction to Cryptography

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Interactive Proof Systems and Cryptographic Protocols	lecture course	Core elective		2.0	
Interactive Proof Systems and Cryptographic Protocols	excercise course	Compulsory		2.0	

Qualification
Upon successful completion of this module, students will be able to understand, evaluate, and apply cryptographic protocols. They will be able to explain the theoretical foundations of interactive proof systems (e.g., AM, IP, MIP, PCP) and analyze their significance for complexity theory and modern cryptography. Additionally, they will be capable of implementing Zero-Knowledge Proofs and related concepts (e.g., Bulletproofs and mental card games) and assessing their applicability to real-world problems.

Examination achievement
Bei mehr als 16 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 16 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).
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. To pass the course work (Studienleistung), you must obtain at least 50% of the exercise points overall.
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) ■

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Name of module	Number of module
Interactive Proof Systems and Cryptographic Protocols	11LE13MO-1351_PO 2020
course	
Interactive Proof Systems and Cryptographic Protocols	
Event type	Number
lecture course	11LE13V-1351_PO 2020
Organizer	
Department of Computer Science, Computer Networks and Telematics	

ECTS-Points	
Attendance	32 Stunden
Independent study	116 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
. Cryptographic Protocols: Fiat-Shamir Protocol, Digital Signatures, Blockchain, Authentication 2. Interactive Proof Systems: Arthur-Merlin Systems (AM), IP (Interactive Proofs), Relationships between Complexity Classes: AM, IP, PSPACE, NP, Multi-Prover Interactive Proofs (MIP), Probabilistically Checkable Proofs (PCP): The PCP Theorem, Zero-Knowledge Proofs, particularly Bulletproofs 3. Mental Card Games: Coin Switching over the Telephone, Mental Poker, Card Game Toolboxes, Bayer-Grothe Shuffle
Examination achievement
Course achievement
Literature
Thaler, J., 2022. Proofs, Arguments, and Zero-knowledge Delfs, H., Knebl, H. and Knebl, H., 2002. Introduction to cryptography
Compulsory requirement
keine / None
Recommended requirement
Introduction to Cryptography

↑

Name of module	**Number of module**
Interactive Proof Systems and Cryptographic Protocols	11LE13MO-1351_PO 2020
course	
Interactive Proof Systems and Cryptographic Protocols	
Event type	Number
excercise course	11LE13Ü-1351_PO 2020
Organizer	
Department of Computer Science, Computer Networks and Telematics	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Compulsory
Language	english

Contents
Design, analysis and implementation of cryptographic protocols. Proof of correctness, soundness and completeness of Interactive Proof Systems. Mathematical questions about the underlying theory.
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	**Number of module**
Introduction to data driven life sciences	11LE13MO-1335_PO 2020
Responsible	
Prof. Dr. Rolf Backofen	
Organizer	
Department of Computer Science, Bioinformatics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Introduction to data driven life sciences	lecture course	Core elective	6.0	2.0	180 hours
Introduction to data driven life sciences	excercise course	Core elective		2.0	

Qualification
In biological and medical research big data analysis is urgently needed for understandig 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)

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Name of module	**Number of module**
Introduction to data driven life sciences	11LE13MO-1335_PO 2020
course	
Introduction to data driven life sciences	
Event type	Number
lecture course	11LE13V-1335
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	6.0
Workload	180 hours
Attendance	30 hours
Independent study	120 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

In biological and medical research big data analysis is urgently needed for understandig 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.

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Name of module	Number of module
Introduction to data driven life sciences	11LE13MO-1335_PO 2020
course	
Introduction to data driven life sciences	
Event type	Number
excercise course	11LE13Ü-1335
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	
Attendance	30 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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

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Name of module	**Number of module**
Isabelle/HOL: programming, verified!	11LE13MO-1336_PO 2020
Responsible	
Prof. Dr. Armin Biere	
Organizer	
Department of Computer Science, Computer Architecture	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

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					
Name	Type	C/E	ECTS	HoW	Workload
Isabelle/HOL: programming, verified!	lecture course	Core elective		2.0	180 Stunden | hours
Isabelle/HOL: programming, verified!	excercise course	Core elective		2.0	

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)

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Name of module	**Number of module**
Isabelle/HOL: programming, verified!	11LE13MO-1336_PO 2020
course	
Isabelle/HOL: programming, verified!	
Event type	Number
lecture course	11LE13V-1336_PO 2020
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	
Workload	180 Stunden | hours
Attendance	28 Stunden | hours
Independent study	124 Stunden | hours
Hours of week	2.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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.

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Name of module	**Number of module**
Isabelle/HOL: programming, verified!	11LE13MO-1336_PO 2020
course	
Isabelle/HOL: programming, verified!	
Event type	Number
excercise course	11LE13Ü-1336_PO 2020
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	
Attendance	28 Stunden | hours
Hours of week	2.0
Recommended semester	2
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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 practise on a larger scale proofs.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science	11LE13MO-1112_PO 2020
Responsible	
Prof. Dr. Rolf Backofen	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
none
Recommended requirement
Knowledge in Machine Learning and Bioinformatics, basic knowledge in Molecular biology, and practical experience in Python.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science - Exercises	excercise course	Core elective		2.0	

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)
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 Students of the M.Sc. programmes Microsystems Engg. and Mikrosystemtechnik (PO 2021) can select this module in the concentration area Biomedical Engineering (Biomedizinische Technik).

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Name of module	Number of module
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science	11LE13MO-1112_PO 2020
course	
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science - Lecture	
Event type	Number
lecture course	11LE13V-1112
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	30 Stunden
Independent study	120 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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 classication: an overview, Bioinformatics 2000
- T Fawcett, An introduction to ROC analysis, Pattern Recognition Letters 2006
- T Dietterich, Approximate statistical tests for comparing supervised classication 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
- P Baldi, G Pollastri, The principled design of large-scale recursive neural network architectures-dag-rnns and the protein structure prediction problem, The Journal of Machine Learning Research 2003
- C Leslie, E Eskin, W Noble, The spectrum kernel: A string kernel for SVM protein classication,Pacic Symposium on Biocomputing 2002
- X.W. Chen, Prediction of protein-protein interactions using random decision forest framework, Bioinformatics 2005

Compulsory requirement
none
Recommended requirement
Knowledge in Machine Learning and Bioinformatics, basic knowledge in Molecular biology, and practical experience in Python.

↑

Name of module	Number of module
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science	11LE13MO-1112_PO 2020
course	
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science - Exercises	
Event type	Number
excercise course	11LE13Ü-1112
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	
Attendance	30 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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	**Number of module**
Modelling and System Identification	11LE50MO-2080_PO 2020
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
keine | none
Recommended requirement
fundamental knowledge in higher mathematics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Modellbildung und Systemidentifikation / Modelling and System Identification - Lecture	lecture course	Core elective	6.0	2.0	180 hours
Modellbildung und Systemidentifikation / Modelling and System Identification - Exercises	excercise course	Core elective		2.0	

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)

Course achievement
The course work is successfully completed if both of the following criteria are met: 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. 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.
Usability
As compulsory elective in ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) in Advanced Microsystems Engineering ■ M.Sc. Microsystems Engineering (PO 2021) in Advanced Microsystems ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme 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)

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Name of module	Number of module
Modelling and System Identification	11LE50MO-2080_PO 2020
course	
Modellbildung und Systemidentifikation / Modelling and System Identification - Lecture	
Event type	Number
lecture course	11LE50V-2080
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	6.0
Workload	180 hours
Attendance	60 hours
Independent study	120 hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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 2. Ljung, L. (1999). System Identification: Theory for the User. Prentice Hall 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	**Number of module**
Modelling and System Identification	11LE50MO-2080_PO 2020
course	
Modellbildung und Systemidentifikation / Modelling and System Identification - Exercises	
Event type	Number
excercise course	11LE50Ü-2080
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	**Number of module**
Netzwerkalgorithmen / Network Algorithms	11LE13MO-1313_PO 2020
Responsible	
Prof. Dr. Fabian Kuhn	
Organizer	
Department of Computer Science, Algorithms and Complexity	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

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					
Name	Type	C/E	ECTS	HoW	Workload
Netzwerkalgorithmen / Network Algorithms - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Netzwerkalgorithmen / Network Algorithms - Exercises	excercise course	Core elective		1.0	

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.)
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)

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Name of module	Number of module
Netzwerkalgorithmen / Network Algorithms	11LE13MO-1313_PO 2020
course	
Netzwerkalgorithmen / Network Algorithms - Lecture	
Event type	Number
lecture course	11LE13V-1313
Organizer	
Department of Computer Science, Algorithms and Complexity	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	39 Stunden
Independent study	128 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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)

↑

Name of module	Number of module
Netzwerkalgorithmen / Network Algorithms	11LE13MO-1313_PO 2020
course	
Netzwerkalgorithmen / Network Algorithms - Exercises	
Event type	Number
excercise course	11LE13Ü-1313
Organizer	
Department of Computer Science, Algorithms and Complexity	

ECTS-Points	
Attendance	13 Stunden
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Numerical Optimal Control in Science and Engineering	11LE50MO-5249_PO 2020
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
None
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses. Numerical Optimization (NUMOPT), Modelling and System Identification (MSI), Systems and Control Bachelor or Master lectures.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Numerical Optimal Control in Science and Engineering	lecture course	Core elective	6.0	6.0	180 hours
Numerical Optimal Control in Science and Engineering	excercise course	Core elective		2.0	

Qualification
The students can formulate optimal control problems and implement and analyze several 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. 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** in Elective Courses in Computer Science ■ 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)

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Name of module	Number of module
Numerical Optimal Control in Science and Engineering	11LE50MO-5249_PO 2020
course	
Numerical Optimal Control in Science and Engineering	
Event type	Number
lecture course	11LE50V-5249
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	6.0
Workload	180 hours
Attendance	78 hours
Independent study	102 hours
Hours of week	6.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

- Introduction: Dynamic Systems and Optimization
- Rehearsal of Numerical Optimization
- Rehearsal of Parameter Estimation
- Discrete Time Optimal Control
- Dynamic Programming
- Continuous Time Optimal Control
- Numerical Simulation Methods
- Hamilton-Jacobi-Bellmann Equation
- Pontryagin and the Indirect Approach
- Direct Optimal Control
- Differential lgebraic Equations
- Periodic Optimal Control
- Real-Time Optimization for Model Predictive Control

Examination achievement

see module details

Course achievement

see module details

Literature

1. Manuscript "Numerical Optimal Control" by M. Diehl and S. Gros
2. Biegler, L.T., Nonlinear Programming, SIAM, 2010

Compulsory requirement

None

Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses. Numerical Optimization (NUMOPT), Modelling and System Identification (MSI), Systems and Control Bachelor or Master lectures.

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Name of module	Number of module
Numerical Optimal Control in Science and Engineering	11LE50MO-5249_PO 2020
course	
Numerical Optimal Control in Science and Engineering	
Event type	Number
excercise course	11LE50Ü-5249
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In the tutorial, the contents of the lecture will be deepened by means of theoretical examples and computer exercises.
Examination achievement
see moodule details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses. Numerical Optimization (NUMOPT), Modelling and System Identification (MSI), Systems and Control Bachelor or Master lectures.

↑

Name of module	**Number of module**
Numerical Optimization	11LE50MO-5243_PO 2020
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
none
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Numerische Optimierung / Numerical Optimization - Lecture	lecture course	Core elective	6.0	4.0	180 hours
Numerische Optimierung / Numerical Optimization - Exercises	excercise course	Core elective		2.0	

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)

↑

Name of module	**Number of module**
Numerical Optimization	11LE50MO-5243_PO 2020
course	
Numerische Optimierung / Numerical Optimization - Lecture	
Event type	Number
lecture course	11LE50V-5243
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	6.0
Workload	180 hours
Attendance	90 hours
Independent study	90 hours
Hours of week	4.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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 Limi- ted 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, Se- quential Quadratic and Convex Programming, Quadratic and Nonlinear Parametric Optimization

Examination achievement

see module details

Course achievement

see module details

Literature

1. Jorge Nocedal and Stephen J. Wright, Numerical Optimization, Springer, 2006
2. Amir Beck, Introduction to Nonlinear Optimization, MOS-SIAM Optimization, 2014
3. Stephen Boyd and Lieven Vandenberghe, Convex Optimization, Cambridge Univ. Press, 2004

Compulsory requirement

None

Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses

↑

Name of module	**Number of module**
Numerical Optimization	11LE50MO-5243_PO 2020
course	
Numerische Optimierung / Numerical Optimization - Exercises	
Event type	Number
excercise course	11LE50Ü-5243
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
In der Übung werden die Inhalte der Vorlesung anhand theoretischer Beispielaufgaben sowie mit Rechner-übungen 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	
Department of Computer Science, Computer Networks and Telematics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Basic knowledge in algorithms and data structures, computer networks, telecommunication systems and distributed systems

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Peer-to-Peer Netzwerke / Peer-to-Peer Networks - Lecture	lecture course	Core elective		2.0	180 Stunden | hours
Peer-to-Peer Netzwerke / Peer-to-Peer Networks - Exercises	excercise course	Core elective		2.0	180 Stunden | hours

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

↑

Name of module	**Number of module**
Peer-to-Peer Netzwerke / Peer-to-Peer Networks	11LE13MO-1314_PO 2020
course	
Peer-to-Peer Netzwerke / Peer-to-Peer Networks - Lecture	
Event type	Number
lecture course	11LE13V-1314
Organizer	
Department of Computer Science, Computer Networks and Telematics	

ECTS-Points	
Workload	180 Stunden | hours
Attendance	32 Stunden
Independent study	116 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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
■ Mahlmann, Schindelhauer: Peer-to-Peer-Netzwerke - Methoden und Algorithmen, Springer 2007 ■ 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	**Number of module**
Peer-to-Peer Netzwerke / Peer-to-Peer Networks	11LE13MO-1314_PO 2020
course	
Peer-to-Peer Netzwerke / Peer-to-Peer Networks - Exercises	
Event type	Number
excercise course	11LE13Ü-1314
Organizer	
Department of Computer Science, Computer Networks and Telematics	

ECTS-Points	
Workload	180 Stunden | hours
Attendance	32 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	Number of module
Probabilistic Graphical Models	11E13MO-1228_PO 2020
Responsible	
Prof. Dr. Joschka Bödecker	
Organizer	
Department of Computer Science, Professorship in Neurorobotics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden / houers
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine / none
Recommended requirement
Prior knowledge of probability theory, machine learning, deep learning, reinforcement learning is an advantage.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Probabilistic Graphical Models	lecture course	Core elective	6.0	3.0	180 Stunden / hours
Probabilistic Graphical Models	excercise course	Core elective		1.0	

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 excercise assignments

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

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Name of module	**Number of module**
Probabilistic Graphical Models	11E13MO-1228_PO 2020
course	
Probabilistic Graphical Models	
Event type	Number
lecture course	11E13V-1228_PO 2020
Organizer	
Department of Computer Science, Professorship in Neurorobotics	

ECTS-Points	6.0
Workload	180 Stunden / hours
Attendance	48 Stunden / hours
Independent study	116 Stunden / Hours
Hours of week	3.0
Recommended semester	1
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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
"Probabilistic Graphical Models: Principles and Applications", second edition, by Luis Enrique Sucar, Springer Nature Switzerland, https://doi.org/10.1007/978-3-030-61943-5
Compulsory requirement
keine / none
Recommended requirement
Prior knowledge of probability theory, machine learning, deep learning, reinforcement learning is an advantage.

↑

Name of module	Number of module
Probabilistic Graphical Models	11E13MO-1228_PO 2020
course	
Probabilistic Graphical Models	
Event type	Number
excercise course	11E13Ü-1228_PO 2020
Organizer	
Department of Computer Science, Professorship in Neurorobotics	

ECTS-Points	
Hours of week	1.0
Recommended semester	1
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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	**Number of module**
Reinforcement Learning	11LE13MO-1141_PO 2020
Responsible	
Prof. Dr. Joschka Bödecker	
Organizer	
Department of Computer Science, Professorship in Neurorobotics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective

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					
Name	Type	C/E	ECTS	HoW	Workload
Reinforcement Learning	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Reinforcement Learning	excercise course	Core elective		1.0	

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
- 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)

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Name of module	Number of module
Reinforcement Learning	11LE13MO-1141_PO 2020
course	
Reinforcement Learning	
Event type	Number
lecture course	11LE13V-1141
Organizer	
Department of Computer Science, Professorship in Neurorobotics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	45 Stunden
Independent study	120 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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. Bertsimas: Neuron Dynamic Programming.
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	**Number of module**
Reinforcement Learning	11LE13MO-1141_PO 2020
course	
Reinforcement Learning	
Event type	Number
excercise course	11LE13Ü-1141
Organizer	
Department of Computer Science, Professorship in Neurorobotics	

ECTS-Points	
Attendance	15 Stunden
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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	**Number of module**
RNA Bioinformatik / RNA Bioinformatics	11LE13MO-1318_PO 2020
Responsible	
Prof. Dr. Rolf Backofen	
Organizer	
Department of Computer Science, Bioinformatics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Fundamental understanding of RNA sequence/structure analysis Knowledge about principle methods used in Bioinformatics

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
RNA Bioinformatik / RNA Bioinformatics - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
RNA Bioinformatik / RNA Bioinformatics-Exercises	excercise course	Core elective		2.0	

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.

Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes) (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.)
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 Biomedical Engineering (BE) in M.Sc. 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**
RNA Bioinformatik / RNA Bioinformatics	11LE13MO-1318_PO 2020
course	
RNA Bioinformatik / RNA Bioinformatics - Lecture	
Event type	Number
lecture course	11LE13V-1318
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	26 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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
▪ Clote, Backofen: Computational Molecular Biologie, An Introduction. Wiley & Sons. ISBN-10: 0471872520 ISBN-13: 978-0471872528 ▪ Durbin et al. Biological Sequence Analysis. Cambridge University Press. ISBN-10: 0521629713 ISBN-13: 978-0521629713
Compulsory requirement
keine | none
Recommended requirement
Fundamental understanding of RNA sequence/structure analysis Knowledge about principle methods used in Bioinformatics

↑

Name of module	**Number of module**
RNA Bioinformatik / RNA Bioinformatics	11LE13MO-1318_PO 2020
course	
RNA Bioinformatik / RNA Bioinformatics- Exercises	
Event type	Number
excercise course	11LE13Ü-1318
Organizer	
Department of Computer Science, Bioinformatics	

ECTS-Points	
Attendance	26 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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	**Number of module**
Robot Mechanics	11LE13MO-5727 PO 2021
Responsible	
JProf. Dr. Edoardo Milana	
Organizer	
Department of Microsystems Engineering, Professorship in Soft Machines	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Foundations in mechanics, calculus, geometry

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Robot Mechanics	lecture course	Core elective	3.0	2.0	90 Stunden | hours
Robot Mechanics	excercise course	Core elective		2.0	

Qualification
This course provides students with the knowledge and tools needed to model and analyze robotic manipulators, with an emphasis on mechanical performance. Students will learn how to analyze robotic systems, model their kinematics and dynamics, and design manipulators based on operational requirements. Application of this knowledge includes designing, modeling, and evaluating robots using real-world examples. Students demonstrate their understanding by presenting real-world use cases and demonstrate their ability to select and evaluate robot types for specific manipulation tasks.
Examination achievement
Klausur | written exam
Course achievement
keine | none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Microsystems Engineering Concentrations Area Materials and Fabrication ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. in Sustainable Systems Engineering (PO 2021), Interdisciplinary Profile ■ M.Sc. Informatik / Computer Science (PO 2020), in Spezialvorlesung | Specialization Courses 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
Robot Mechanics	11LE13MO-5727 PO 2021
course	
Robot Mechanics	
Event type	Number
lecture course	11LE50V-5727 PO 2021
Organizer	
Department of Microsystems Engineering, Professorship in Soft Machines	

ECTS-Points	3.0
Workload	90 Stunden | hours
Attendance	64 Stunden | hours
Independent study	26 Stunden | hours
Hours of week	2.0
Recommended semester	2
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Kinematic chains, joints, mobility, types of manipulators, reference frames, forward kinematics, inverse kinematics, Jacobian, trajectory planning, dynamics
Qualification
This course provides students with the knowledge and tools needed to model and analyze robotic manipulators, with an emphasis on mechanical performance. Students will learn how to analyze robotic systems, model their kinematics and dynamics, and design manipulators based on operational requirements. Application of this knowledge includes designing, modeling, and evaluating robots using real-world examples. Students demonstrate their understanding by presenting real-world use cases and demonstrate their ability to select and evaluate robot types for specific manipulation.
Examination achievement
siehe Moduleebene | see module level
Course achievement
siehe Moduleebene | see module level
Literature
Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, and Giuseppe Oriolo. 2008. Robotics: Modelling, Planning and Control (1st. ed.). Springer Publishing Company, Incorporated.
Compulsory requirement
keine | none
Recommended requirement
Foundations in mechanics, calculus, geometry

↑

Name of module	**Number of module**
Robot Mechanics	11LE13MO-5727 PO 2021
course	
Robot Mechanics	
Event type	Number
excercise course	11LE50Ü-5727 PO 2021
Organizer	
Department of Microsystems Engineering, Professorship in Soft Machines	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
The exercises will reinforce the lecture material through practical sample problems. The lecture includes the theoretical framework of Robot Mechanics, whereas the exercise session provides the students with the possibility to apply their acquired knowledge to solve applied problems, such as calculating the number of degrees of freedom of a rigid-body mechanism, to compute rotation matrices and to solve direct kinematics of planar/3D robots. Exercise problems are not graded and do not count for the final course grade, they are meant to help the students preparing for the final exam.
Examination achievement
siehe Modulebene | see module level
Course achievement
siehe Modulebene | see module level
Compulsory requirement

↑

Name of module	Number of module
SAT Solving	11LE13MO-1165_PO 2020
Responsible	
Prof. Dr. Armin Biere	
Organizer	
Department of Computer Science, Computer Architecture	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
none
Recommended requirement
none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
SAT Solving	lecture course	Core elective	6.0	3.0	180 Stunden | hours
SAT Solving	excercise course	Core elective		1.0	

Qualification
Proficiency in applying and developping 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 reachedat 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)

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Name of module	**Number of module**
SAT Solving	11LE13MO-1165_PO 2020
course	
SAT Solving	
Event type	Number
lecture course	11LE13V-1165
Organizer	
Department of Computer Science, Computer Architecture	

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	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	Number of module
SAT Solving	11LE13MO-1165_PO 2020
course	
SAT Solving	
Event type	Number
excercise course	11LE13Ü-1165

ECTS-Points	
Attendance	13 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Simulation in Computer Graphics	11LE13MO-1113_PO 2020
Responsible	
Prof. Dr.-Ing. Matthias Teschner	
Organizer	
Department of Computer Science, Computer Graphics	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
■ Programming Skills ■ Knowledge in Algorithms and Data Structures, Linear Algebra and Analysis

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Simulation in Computergraphik / Simulation in Computer Graphics - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Simulation in Computergraphik / Simulation in Computer Graphics - Exercises	excercise course	Core elective		2.0	

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)

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Name of module	Number of module
Simulation in Computer Graphics	11LE13MO-1113_PO 2020
course	
Simulation in Computergraphik / Simulation in Computer Graphics - Lecture	
Event type	Number
lecture course	11LE13V-1113
Organizer	
Department of Computer Science, Computer Graphics	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	30 Stunden
Independent study	120 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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

- Koschier et al: Smoothed Particle Hydrodynamics Techniques for the Physics Based Simulation of Fluids and Solids.

- Ihmsen et al: SPH Fluids in Computer Graphics.
- Bridson: Fluid Simulation for Computer Graphics.
- Ericson: Real-time Collision Detection.

Compulsory requirement
keine | none
Recommended requirement
■ Programming Skills (C, C++, Java) ■ Knowledge in Algorithms and Data Structures, Linear Algebra and Analysis
Teaching method
Lectures, discussions, theoretical and practical exercises.

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Name of module	**Number of module**
Simulation in Computer Graphics	11LE13MO-1113_PO 2020
course	
Simulation in Computergraphik / Simulation in Computer Graphics - Exercises	
Event type	Number
excercise course	11LE13Ü-1113
Organizer	
Department of Computer Science, Computer Graphics	

ECTS-Points	
Attendance	30 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	Number of module
Soft Robotics	11LE13MO-5374_PO 2020
Responsible	
JProf. Dr. Edoardo Milana	
Organizer	
Department of Microsystems Engineering, Professorship in Soft Machines	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden/hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each winter term

Compulsory requirement
none
Recommended requirement
none

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Soft Robotics	lecture course	Core elective	6.0	2.0	180 hours
Soft Robotics - Projekt	Alle Arten, soweit keine ständige Betreuung der Studierenden erforderlich ist	Core elective		2.0	

Qualification
The objective of this course it to provide students of engineering with the basics of Soft Robotics. Thus, the following topics will be addressed: - design and modeling of soft robots - soft actuation principles - materials and fabrication processes - control of soft robots - multifunctional embodiement

Examination achievement
oral examination oral presentation The final grade will be a weighted average of the project presentation (30%) and oral exam (70%)
Course achievement
none
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 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 ■ Master of Science in Sustainable Systems Engineering - Interdisciplinary Profile

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Name of module	**Number of module**
Soft Robotics	11LE13MO-5374_PO 2020
course	
Soft Robotics	
Event type	Number
lecture course	11LE50V-5374
Organizer	
Department of Microsystems Engineering, Professorship in Soft Machines	

ECTS-Points	6.0
Workload	180 hours
Hours of week	2.0
Recommended semester	3
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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 embodiement of sensing, actuation, control and energy will be discussed.
Examination achievement
See module level
Course achievement
See module level
Literature
Della Santina, Cosimo, et al. "Soft robots." Encyclopedia of Robotics 489 (2020). Rus, Daniela, and Michael T. Tolley. "Design, fabrication and control of soft robots." Nature 521.7553 (2015): 467-475. Gorissen, Benjamin, et al. "Elastic inflatable actuators for soft robotic applications." Advanced Materials 29.43 (2017): 1604977. Suzumori et al "The Science of Soft Robots: Design, Materials and Information Processing", Springer (2023)
Compulsory requirement
None
Recommended requirement
Continuum Mechanics (Solid and Fluid), Electromagnetism, Thermodynamics

↑

Name of module	Number of module
Soft Robotics	11LE13MO-5374_PO 2020
course	
Soft Robotics - Projekt	
Event type	Number
Alle Arten, soweit keine ständige Betreuung der Studierenden erforderlich ist	11LE50P-5374
Organizer	
Department of Microsystems Engineering, Professorship in Soft Machines	

ECTS-Points	
Hours of week	2.0
Recommended semester	3
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
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
Compulsory requirement

↑

Name of module	Number of module
Statistical Pattern Recognition	11LE13MO-1114_PO 2020
Responsible	
Prof. Dr. Thomas Brox	
Organizer	
Department of Computer Science, Pattern Recognition and Image Processing	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

Compulsory requirement
keine | none
Recommended requirement
Fundamental mathematical knowledge, particularly statistic

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Statistische Mustererkennung / Statistical Pattern Recognition - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Statistische Mustererkennung / Statistical Pattern Recognition - Exercises	excercise course	Core elective		2.0	

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

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 ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

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Name of module	**Number of module**
Statistical Pattern Recognition	11LE13MO-1114_PO 2020
course	
Statistische Mustererkennung / Statistical Pattern Recognition - Lecture	
Event type	Number
lecture course	11LE13V-1114
Organizer	
Department of Computer Science, Pattern Recognition and Image Processing	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	28 Stunden
Independent study	126 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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

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Name of module	**Number of module**
Statistical Pattern Recognition	11LE13MO-1114_PO 2020
course	
Statistische Mustererkennung / Statistical Pattern Recognition - Exercises	
Event type	Number
excercise course	11LE13Ü-1114
Organizer	
Department of Computer Science, Pattern Recognition and Image Processing	

ECTS-Points	
Attendance	26 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
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

↑

Name of module	**Number of module**
Test und Zuverlässigkeit / Test and Reliability	11LE13MO-1202_PO 2020
Responsible	
Prof. Dr. Armin Biere	
Organizer	
Department of Computer Science, Computer Architecture	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Kenntnisse in Technische Informatik und Rechnerarchitektur / Computer Architecture | Knowledge of technical informatics and computer architecture

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Test und Zuverlässigkeit / Test and Reliability - Lecture	lecture course	Core elective	6.0	3.0	180 Stunden | hours
Test und Zuverlässigkeit / Test and Reliability - Exercises	excercise course	Core elective		1.0	

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.

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 ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	Number of module
Test und Zuverlässigkeit / Test and Reliability	11LE13MO-1202_PO 2020
course	
Test und Zuverlässigkeit / Test and Reliability - Lecture	
Event type	Number
lecture course	11LE13V-1202
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	45 Stunden
Independent study	120 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

Contents

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

- Abramovici, Breuer, Friedman, "Digital Systems Testing & Testable Design", IEEE Press, 1994, ISBN: 0780310624 (available in our library).

- Jha, Gupta, "Testing of Digital Systems", Cambridge University Press, 2003, ISBN 05217 73563 (available in our library).

Compulsory requirement
keine | none

Recommended requirement
Kenntnisse in Technische Informatik und Rechnerarchitektur / Computer Architecture | Knowledge of technical informatics and computer architecture

↑

Name of module	**Number of module**
Test und Zuverlässigkeit / Test and Reliability	11LE13MO-1202_PO 2020
course	
Test und Zuverlässigkeit / Test and Reliability - Exercises	
Event type	Number
excercise course	11LE13Ü-1202
Organizer	
Department of Computer Science, Computer Architecture	

ECTS-Points	
Attendance	15 Stunden
Hours of week	1.0
Recommended semester	
Frequency	takes place each winter term
Compulsory/Elective (C/E)	Core elective
Language	english

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	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

Compulsory requirement
keine | none
Recommended requirement
Requires basic knowledge in Technical Computer Science

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Verifikation Digitaler Schaltungen / Verification of Digital Circuits - Lecture	lecture course	Core elective		3.0	180 Stunden
Verifikation Digitaler Schaltungen / Verification of Digital Circuits - Exercises	excercise course	Core elective		1.0	

Qualification
Students know about formal methods used in semi conductor 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.

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)

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Name of module	Number of module
Verifikation Digitaler Schaltungen / Verification of Digital Circuits	11LE13MO-1223_PO 2020
course	
Verifikation Digitaler Schaltungen / Verification of Digital Circuits - Lecture	
Event type	Number
lecture course	11LE13V-1223
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	

ECTS-Points	
Workload	180 Stunden
Hours of week	3.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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.
Während Anforderung (2) durch Testmethoden und Anforderung (3) durch Methoden zur Erhöhung der Ausfallsicherheit behandelt werden, spielen für die Einhaltung von Anforderung (1) Verifikations- und Validierungsmethoden eine Rolle. Der Schwerpunkt der Vorlesung liegt auf Verifikations- und Validierungsmethoden für digitale Komponenten. Dabei interessiert sowohl der formale Nachweis von Systemeigenschaften als auch die Übereinstimmung des Entwurfs im Vergleich zu einer gegebenen Spezifikation. Es werden zunächst verschiedene existierende Basistechniken zur formalen Verifikation vorgestellt, wie z.B. Decision Diagrams, SAT-Solver und And-Inverter-Graphen. Darauf aufsetzend werden auf symbolischen Methoden beruhende Ansätze zum Äquivalenzvergleich kombinatorischer und sequentieller Schaltungen sowie zur Eigenschaftsprüfung beschrieben

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature

- Kropf: "Introduction to Formal Hardware Verification" , Springer, 1999, ISBN 3-540-65445-3
- Clarke, Grumberg, Peled, "Model Checking", MIT Press 1999
- Kropf (Ed.): "Formal Hardware Verification", Springer, 1997, ISBN 3-540-63475-4

- Diverse Originalarbeiten
- Presentation of powerpoint slides. Slides and exercise sheets can be downloaded from the course web-site.

Compulsory requirement
Recommended requirement
Basiswissen in Technische Informatik

↑

Name of module	**Number of module**
Verifikation Digitaler Schaltungen / Verification of Digital Circuits	11LE13MO-1223_PO 2020
course	
Verifikation Digitaler Schaltungen / Verification of Digital Circuits - Exercises	
Event type	Number
excercise course	11LE13Ü-1223
Organizer	
Department of Computer Science, Computer Architecture Department of Computer Science, Operating Systems	

ECTS-Points	
Attendance	16 Stunden
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

Contents
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Verteilte Systeme / Distributed Systems	11LE13MO-1312_PO 2020
Responsible	
Prof. Dr. Fabian Kuhn	
Organizer	
Department of Computer Science, Algorithms and Complexity	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	1
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place once or irregularly

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					
Name	Type	C/E	ECTS	HoW	Workload
Verteilte Systeme / Distributed Systems - Lecture	lecture course	Core elective	6.0	2.0	180 Stunden | hours
Verteilte Systeme / Distributed Systems - Exercises	excercise course	Core elective		2.0	

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
course	
Verteilte Systeme / Distributed Systems - Lecture	
Event type	Number
lecture course	11LE13V-1312
Organizer	
Department of Computer Science, Algorithms and Complexity	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	26 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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
- sychronous 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.
McGraw-Hill Publishing, 1998, ISBN 0-07-709352 6

Distributed Computing: A Locality-Sensitive Approach David Peleg. Society for Industrial and Applied Mathematics (SIAM), 2000, ISBN 0-89871-464-8 Additional literature will be provided in the lecture.
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)

↑

Name of module	**Number of module**
Verteilte Systeme / Distributed Systems	11LE13MO-1312_PO 2020
course	
Verteilte Systeme / Distributed Systems - Exercises	
Event type	Number
excercise course	11LE13Ü-1312
Organizer	
Department of Computer Science, Algorithms and Complexity	

ECTS-Points	
Attendance	26 Stunden
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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	
Department of Computer Science, Professorship in Intelligent Embedded Systems	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Attendance	32 Stunden / Hours
Independent study	116 Stunden / Hours
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective
Frequency	takes place each summer term

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

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Wearable and Implantable Computing (WIC)	lecture course	Core elective	6.0	2.0	180 Stunden / Hours
Wearable and Implantable Computing (WIC)	excercise course	Core elective		2.0	

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
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.
Course achievement
Durchführung von Versuchen und Ergebnisprotokoll | Execution of experiments and written report of results
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 Enginee-ring ■ 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. M.Sc. Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. M.Sc. Embedded Systems Engineering

↑

Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
course	
Wearable and Implantable Computing (WIC)	
Event type	Number
lecture course	11E13V-1402_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

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	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	Number of module
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
course	
Wearable and Implantable Computing (WIC)	
Event type	Number
excercise course	11E13Ü-1402_PO 2020
Organizer	
Department of Computer Science, Professorship in Intelligent Embedded Systems	

ECTS-Points	
Attendance	32 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	takes place each summer term
Compulsory/Elective (C/E)	Core elective
Language	english

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

↑

Name of module	**Number of module**
Windenergiesysteme / Wind Energy Systems	11LE50MO-5256_PO 2020
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 hours
Hours of week	
Recommended semester	3
Duration	1 Semester
Compulsory/Elective (C/E)	Core elective

Compulsory requirement
None
Recommended requirement
Undergraduate knowledge in physics, mathematics as well as in systems and control.

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Windenergiesysteme / Wind Energy Systems	lecture course	Core elective	6.0	3.0	180 hours
Windenergiesysteme / Wind Energy Systems	excercise course	Core elective		1.0	-

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:** 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.

↑

Name of module	**Number of module**
Windenergiesysteme / Wind Energy Systems	11LE50MO-5256_PO 2020
course	
Windenergiesysteme / Wind Energy Systems	
Event type	Number
lecture course	11LE50V-5256
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	6.0
Workload	180 hours
Attendance	52 hours
Independent study	128 hours
Hours of week	3.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	english

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
"Wind Energy Handbook" by T. Burton, N. Jenkins, D. Sharpe, E. Bossanyi, 2nd edition, Wiley, 2011
Compulsory requirement
Recommended requirement
Undergraduate knowledge in physics, mathematics as well as in systems and control.

↑

Name of module	Number of module
Windenergiesysteme / Wind Energy Systems	11LE50MO-5256_PO 2020
course	
Windenergiesysteme / Wind Energy Systems	
Event type	Number
excercise course	11LE50Ü-5256
Organizer	
Department of Microsystems Engineering, Systems Control and Optimization	

ECTS-Points	
Workload	-
Attendance	-
Independent study	-
Hours of week	1.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Language	german

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

↑

Name of node	Number of node
Seminars	11LE13KT-Seminare
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory
ECTS-Points	6.0

Comment
Students have to take 2 Seminars.

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Name of module	Number of module
Seminar 1	11LE13MO-Seminar 1
Responsible	
Prof. Dr. Hannah Bast	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	1
Duration	
Compulsory/Elective (C/E)	Compulsory
Frequency	each term

Compulsory requirement
keine | none
Recommended requirement
allgmeine 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					
Name	Type	C/E	ECTS	HoW	Workload
VG Seminar 1 M	Veranstaltung (ohne Deputatanrechnung)	Compulsory		2.0	90 Stunden | hours

Qualification
Die Studierenden erhalten einen vertieften Einblick in das wissenschaftliche Arbeiten auf einem speziellen Fachgebiet der Informatik. Anhand ausgesuchter Themen aus den unterschiedlichen Forschungs- und Arbeitsgebiete der Professuren und Arbeitsgruppen vertiefen die Studierenden ihre Kenntnisse, wie man wissenschaftliche Texte liest, Hintergrundrecherche durchführt, wissenschaftliche Ergebnisse präsentiert und an wissenschaftlichen bzw. fachlichen Diskussionen teilnimmt. 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 pogram ■ 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 pogram ■ Master of Education Erweiterungsfach Informatik (PO 2021) ■ M.Sc. Embedded Systems Engineering (PO 2021)

↑

Name of module	**Number of module**
Seminar 1	11LE13MO-Seminar 1
course group	
VG Seminar 1 M	
Event type	Number
Veranstaltung (ohne Deputatanrechnung)	11LE13VG-Seminar

ECTS-Points	
Workload	90 Stunden | hours
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Compulsory
Languages	german, english

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
allgmeine 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)

↑

Name of module	**Number of module**
Seminar 2	11LE13MO-Seminar 2
Responsible	
Prof. Dr. Hannah Bast	
Faculty	
Faculty of Engineering	

ECTS-Points	3.0
Workload	90 Stunden | hours
Hours of week	2.0
Recommended semester	1
Duration	
Compulsory/Elective (C/E)	Compulsory
Frequency	each term

Compulsory requirement
keine | none
Recommended requirement
allgmeine 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					
Name	Type	C/E	ECTS	HoW	Workload
Seminar 2	Veranstaltung (ohne Deputatanrechnung)	Compulsory		2.0	90 Stunden | hours

Qualification
Die Studierenden erhalten einen vertieften Einblick in das wissenschaftliche Arbeiten auf einem speziellen Fachgebiet der Informatik. Anhand ausgesuchter Themen aus den unterschiedlichen Forschungs- und Arbeitsgebiete der Professuren und Arbeitsgruppen vertiefen die Studierenden ihre Kenntnisse, wie man wissenschaftliche Texte liest, Hintergrundrecherche durchführt, wissenschaftliche Ergebnisse präsentiert und an wissenschaftlichen bzw. fachlichen Diskussionen teilnimmt. 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 pogram
- 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 pogram
- 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
course group	
Seminar 2	
Event type	Number
Veranstaltung (ohne Deputatanrechnung)	11LE13VG-Seminar

ECTS-Points	
Workload	90 Stunden | hours
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Compulsory
Languages	german, english

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
allgmeine 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)

↑

Name of node	**Number of node**
Lab Course	11LE13KT-Praktikum
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory
ECTS-Points	6.0

Comment
Students have to take 1 lab course.

↑

Name of module	**Number of module**
Praktikum	11LE13MO-7110 PO 2020
Responsible	
Prof. Dr. Hannah Bast	
Faculty	
Faculty of Engineering	

ECTS-Points	6.0
Workload	180 Stunden | hours
Hours of week	4.0
Recommended semester	2
Duration	1 Semester
Compulsory/Elective (C/E)	Compulsory
Frequency	each term

Compulsory requirement
keine | none
Recommended requirement
allgmeine 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					
Name	Type	C/E	ECTS	HoW	Workload
Praktikum Informatik1	Veranstaltung (ohne Deputatanrechnung)	Core elective			180 Stunden | hours

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 ■ M.Sc. Informatik / Computer Science (2020) 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**
Praktikum	11LE13MO-7110 PO 2020
course group	
Praktikum Informatik1	
Event type	Number
Veranstaltung (ohne Deputatanrechnung)	11LE13VG-7110-P1

ECTS-Points	
Workload	180 Stunden | hours
Attendance	60 Stunden
Independent study	120 Stunden
Hours of week	
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Core elective
Languages	german, english

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
allgmeine 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

↑

Name of node	**Number of node**
Customized Course Selection	11LE13KT-Indiv STG
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory
ECTS-Points	18.0

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.

↑

Name of node	**Number of node**
Advanced Lecture in Customized Course Selection	11LE13KT-Indiv STG- WVorlesung
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Core elective
ECTS-Points	6.0

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".**

↑

Name of node	Number of node
Specialization Course in Customized Course Selection	11LE13KT-Indiv STG-Spez-Vorl
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Core elective
ECTS-Points	6.0

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".**

↑

Name of node	Number of node
Courses offered in other departments of the University	11LE13KT-Indiv STG-FWB
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory

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: https://www.tf.uni-freiburg.de/bilder/studium_lehre/studienplaene/liste-fachfremder-wahlmodule-msc-informatik-po-2020 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.

↑

Name of node	Number of node
Applied Bioinformatics	11LE13KT-FWB
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Core elective

Comment
In "Applied Bioinformtics" 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.

↑

Name of node	**Number of node**
Kognitionswissenschaften	11LE13KT-FWB-Kognition
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Core elective

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.

↑

Name of node	Number of node
Mathematik	11LE13KT-FWB-Mathematik
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Core elective

Comment
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) ■ 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) ■ Mathematical Introduction to Deep Learning (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) ■ 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.

↑

Name of node	**Number of node**
Medizin	11LE13KT-FWB Medizin
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Core elective

Comment
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
Microsystems Engineering	11LE13KT-FWB-MST
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Core elective

Comment
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. Please note: ***NOT*** available as a course outside of Computer Science (as they are part of specialization courses in C.S.) are the following MSE courses ■ High-Performance Computing: Molecular Dynamics with C++ ■ High-Performance Computing: Fluid Mechanics with Python ■ High-performance computing: Distributed-memory parallelization on GPUs and accelarators ■ Optimale Steuerung und Modellprädiktive Regelung / Optimal and Model Predictive Control ■ Model Predictive Control A special role have the modules ■ Modellbildung und Systemidentifikation / Modelling and Systems Identification ■ Numerical Optimal Control in Science and Engineering ■ Numerical Optimization Please mind the information provided in the respective module descriptions in the section "Usability of the course" in the module version as Specialization Course in Computer Science.

↑

Name of node	**Number of node**
Neuroscience	11LE13KT-FWB Neuroscience
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Core elective

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.

↑

Name of node	Number of node
Physik	11LE13KT-FWB-Physik
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Core elective

Comment
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.

↑

Name of node	**Number of node**
Psychologie	11LE13KT-FWB Psychologie
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Core elective

Comment
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.

↑

Name of node	Number of node
Sustainable Systems Engineering	11LE13KT-FWB SSE
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Core elective

Comment
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.

↑

Name of node	Number of node
Economics	11LE13KT-FWB-WiWi
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Core elective

Comment
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.

↑

Name of node	Number of node
Weitere genehmigte Module/Veranstaltungen im fachfremden Bereich	11LE13KT-FWB
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Core elective

Comment
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.

↑

Name of node	**Number of node**
Study Project	11LE13KT-9140
Faculty	
Faculty of Engineering	

Compulsory/Elective (C/E)	Compulsory
ECTS-Points	18.0

Comment
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.

↑

Name of module	**Number of module**
Studienprojekt	11LE13MO-9140 Studienprojekt Allgemein
Responsible	
Prof. Dr. Hannah Bast	
Faculty	
Faculty of Engineering	

ECTS-Points	18.0
Workload	540 Stunden | hours
Hours of week	
Recommended semester	3
Duration	
Compulsory/Elective (C/E)	Compulsory
Frequency	each term

Compulsory requirement
keine | none
Recommended requirement
allgmeine 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

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Studienprojekt Allgemein	Veranstaltung (ohne Deputatanrechnung)	Compulsory			540 Stunden | hours

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 indepent 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) If a specialization is intended, students have to take the study project in the respective specialization area (AI or CPS).

↑

Name of module	Number of module
Studienprojekt	11LE13MO-9140 Studienprojekt Allgemein
course group	
Studienprojekt Allgemein	
Event type	Number
Veranstaltung (ohne Deputatanrechnung)	11LE13VG-9140 Studienprojekt-Allgemein

ECTS-Points	
Workload	540 Stunden | hours
Attendance	ca. 20 Stunden
Independent study	ca. 520 Stunden
Hours of week	
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Compulsory
Languages	german, english

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 enviroments or lab equipment.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Literature
Depends on topic; provided by the supvervisor
Compulsory requirement
keine | none
Recommended requirement
allgmeine 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

↑

Name of module	**Number of module**
Studienprojekt KI	11LE13MO-9140KI
Responsible	
Prof. Dr. Hannah Bast	
Faculty	
Faculty of Engineering	

ECTS-Points	18.0
Workload	540 Stunden | hours
Hours of week	
Recommended semester	3
Duration	
Compulsory/Elective (C/E)	Compulsory
Frequency	each term

Compulsory requirement
keine | none
Recommended requirement
allgmeine 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					
Name	Type	C/E	ECTS	HoW	Workload
Studienprojekt im Bereich KI	Veranstaltung (ohne Deputatanrechnung)	Compulsory			540 Stunden | hours

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 indepent 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 theo-retical 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	**Number of module**
Studienprojekt KI	11LE13MO-9140KI
course group	
Studienprojekt im Bereich KI	
Event type	Number
Veranstaltung (ohne Deputatanrechnung)	11LE13VG-9140KI-Studien-projekt-KI

ECTS-Points	
Workload	540 Stunden | hours
Attendance	ca. 20 Stunden
Independent study	ca. 520 Stunden
Hours of week	
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Compulsory

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 enviroments 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 supvervisor
Compulsory requirement
keine | none
Recommended requirement
allgmeine 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

↑

Name of module	**Number of module**
Studienprojekt CPS	11LE13MO-9140 CPS
Responsible	
Prof. Dr. Hannah Bast	
Faculty	
Faculty of Engineering	

ECTS-Points	18.0
Workload	540 Stunden | hours
Hours of week	
Recommended semester	3
Duration	
Compulsory/Elective (C/E)	Compulsory
Frequency	each term

Compulsory requirement
keine | none
Recommended requirement
allgmeine 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-Physial Systems

Assigned Courses					
Name	Type	C/E	ECTS	HoW	Workload
Studienprojekt im Bereich CPS	Veranstaltung (ohne Deputatanrechnung)	Compulsory			540 Stunden | hours

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 indepent 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 CPS. If no specialization is intended, students have to take the general study project "Studienprojekt Allgemein"

↑

Name of module	Number of module
Studienprojekt CPS	11LE13MO-9140 CPS
course group	
Studienprojekt im Bereich CPS	
Event type	Number
Veranstaltung (ohne Deputatanrechnung)	11LE13VG-9140CPS-Studien-projekt-CPS

ECTS-Points	
Workload	540 Stunden | hours
Attendance	ca. 20 Stunden
Independent study	ca. 520 Stunden
Hours of week	
Recommended semester	
Frequency	takes place once or irregularly
Compulsory/Elective (C/E)	Compulsory
Languages	german, english

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 enviroments 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 supvervisor
Compulsory requirement
keine | none
Recommended requirement
allgmeine 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-Physial Systems

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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 o 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.