Introduction

The Master of Science degree program in Computer Science is a two-year program for highly qualified foreign and German students holding a Bachelor of Science degree in computer science or a similar discipline.

The curriculum includes a selection of courses of the department for computer science (theory of algorithms, computer architecture, software engineering, foundations of artificial intelligence, image processing and computer graphics, databases and information systems), a wide variety of advanced courses in computer science and numerical analysis as well as an application modules from another discipline (e.g. microsystems engineering, bioinformatics, biology). Students will specialize in one of the following three areas:

- Cyber-Physical Systems
- Cognitive Technical Systems
- Information Systems

Seminars, internships and an extensive master project complete the master's curriculum and promote the social and transferable skills of the students. The thesis covers a period of six months and is supervised by one of the research groups of the department of computer science.

This module catalogue has been compiled according to the academic regulations for the study program Master of Science in the subject Computer Science in the version of 19th of August 2005, as amended on 03rd of November 2014. The academic regulations define the modules which constitute the curriculum as well as how the curriculum is divided into terms and areas.

In the module descriptions it is stated how many credit points a student receives for a specific course, course work and examination, according to the „European Credit Transfer and Accumulation System“ (short: ECTS system). These credit points define the student's work load (one point is equivalent to a work load of 30 hours). They also define the weighting of a module within the whole study program and its impact on the final average grade. The recommended number of ECTS points to be completed per term is 30.

Students of the M. Sc. Computer Science have to complete at least 120 ECTS points, which usually requires 4 terms.

You will find more information about the exam regulations of the Master’s program at http://www.tf.uni-freiburg.de/studium/studiengaenge/master/mscinformatik
Structure of this module catalogue

1. Parts
The Master of Science program is divided into mandatory and elective part.

2. Modules
A module is a self-contained unit within a scientific topic or area and may consist of several part-modules. Modules can consist of one or more courses and examinations and coursework.

3. Types of courses
A course is the smallest unit described in this catalogue. There are different types of courses, including lectures, exercises, laboratory courses, seminars, …

4. Overview
The Master’s programme is divided into the following two areas:
- Mandatory Modules
- Elective Modules
- Prerequired modules for permission of study

The modules are sorted alphabetically in the different parts.

In the Mandatory Modules students have to complete modules with a total volume of at least 70 ECTS credits.

The elective part is divided in the Application Area and the Specialization Area.
In the Application Area there is a range of different application fields. Students have to choose one of the application fields and have to complete the modules of this field with a total volume of 18 ECTS.

In Specialization in Computer Science (Specialization modules) students have to complete Specialization Modules and Seminars with a total volume of 32 ECTS. The Specialization Modules and Seminars are offered in 3 different specialization areas:
- Cyber-Physical Systems
- Informationssysteme / Information Systems
- Kognitive technische Systeme / Kognitive Technical Systems

Students have to select 1 area. Students have to complete 2 Seminars. Minimum 1 Seminar must be part of the selected specialization area.

Prerequired modules for permission of study
All of the modules which can be specified by the admission committee as a prerequisite for the admission to study in this Master’s program are listed in this part.
If the candidate does not meet the necessary requirements for the study program, the committee can pronounce a provisionally admission which includes preconditions. Within the 1st and 2nd semester the student has to fulfill certain modules as a precondition to the study program. The student will be notified in written which modules they have to fulfill additionally.
Study plan

The curricula - or study plans - are meant to help the students to organise their studies. It is not mandatory to take the courses in the same order displayed in the curriculum. The curriculum, sorted by terms, is given below:

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**Description:** You can find the weekly working hours in the column hours which are structures in the types of the courses (V= lecture, Ü= exercises, S= seminar, P= laboratory)
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<td>Datenanalyse und Abfragesprachen / Data Analysis and Query Languages</td>
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<tr>
<td>Einführung in die Modallogik / Introduction to Modal Logic</td>
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<tr>
<td>Einführung in die Multiagentensysteme / Introduction to Multiagent Systems</td>
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<td>Handlungsplanung / Artificial Intelligence Planning</td>
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<tr>
<td>Informationswiedergewinnung / Information Retrieval</td>
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<td>Komplexitätstheorie / Computational Complexity</td>
</tr>
<tr>
<td>Maschinelles Lernen / Machine Learning</td>
</tr>
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<td>Maschinelles Lernen und Optimierung für Algorithmendesign / Machine Learning and Optimization for Algorithm Design</td>
</tr>
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<td>Netzwerkalgorithmen / Network Algorithms</td>
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<td>Numerik / Numerics</td>
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<td>Peer-to-Peer Netzwerke / Peer-to-Peer Networks</td>
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<td>Prinzipien der Wissensrepräsentation / Knowledge Representation</td>
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<td>RNA Bioinformatik / RNA Bioinformatics</td>
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<tr>
<td>Sicherheit im Geschäftsprozessmanagement / Security in Business Process Management</td>
</tr>
<tr>
<td>Software Design, Modellierung und Analyse in UML / Software Design, Modelling and Analysis in UML</td>
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<tr>
<td>Spieltheorie / Game Theory</td>
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<td>Systeminfrastruktur für Data Science / System Infrastructure for Data Science</td>
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<td>Bioinformatik II / Bioinformatics II</td>
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Pflichtbereich / Mandatory Part

In the Mandatory Modules students have to complete modules with a total volume of at least 70 ECTS credits.
# Conclusion Module

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<th>11LE50MO-8700-MSc</th>
</tr>
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<td>Examiners of the Department of Computer Science</td>
</tr>
<tr>
<td>Module Type</td>
<td>Mandatory module</td>
</tr>
<tr>
<td>Type of course</td>
<td>Written thesis</td>
</tr>
<tr>
<td>Language</td>
<td>German or english</td>
</tr>
<tr>
<td>Admission for the thesis can be granted if at least 75 ECTS-credits have been acquired within the course program.</td>
<td></td>
</tr>
</tbody>
</table>

### Recommended term of study

<table>
<thead>
<tr>
<th>Term week hours</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-points</td>
<td>25 ECTS written report</td>
</tr>
<tr>
<td>Angebotsfrequenz</td>
<td>Each term</td>
</tr>
</tbody>
</table>

### Workload

| Workload | 900 hours (900 hours Self-study) |

### Usability of the module

Mandatory Module for students of the study program
- Master of Science in Mikrosystemtechnik

### Learning target

The goal of the master's thesis is that students work independently on a given topic. They search for the respective literature, select the appropriate scientific approach and methods and apply them. The candidate has to demonstrate that he/she is able to work on a problem within a prescribed period without any assistance within the field of Computer Science, applying scientific methods. The results will be evaluated and critically compared with the current state of research. Finally, the students have to present their findings in a clear and scientific way.

### Content

The topic of the master's thesis is set by a professor of the Department of Computer Science in consultation with the student. The work on this topic may also take place outside the Faculty of Engineering, if the student is integrated into a computer science workgroup and if a professor agrees to assess and evaluate the thesis. In general, a tutor qualified at university level is assigned to coach the student. The scientific contents are task-specific and are mostly acquired by self-study and self-contained research.
### Zu erbringende Prüfungsleistung / Examination result

- work on a problem in the field of Computer Science
- Written report
- Oral presentation of the results

### Zu erbringende Studienleistung / Course Achievement

Presentation of the results in a colloquium

### Benotung / Grading

The module grade is calculated from the results of the written report.

### Gewichtung der Prüfungsleistung / Weight of examination result

The grade of the module is double-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Kerngebiete der Informatik / Core Field in Computer Science

In the module "Core field in Computer Science" students have to complete 1 or 2 Key courses with a total volume of 6 or 12 ECTS.

Student can select 1 or 2 Key modules from the following modules:
- Algorithmentheorie / Algorithms Theorie
- Bildverarbeitung und Computergraphik / Image Processing and Computer Graphics
- Datenbanken und Informationssysteme / Data Bases and Information Systems
- Grundlagen der Künstlichen Intelligenz / Foundations of Artificial Intelligence
- Rechnerarchitektur / Computer Architecture
- Softwaretechnik / Software Engineering

Students who complete 6 ECTS points in this module must complete 12 ECTS-points in the module "Deepening in Computer Science".

Students who complete 12 ECTS points in this module must complete 6 ECTS-points in the module "Deepening in Computer Science".

## Modul / Module

### Algorithmentheorie / Algorithms Theory

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-2010</th>
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<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Bast, Prof. Dr. F. Kuhn</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Algorithmen and Datenstrukturen, Chair Algorithmen and Komplezität</td>
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<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<td>Modulduer Module duration</td>
<td>1 Term</td>
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<td>Lecture and exercises</td>
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<tr>
<td>Sprache: Language</td>
<td>german or english</td>
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<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in algorithms and data structures</td>
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<td>Empfohlenes Fachterm: Recommended term of study</td>
<td>1</td>
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<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
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<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
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<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
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<td>Arbeitsaufwand: Workload</td>
<td>180 Hours (64 Full-time attendance course of study + 116 Self-study)</td>
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</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Mandatory Module for students of the study program
- 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

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Informatik
- Bachelor of Science polyvalent in Informatik
- Bachelor of Science in Mathematik
- Bachelor of Science in Physik
- Master of Science in Embedded Systems Engineering
- Master of Science in Informatik

**Lernziele / Learning target**

Students should learn fundamental algorithms and data structures, and a variety of fundamental techniques for their design and analysis. They should be able to apply them and also adapt them to slightly changed circumstances. They should learn to understand when the various principles are appropriate and they should be able to mathematically analyze algorithms that were designed according to these principles.

**Inhalte Vorlesung / Content of the lecture**

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.

**Inhalte Übung / Content of the exercises**

In order to be admitted to the exam, you need to have 50% of all exercise points. 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.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Zu erbringende Studienleistung / Course Achievement**

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

**Bemotung / Grading**

The module grade is calculated from the results of the final examination.
### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Bachelor of Science in Informatik, 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 Informatik, 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 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.

### Literatur / Literature

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

### Bildverarbeitung and Computergraphik / Image Processing and Computer Graphics

<table>
<thead>
<tr>
<th><strong>Nummer:</strong> Number</th>
<th>11LE13MO-2050</th>
</tr>
</thead>
</table>

| **Modulverantwortlicher:** Responsible person | Prof. Dr. T. Brox, Prof. Dr. M. Teschner |
| **Einrichtung:** Organisational unit | Chair Mustererkennung und Bildverarbeitung, Chair Graphische Datenverarbeitung |

| **Modultyp:** Module Type | Elective Module |
| **Moduldauer:** Module duration | 1 Term |

| **Zugehörige Lehrveranstaltungen:** Connected events | Lecture and exercises |
| **Sprache:** Language | german or english |

| **Empfohlene Voraussetzungen:** Recommended preconditions | Knowledge in algorithms and data structures as well as in advanced programming and mathematical foundations. |

| **Empfohlenes Fachterm:** Recommended term of study | 1 |
| **ECTS-Punkte:** ECTS-points | 6 |

| **SWS:** Term week hours | 3 Lecture + 1 Exercises |
| **Angebotsfrequenz:** Regular cycle | only in the winter term |

| **Arbeitsaufwand:** Workload | 180 Hours (64 Full-time attendance course of study + 116 Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Informatik
- Bachelor of Science polyvalent in Informatik
- Bachelor of Science in Mathematik
- 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
- Master of Science in Informatik

### Lernziele / Learning target

The students get an introduction to basic approaches in image processing and computer graphics. The students learn how to approach typical problems in image processing and in generative computer graphics. The students get familiar with recent publications in image processing and computer graphics.
### Inhalte Vorlesung / Content of the lecture

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.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the results of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- Bachelor of Science in Informatik, 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 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.

### Literatur / Literature

Will be announced in each lesson.
Datenbanken and Informationssysteme / Data Bases and Information Systems

Number: 11LE13MO-2060

Modulverantwortlicher: Prof. Dr. G. Lausen

Modultyp: Elective Module

Moduldauer: 1 Term

Zugehörige Lehrveranstaltungen: Lecture and exercises

Sprache: German

Empfohlene Voraussetzungen: Knowledge in
- Einführung in die Programmierung oder Einführung in die Informatik
- Systeme I: Betriebssysteme
- Informatik II: Algorithmen and Datenstrukturen oder Algorithmen and Datenstrukturen

Empfohlenes Fachterm: 1

ECTS-Punkte: 6

SWS: 3 Lecture + 1 Exercises

Angebotsfrequenz: only in the winter term

Arbeitsaufwand: 180 Hours (64 Full-time attendance course of study + 116 Self-study)

Verwendbarkeit der Veranstaltung

Mandatory Module for students of the study program
- Bachelor of Science in Informatik
- Bachelor of Science polyvalent 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

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Mathematik
- Master of Science in Embedded Systems Engineering
- Master of Science in Informatik
<table>
<thead>
<tr>
<th>Lernziele / Learning target</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Verständnis der grundlegenden Konzepte zu Datenbanken.</td>
</tr>
<tr>
<td>• Fähigkeit des Denkens auf unterschiedlichen Abstraktionsebenen</td>
</tr>
<tr>
<td>• Methodische Fähigkeiten einen Datenbankentwurf vorzunehmen</td>
</tr>
<tr>
<td>• Kennenlernen wesentlicher Konzepte des SQL-Standards</td>
</tr>
<tr>
<td>• Praktische Erfahrung in der Verwendung einer deklarativen, mengenorientierten Sprache für Datenbanken</td>
</tr>
<tr>
<td>• Fähigkeit den Bearbeitungsaufwand einer Anfrage abschätzen zu können</td>
</tr>
<tr>
<td>• Fähigkeit zum Umgang mit Zugriffsrechten</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
</tr>
<tr>
<td>Der Stoff der Lecture wird in Exercisesen and einem parallel laufenden Praktikum anhand verschiedener Datenbanksysteme konkretisiert.</td>
</tr>
<tr>
<td>Es werden im einzelnen die folgenden Aspekte behandelt:</td>
</tr>
<tr>
<td>• Einführung in Datenbanken</td>
</tr>
<tr>
<td>• Datenbankentwurf and Datenmodelle</td>
</tr>
<tr>
<td>• Datenmanipulationssprachen</td>
</tr>
<tr>
<td>• Entwurfstheorie</td>
</tr>
<tr>
<td>• Datenintegrität</td>
</tr>
<tr>
<td>• Transaktionsverwaltung</td>
</tr>
<tr>
<td>• Physische Datenorganisation and aktuelle Entwicklungen.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inhalte Übung / Content of the exercises</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Studienleistung / Course Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.</td>
</tr>
</tbody>
</table>
The module grade is calculated from the results of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
- Bachelor of Science in Informatik, 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 Informatik, 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 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.

**Literatur / Literature**

## Modul / Module

### Grundlagen der Künstlichen Intelligenz / Foundations of Artificial Intelligence

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-2040</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
<td>Prof. Dr. W. Burgard, Prof. Dr. B. Nebel, NN</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
<td>Chair Autonome Intelligente Systeme, Chair Grundlagen der Künstlichen Intelligenz, Chair Maschinelles Lernen and natürlichsprachliche Systeme</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer Module duration</strong></td>
<td>1 Term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
<td>German or english</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachterm:: Recommended term of study | 2 |
| **ECTS-Punkte:** ECTS-points | 6 |
| **SWS:** Term week hours | 3 Lecture + 1 Exercises |
| **Angebotsfrequenz:** Regular cycle | only in the summer term |
| **Arbeitsaufwand:** Workload | 180 Hours (56 Full-time attendance course of study + 124 Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program:
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Informatik
- Bachelor of Science polyvalent in Informatik
- Bachelor of Science in Mathematik
- 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
- Master of Science in Informatik

### Lernziele / Learning target

The goal of this module is to give an overview of the various techniques and methods in Artificial Intelligence. The students will learn the basic principles of Artificial Intelligence and will be able to use the scientific terminology and methods of this field. They will be able to interpret problems in terms of search in a formal search space and will be able to apply search algorithms to new situations. They will learn how to apply various Artificial Intelligence techniques and how to assess the application of such techniques in new situations.
### Inhalte Vorlesung / Content of the lecture

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

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the results of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Bachelor of Science in Informatik, 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 Informatik, 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 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.

### Literatur / Literature

Artificial Intelligence: A modern approach, Stuart Russel and Peter Norvig, Prentice Hall, 2003
**Rechnerarchitektur / Computer Architecture**

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>Number</th>
<th>11LE13MO-2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Responsible person</td>
<td>Prof. Dr. B. Becker, Prof. Dr. C. Scholl</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Organisational unit</td>
<td>Chair Rechnerarchitektur, Chair Betriebssysteme</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer:</td>
<td>Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>German or english</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen:</td>
<td>Recommended preconditions</td>
<td>Basic knowledge in operation systems and technical computer science</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachterm: | Recommended term of study | 2 |
| ECTS-Punkte: | ECTS-points | 6 |
| SWS: | Term week hours | 3 Lecture + 1 Exercises |
| Angebotsfrequenz: | Regular cycle | only in the summer term |
| Arbeitsaufwand: | Workload | 180 Hours |
| | | (56 Full-time attendance course of study + 124 Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Informatik
- Bachelor of Science polyvalent in Informatik
- Bachelor of Science in Mathematik
- 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
- Master of Science in Informatik

**Lernziele / Learning target**

The students are familiar with the main steps for the design of digital systems on the one hand side. On the other hand side they acquire architectural knowledge about computers. The module aims at a deepened understanding of methods for modeling and validation/verification and corresponding optimization methods. Students are able to judge the specific restrictions arising from the physics of technical systems and gain experience to include them into the design process. Finally they understand how limitations resulting from digital technology and specific computer architectures influence higher levels of abstraction, in particular the software level.
### Inhalte Vorlesung / Content of the lecture

An introduction to elementary questions, methods and techniques of computer design and architecture is given. In particular the following areas are of interest: Integrated circuits, design, test, machine languages, computer arithmetic, data path and control, pipelining, memory hierarchy, processes, interrupts, interfaces, parallel computing.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the results of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Bachelor of Science in Informatik, 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 Informatik, 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 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.

### Literatur / Literature

### Modul / Module

**Softwaretechnik / Software Engineering**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. A. Podelski, Prof. Dr. P. Thiemann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Softwaretechnik, Chair Programmiersprachen</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German or english</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in advanced programming, algorithms and data structures, computer science theory and mathematics.</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachterm:: Recommended term of study | 2 |
| ECTS-Punkte:: ECTS-points | 6 |
| SWS:: Term week hours | 3 Lecture + 1 Exercises |
| Angebotsfrequenz: Regular cycle | only in the summer term |
| Arbeitsaufwand: Workload | 180 Hours |
| | (56 Full-time attendance course of study + 124 Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Mandatory Module for students of the study program
- 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

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science polyvalent in Informatik
- Bachelor of Science in Mathematik
- Master of Science in Embedded Systems Engineering
- Master of Science in Informatik
Lernziele / Learning target

The students master basic modeling techniques and principles of design, construction, testing, and verification for software systems. They are able to apply these techniques in the small and to acquire advanced techniques by themselves. The applied formal methods to examples and are able to assess in which situations it is necessary to apply such methods.

Inhalte Vorlesung / Content of the lecture

Basic techniques in software engineering: Revision Control, Process Models, Requirements Analysis, Formal and Semiformal Modeling Techniques, Object Oriented Analysis, Object Oriented Design, Design Patterns, Testing.

Inhalte Übung / Content of the exercises

For admission to the exam at least 50% of the admission points must be achieved from the exercise sheets.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the results of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.

**Literatur / Literature**

- Balzert, H. Lehrbuch der Softwaretechnik, Bd. 1 + 2 (main source of the lecture)
- Jacobson, I. et al. Object Oriented Software-Engineering - A Use Case Driven Approach
- Davis, A. Software Requirements - Analysis and Specification
# Masterprojekt

## Modul / Module

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE13MO-7140</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Examiners of the Department of Computer Science</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Department of Computer Science</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration:</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Project</td>
</tr>
<tr>
<td>Sprache:</td>
<td>German or English</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachterm: Recommended term of study: | 3 |
| ECTS-Punkte: ECTS-points: | 16 |
| SWS: Term week hours: | | Angebotsfrequenz: Regular cycle: | Each term |
| Arbeitsaufwand: Workload: | 480 Hours (480 Self-study) |

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Informatik

## Lernziele / Learning target

The goal of this module is to give the students the opportunity to participate in the research activities of the chairs. Students will learn to tackle specific assignments under the given technical conditions, to develop the respective systems and to participate in the project. They will furthermore acquire the ability to acquaint themselves independently into a given topic, to work in a modern development environment and to observe common quality standards.

## Inhalte Vorlesung / Content of the lecture

Special topics from the selected working area
- Topics: proper citation, references, documentation of results, avoids misconduct (plagiarism, misrepresentation, etc.)

## Zu erbringende Prüfungsleistung / Examination result

The exam consists of a final presentation and a written project report.
### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Will be announced from the supervisor of the project
### Praktikum

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE13MO-7110</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Examiners of the Department of Computer Science</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen:</td>
<td>Advanced (practical) knowledge in the appropriate topic</td>
</tr>
<tr>
<td>Fachsemester:</td>
<td>2 or 3</td>
</tr>
<tr>
<td>SWS:</td>
<td>4 Laboratory</td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>180 hours (56 or 64 hours Full-time attendance course of study + 124 or 116 hours self-study)</td>
</tr>
</tbody>
</table>

**Lernziele / Learning target**

In the module "Laboratory" students have to choose 1 laboratory course offered at the department of computer science. The participants learn to work on tasks from different areas of computer science under the technical conditions given. They will develop the required systems and participate in projects. Students will learn to acquaint themselves with a given topic, to work in a modern development environment and to observe common quality standards.

**Zu erbringende Studienleistung / Course achievement**

The coursework consists of a final presentation and / or preparing a project report.
<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic performance, which can be graded but usually is evaluated with pass or fail.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic performance which can be graded but is not taken into account in the final grade.</td>
</tr>
</tbody>
</table>
Vertiefung der Informatik / Deepening in Computer Science

In the module "Deepening in Computer Science" students have to complete 1 module with the volume of 6 ECTS or 2 modules with a total volume of 12 ECTS.

Students who complete 6 ECTS points in this module must complete 12 ECTS-points in the module "Core field in Computer Science". Students who complete 12 ECTS points in this module must complete 6 ECTS-points in the module "Core field in Computer Science".

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Bildanalyse / 3D Image Analysis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1105</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Ronneberger</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Bildanalyse</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>english</td>
</tr>
</tbody>
</table>
| Empfohlene Voraussetzungen: Recommended preconditions | Skills in  
- Image Processing and Computer Graphics  
- Programming skills (preferably in C++) |
| Empfohlenes Fachterm: Recommended term of study | 2 |
| ECTS-Punkte: ECTS-points | 6 |
| SWS: Term week hours | 3 Lecture + 1 Exercises |
| Angebotsfrequenz: Regular cycle | only in the summer term |
| Arbeitsaufwand: Workload | 180 Hours  
(56 Full-time attendance course of study + 124 Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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  
  o Robotics and Computer Vision  
  o Personal Profile
- Master of Science in Informatik  
  o Kognitive technische Systeme
# Lernziele / Learning target

The students understand the basic concepts for analysis of 3D volumetric data sets, with focus on registration and feature extraction. They have an overview over existing state-of-the-art methods. They apply these concepts to solve tasks in biomedical applications.

# Inhalte Vorlesung / Content of the lecture

This course will introduce the basic concepts and techniques that are used in analysis of 3D images (volumetric data sets). The focus will be on data sets that are recorded in the biomedical research. The exercises will focus on practical applications of the concepts, efficient 3D data handling and processing in C++, common libraries and tools in this area. The students are expected to write small programs that solve given 3D image analysis tasks.

# Zu erbringende Prüfungsleistung / Examination result

written or oral examination

# Benotung / Grading

The module grade is calculated from the result of the final examination.

# Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
# Modul / Module

## Algorithmen für Funknetze / Algorithms for Radio Networks

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1301</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. C. Schindelhauer</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Rechnernetze and Telematik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>english</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in algorithms and data structures and computer networks</td>
</tr>
<tr>
<td>Empfohlenes Fachterm: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Term week hours</td>
<td>2 Lecture + 2 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours</td>
</tr>
<tr>
<td>(64 Full-time attendance course of study + 116 Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme

### Lernziele / Learning target

The knowledge can used to design wireless network protocols. Participants can create and evaluate wireless sensor network protocols. They understand the problems of mobile networks, know the current technology and can create complex routing algorithms.
## Inhalte Vorlesung / Content of the lecture

We classify wireless networks cellular networks, ad-hoc networks, wireless sensor networks and hybrid versions. For each of these types we present and evaluate algorithms. Cellular networks are known from mobile (phone) networks and WLAN. Communication is handled via dedicated hardware routers or base stations, while direct connections between terminals are not provided. We discuss the effects of the partitioning of the network into cells and the geometric properties of these cells. The allocation of radio frequencies is a combinatorially hard problem. For this and other problems like hand-off we present algorithmic solutions. Ad hoc networks have no infrastructure. Nodes communicate using multi-hop connections with the help of other participants. Routing in such networks is more challenging. We discuss medium-access protocols, routing algorithms and topology control. Wireless Sensor Networks connect sensors and actuators with a control station. These sensor nodes have only simple hardware for computation and data transfer. Most importantly the energy resources are very restricted. We present energy-efficient medium access and routing algorithms, which follow a data-centric approach. Special topics may be included addressing current research like anchor-less localization in radio networks, or communication using coordinated antennas, known as MIMO (multiple input multiple output).

## Zu erbringende Prüfungsleistung / Examination result

written or oral examination

## Benotung / Grading

The module grade is calculated from the result of the final examination.

## Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.
Literatur / Literature

- Schiller, Mobile Communications, Addison-Wesley, 2000.

Further literature will be recommended in the course.
Algorithmische Grundlagen der Bioinformatik / Algorithmic Foundations of Bioinformatics

Modul / Module

Algorithmische Grundlagen der Bioinformatik / Algorithmic Foundations of Bioinformatics

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<td>Lecture</td>
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<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
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<td>ECTS-Punkte: ECTS-points</td>
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<td>SWS: Term week hours</td>
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<td>Angebotsfrequenz: Regular cycle</td>
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<td>Arbeitsaufwand: Workload</td>
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Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program:
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme

Lernziele / Learning target

Die Studierenden haben Verständnis des Entwurfs und der Analyse von Zeichenkettenalgorithmen in der Bioinformatik. Sie können mit den gängigen Ansätzen zur Analyse umgehen.

Inhalte Vorlesung / Content of the lecture

- Suffixbäume
- Editierdistanz
Multiples Zeichenkettenalignment
Suchheuristiken
Hidden Markov Modelle für die Alignierung von Zeichenketten

Zu erbringende Prüfungsleistung / Examination result
written or oral examination

Bewertung / Grading
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result
- 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.
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- 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.

Literatur / Literature
Algorithms on Strings, Trees and Sequences: Computer Science and Computational Biology von Dan Gusfield von Cambridge University Press
Bioinformatics I / Bioinformatics I

Nummer: 11LE13MO-1309

Modulverantwortlicher: Prof. Dr. R. Backofen

Einrichtung: Chair Bioinformatik

Modultyp: Elective Module

Modulduer: 1 Term

Zugehörrige Lehrveranstaltungen: Lecture and exercises

Sprache: English

Empfohlene Voraussetzungen: Basic knowledge in molecular biology, Basic knowledge in algorithms

Empfohlenes Fachterm?: 2

ECTS-Punkte: 6

SWS: 2 Lecture + 2 Exercises

Angebotsfrequenz: only in the summer term

Arbeitsaufwand: 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
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- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme
  - Fachfremder Wahlbereich “Bioinformatik”

Lernziele / Learning target

This module is an introduction to major topics in the field of bioinformatics with a special focus on sequence analysis. In the course we revise fundamental principles in biology 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 course, students will become familiar with applications of
Markov models in Bioinformatics and be able to compute phylogenetic trees.

### Inhalte Vorlesung / Content of the lecture

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

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

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

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

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- 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.
Modul / Module

Bioinformatik II / Bioinformatics II

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<tr>
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<td>Einrichtung:</td>
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<tr>
<td>SWS:</td>
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<tr>
<td>Angebotsfrequenz:</td>
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<tr>
<td>Arbeitsaufwand:</td>
<td>180 Hours (64 Full-time attendance course of study + 116 Self-study)</td>
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</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
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- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme
  - Fachfremder Wahlbereich “Bioinformatik”

Lernziele / Learning target

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.
### Inhalte Vorlesung / Content of the lecture

<table>
<thead>
<tr>
<th>Module</th>
<th>Content</th>
</tr>
</thead>
</table>
| 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  
- Protein threading |
| RNA structure prediction | - Nussinov algorithm  
- Zuker algorithm |
| Energy Landscapes   | - Monte-Carlo sampling  
- Abstractions  
- Folding dynamics |

### Zu erbringende Prüfungsleistung / Examination result

- written or oral examination

### Benotung / Grading

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### Gewichtung der Prüfungsleistung / Weight of examination result

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- 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.
### Literature

- D.W. Mount: Bioinformatics - Sequence and Genome Analysis Cold Spring Harbor
## Modul / Module

### Compilerbau / Compiler Construction

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<th>Nummer: Number</th>
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<td>Lecture and exercises</td>
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<td>Sprache: Language</td>
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<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in • Algorithms and Data Structures • Theoretical Computer Science and Programming Skills in Java</td>
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<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
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<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the summer term</td>
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<td>Arbeitsaufwand: Workload</td>
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</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

### Lernziele / Learning target

Students recognize fundamental methods of compiler construction and are able to apply them. They can use tools to implement scanners and parsers; they can implement a compiler for a simple language with some optimizations. They understand abstract representations of intermediate code as well as the idea of staging different processing phases in a compiler and are able to apply this understanding in practical examples.

### Inhalte Vorlesung / Content of the lecture

- Syntactic analysis
- Semantic analysis
- Intermediate code
- Code transformation
- Optimization
- Generation of machine code: instruction selection, scheduling, register allocation.
### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

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- 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.

### Literatur / Literature

- Appel: Compiling with Continuations. Cambridge University Press, 1992
- Appel: Modern Compiler Implementation in ML. Cambridge University Press, 1998
- Fraser, Hanson: A Retargetable C Compiler: Design and Implementation. Benjamin/Cummings, 1995
# Computerunterstützte Modellierung / Computer Supported Modeling and Reasoning

**Modulhandbuch M.Sc. Informatik – Computerunterstützte Modellierung / Computer Supported Modeling and Reasoning**

## Modul / Module

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## Verwendbarkeit der Veranstaltung / Usability of the module

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- 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
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

## Lernziele / Learning target

The aim of this module is to show how to use logic as a practical tool. Participants will learn how to use a theorem prover to build mathematical theories and carry out machine-checked proofs. The theories can be about artifacts in computer science like system models and requirements, programs, circuits, and the like.

## Inhalte Vorlesung / Content of the lecture

This lecture is about using logic for program development and program analysis. Programming languages and desired program properties can both be formalised using logic, for the purpose of verifying the properties using computer support. The lecture is roughly structured in four parts. In part 1, we shall introduce various logic systems including propositional logic, first-order logic, and (naive) set theory. We shall see how proofs in these systems can be conducted both using paper and pencil and using the interactive theorem tool.
prover Isabelle. In part 2, we shall attempt to understand what happens behind the scenes: we shall study meta-logic, which is the general theory allowing us to implement all kinds of logic systems using a single tool. In part 3, we shall see how an important part of mathematics and programming languages can be modeled in this framework, including concepts such as arithmetic, data-types, and recursion. Part 4 will be a case study coming from functional or imperative programming or from the area of specification languages.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
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<td>written or oral examination</td>
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<table>
<thead>
<tr>
<th>Literatur / Literature</th>
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<tbody>
<tr>
<td>D. van Dalen: Logic and Structure. Springer-Verlag, 1980. An introductory textbook on logic</td>
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## Computer Vision I

<table>
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<td>Prof. Dr. T. Brox</td>
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<td>Chair Mustererkennung und Bildverarbeitung</td>
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<td>Zugehörige Lehrveranstaltungen: / Connected events</td>
<td>Lecture and exercises</td>
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<td>Sprache: / Language</td>
<td>English</td>
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<tr>
<td>Empfohlene Voraussetzungen: / Recommended preconditions</td>
<td>Image Processing and Computer Graphics</td>
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<td>Empfohlenes Fachterm: / Recommended term of study</td>
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<td>ECTS-Punkte: / ECTS-points</td>
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<tr>
<td>SWS: / Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
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### Verwendbarkeit der Veranstaltung / Usability of the module

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- 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
  - Personal Profile
- Master of Science in Informatik
- Kognitive technische Systeme

### Lernziele / Learning target

Students learn about some of the typical problems and methodologies in computer vision. After the course, they should be capable to read the current literature and understand standard concepts used in computer vision research. Moreover, they should be able to implement the techniques discussed in the lectures and to adapt them to their needs, if necessary.

### Inhalte Vorlesung / Content of the lecture

The course presents some of the typical computer vision tasks and current solutions. This includes various image enhancement methods like nonlinear diffusion and deblurring. The
main focus is on various segmentation techniques and motion estimation in video sequences. Further topics will be covered by the successive course Computer Vision II in the summer term. The exercises mainly consist of programming assignments and help to get a deeper insight in the discussed methods. The most relevant techniques will be implemented in C++ and leave the students with a useful toolbox at the end of the course.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
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<tr>
<td>• 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.</td>
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<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
</tbody>
</table>
Computer Vision II

Modul / Module

Nummer: 11LE13MO-1108

Modulverantwortlicher: Prof. Dr. T. Brox
Einrichtung: Chair Mustererkennung und Bildverarbeitung

Modultyp: Elective Module
Moduldauer: 1 Term

Zugehörige Lehrveranstaltungen: Lecture and exercises
Sprache: English

Empfohlene Voraussetzungen:
- Bildverarbeitung und Computergraphik / Image Processing and Computer Graphics
- Computer Vision I

Empfohlenes Fachterm:
- 2
ECTS-Punkte: 6

SWS:
- 3 Lecture + 1 Exercises
- Angebotsfrequenz: only in the winter term

Arbeitsaufwand: 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme

Lernziele / Learning target

Students learn about the typical problems and methodologies in computer vision not covered in the course Computer Vision I. After the course, they should be capable to read the current literature and understand almost all of the standard concepts currently used in computer vision research. They should be able to implement the techniques discussed in the lectures and to adapt them to their needs, if necessary.

Inhalte Vorlesung / Content of the lecture

The course continues the course Computer Vision I. It presents the typical computer vision tasks not covered in the previous course. This includes point and objects tracking, 3D...
geometry and reconstruction of 3D scenes from stereo images or videos, as well as object recognition. The exercises mainly consist of programming assignments and help to get a deeper insight in the discussed methods. Some of the most relevant techniques will be implemented in C++ and leave the students with a useful toolbox at the end of the course.

### Inhalte Übung / Content of the exercises

Programming assignments, completion and presentation of a project work

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination (4 ECTS)

### Zu erbringende Studienleistung / Course Achievement

Programming assignments, completion and presentation of a project work (2 ECTS)

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.
## Concurrency – Theory and Practice

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1220</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. P. Thiemann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Programmiersprachen</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in algorithms and data structures and computer science theory; key course in software engineering</td>
</tr>
<tr>
<td>Empfohlenes Fachterm: Recommended term of study</td>
<td>3</td>
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<tr>
<td>ECTS-Punkte: ECTS-points</td>
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</tr>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours (64 Full-time attendance course of study + 116 Self-study)</td>
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</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

### Lernziele / Learning target

- Understanding the problems with programming multiple threads accessing shared memory.
- Understanding today's hardware support for concurrent programming.
- Understanding the key elements of the design of most mainstream concurrent data structures.
- Knowledge of traditional and modern synchronization techniques.
- Ability to apply the above points in practical Java programs.
- Knowledge of declarative approaches to concurrent programming.
Inhalte Vorlesung / Content of the lecture

The lecture provides an extensive introduction into the domain of constraint satisfaction problems. For this purpose both theoretic and algorithmic questions will be examined.

In particular, the following topics are planned:

- Foundations and introduction: sets, relations, graphs, constraint networks and satisfiability, binary constraint networks
- Inference-based methods: arc and path consistency, n-consistency and global consistency
- Search: backtracking, backjumping, comparison of methods, stochastic local search
- Selected advanced topics: expressiveness and complexity of constraint languages, qualitative constraint networks

Inhalte Übung / Content of the exercises

To be admitted to the exam, it is mandatory to submit something for each sheet.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

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<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Goetz: Java Concurrency in Practice. Addison-Wesley. 2006.</td>
</tr>
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</table>
# Constraint-Satisfaction-Problems

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE13MO-1119</th>
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<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. B. Nebel</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Chair Grundlagen der Künstlichen Intelligenz</td>
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<td>Modultyp:</td>
<td>Elective Module</td>
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<td>Moduldauer:</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Lecture and exercises</td>
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<tr>
<td>Sprache:</td>
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<tr>
<td>Empfohlene Voraussetzungen:</td>
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<table>
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<tr>
<th>Empfohlenes Fachterm:</th>
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<tbody>
<tr>
<td>ECTS-Punkte:</td>
<td>6</td>
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<tr>
<td>SWS:</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz:</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>180 Hours</td>
</tr>
</tbody>
</table>

The aim of this module is to deepen the understanding of a broad variety of standard techniques used for solving constraint satisfaction problems. After the course students should be able to implement and evaluate such techniques. Moreover students should then be able to understand current research papers and to start qualifying projects or theses on topics related to the lecture.
### Inhalte Vorlesung / Content of the lecture

The lecture provides an in-depth introduction into the field of constraint satisfaction problems (CSP), one of the major fields in current AI research. In particular, we study the following topics:

- Foundations
- Constraint propagation (arc consistency, path consistency, global consistency)
- Search methods (backtracking, backjumping, local search)
- Constraint optimization problems (COP)
- Expressiveness and computational complexity of constraint languages
- CSP on infinite domains

### Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

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<tr>
<td>• Dechter, Constraint Processing, Morgan Kaufmann, 2003</td>
</tr>
<tr>
<td>• Rossi, van Beek, Walsh, Handbook of Constraint Programming, Elsevier, 2006</td>
</tr>
</tbody>
</table>
## Modul / Module

### Cyber-Physikalische Systeme – Diskrete Modelle / Cyber-Physical Systems – Discrete Models

<table>
<thead>
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<th>11LE13MO-2070</th>
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</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Becker, Prof. Dr. A. Podelski, Prof. Dr. P. Thiemann, Prof. Dr. C. Scholl,</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Rechnerarchitektur, Chair Softwaretechnik, Chair Programmiersprachen, Chair Betriebssysteme</td>
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<td>Lecture and exercises</td>
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<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Rechnerarchitektur / Computer Architecture and Softwaretechnik / Software Engineering</td>
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### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- 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
- Master of Science in Informatik
  - Cyber-Physical Systems

### Lernziele / Learning target

Students understand how cyber-physical systems, in the wide range of their heterogeneous aspects (large-scale systems, system of systems, embedded systems, concurrent systems, hardware systems, software systems) can be modeled using the basic notion of transition systems. They know relevant formalisms for modeling correctness properties of cyber-physical systems, and they understand how the models can be analyzed using algorithmic methods in order to prove correctness or find errors.
**Inhalte Vorlesung / Content of the lecture**

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

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

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
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**Literatur / Literature**

Modul / Module

Cyber-Physikalische Systeme – Hybrid-Modelle / Cyber-Physical Systems – Hybrid Models

Nummer: Number 11LE13MO-1207

Modulverantwortlicher: Responsible person Prof. Dr. B. Becker, Prof. Dr. A. Podelski, Prof. Dr. P. Thiemann, Prof. Dr. C. Scholl

Einrichtung: Organisational unit Chair Rechnerarchitektur, Chair Softwaretechnik, Chair Programmiersprachen, Chair Betriebssysteme

Modultyp: Module Type Elective Module

Moduldauer: Module duration 1 Term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises

Sprache: Language English

Empfohlene Voraussetzungen: Recommended preconditions Knowledge in Rechnerarchitektur / Computer Architecture and Softwaretechnik / Software Engineering

Empfohlenes Fachterm: Recommended term of study 2

ECTS-Punkte: ECTS-points 6

SWS: Term week hours 3 Lecture + 1 Exercises

Angebotsfrequenz: Regular cycle only in the summer term

Arbeitsaufwand: Workload 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

Lernziele / Learning target

Students understand how cyber-physical systems handling continuous data (e.g. receiving sensor values and controlling actuators) can be modeled based on transition systems. They know relevant formalisms for modeling systems with continuous parameters including time and probabilities, and they understand how the models can be analyzed using algorithmic
methods in order to prove correctness or find errors.

Inhalte Vorlesung / Content of the lecture

The course provides an introduction to the modeling and analysis of hybrid systems, i.e. systems with discrete-continuous behavior, from the viewpoint of computer science.

- Hybrid automata are introduced as a syntactic model for hybrid systems. Corresponding labeled transition systems are used to define their semantics.
- Timed automata, as an important subclass of hybrid automata that extend discrete systems with a notion of time are considered. The branching time temporal logic TCTL is introduced to specify properties of timed automata and corresponding model checking algorithms are developed.
- As a further important subclass – more general than timed automata – we define linear hybrid automata. We show that the reachability problem for linear hybrid automata is in general undecidable, whereas bounded reachability, i.e., reachability within a fixed number of steps, is still decidable and can be efficiently computed. We also consider bounded reachability for general hybrid automata and discuss corresponding solution approaches.
- Finally, the course provides basic knowledge on stochastic systems and corresponding model checking algorithms. To do so, we introduce discrete-time Markov chains (DTMMs) and probabilistic computation tree logic (PCTL).

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Bewertung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.

Literatur / Literature

9780262026499
### Modulhandbuch M.Sc. Informatik – Datenanalyse and Abfragesprachen / Data Analysis and Query Languages

#### Modul / Module

### Datenanalyse and Abfragesprachen / Data Analysis and Query Languages

#### Nummer: Number
11LE13MO-1322

#### Modulverantwortlicher: Responsible person
Prof. Dr. G. Lausen

#### Einrichtung: Organisational unit
Chair Datenbaneken and Informationssysteme

#### Modultyp: Module Type
Elective Module

#### Moduldauer: Module duration
1 Term

#### Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

#### Sprache: Language
English

#### Empfohlene Voraussetzungen: Recommended preconditions
Knowledge in Datenbaneken and Informationssysteme / Data Bases and Information Systems

#### Empfohlenes Fachterm: Recommended term of study
2

#### ECTS-Punkte: ECTS-points
6

#### SWS: Term week hours
3 Lecture + 1 Exercises

#### Angebotsfrequenz: Regular cycle
only in the summer term

#### Arbeitsaufwand: Workload
180 Hours (56 Full-time attendance course of study + 124 Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

### Lernziele / Learning target

Students will learn to use basic techniques for analysis of web-scale massive datasets. Students will be able to apply these techniques on basic examples. Students will be familiar with query languages designed for the web of data. Students will know how to design processing tasks using the MapReduce paradigm.
### Inhalte Vorlesung / Content of the lecture

1. Basics of the Web
2. Search Engines and Link Analysis
3. Query language SPARQL
4. Web-scale Computation
5. Finding Similar Items
6. Mining Data Streams
7. Advertising and Recommendations
8. Mining Social Network Graphs / Matrix Dimensionality Reduction

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

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### Gewichtung der Prüfungsleistung / Weight of examination result

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### Literatur / Literature

## Echtzeitbetriebssysteme und Zuverlässigkeit / Real-time Systems and Reliability

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<td>Prof. Dr. B. Becker, Prof. Dr. A. Podelski, Prof. Dr. P. Thiemann, Prof. Dr. C. Scholl,</td>
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<td>English</td>
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<tr>
<td><strong>Empfohlene Voraussetzungen: Recommended preconditions</strong></td>
<td>Knowledge in Rechnerarchitektur / Computer Architecture and Softwaretechnik / Software Engineering</td>
</tr>
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</table>

| **Empfohlenes Fachterm: Recommended term of study** | 2 |
| **ECTS-Punkte: ECTS-points** | 6 |
| **SWS: Term week hours** | 3 Lecture + 1 Exercises |
| **Angebotsfrequenz: Regular cycle** | only in the summer term |
| **Arbeitsaufwand: Workload** | 180 Hours (56 Full-time attendance course of study + 124 Self-study) |

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

## Lernziele / Learning target

The students are familiar with basic methods of real-time operating systems. In particular, they know the essential differences between standard operating systems and real-time operating systems for embedded systems both concerning requirements and concerning concepts of realization (especially in the area of scheduling). The students know basic functions of real-time operating systems and have experience with programming of real-time
Inhalte Vorlesung / Content of the lecture

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.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

Literatur / Literature

Will be announced at the beginning of the course.
## Modul / Module

### Echtzeitsysteme / Real-Time Systems

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>Number</th>
<th>11LE13MO-1212</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Responsible person</td>
<td>Prof. Dr. A. Podelski</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Organisational unit</td>
<td>Chair Softwaretechnik</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer</td>
<td>Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen:</td>
<td>Recommended preconditions</td>
<td>Knowledge in Logik für Informatiker</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachterm:</th>
<th>Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte:</td>
<td>ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS:</td>
<td>Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz:</td>
<td>Regular cycle</td>
<td>only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>Workload</td>
<td>180 Hours (56 Full-time attendance course of study + 124 Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

### Lernziele / Learning target

- Basic knowledge in the use of formal methods in the development of safety-critical systems with real-time requirements, from requirements gathering, through the description of designs and implementations for (automatic) verification of correctness
- Ability to formalize properties in logic form using the Duration Calculus or in the form of Timed Automata and understand formalization
- Overview of decidability results for real-time models.
**Inhalte Vorlesung / Content of the lecture**

The course largely follows the book "Real-Time Systems" by Olderog and Dierks. For the topics Timed Automata and Live Sequence Charts we use the original literature.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Bewertung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.

**Literatur / Literature**

<table>
<thead>
<tr>
<th>Modul / Module</th>
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</table>

**Einführung in die Mobile Robotik / Introduction to Mobile Robotics**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1115</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. W. Burgard</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Autonome Intelligente Systeme</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

Knowledge in Grundlagen der Künstlichen Intelligenz / Foundations in Artificial Intelligence

**Empfohlenes Fachterm: Recommended term of study**

<table>
<thead>
<tr>
<th>SWS: Term week hours</th>
<th>3 Lecture + 1 Exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
</tbody>
</table>

**Arbeitsaufwand: Workload**

180 Hours

(56 Full-time attendance course of study + 124 Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme

**Lernziele / Learning target**

Throughout this module participants will learn foundations of mobile robotics. They will learn basic principles of drives and sensors. Additionally, they will learn the mathematical foundations of state estimation processes and different implementations of recursive Bayes filters including the discrete filter, the Kalman filter and the particle filter. Furthermore, participants will understand how to apply these filters in the context of different state estimation problems in robotics. Finally, participants will get to know basic approaches to navigation including localization, mapping, path planning, collision avoidance and perception.
### Inhalte Vorlesung / Content of the lecture

Throughout the course, the following concepts will be presented: Drives and sensors for mobile robotics including their characteristics, recursive Bayes filters, Kalman filter, particle filter, discrete filter, probabilistic localization, mapping, simultaneous localization and mapping, path planning, collision avoidance and sensor interpretation.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

### Literatur / Literature

Einführung in die Modallogik / Introduction to Modal Logic

Nummer: 11LE13MO-1121

Modulverantwortlicher: Prof. Dr. B. Nebel
Einrichtung: Chair Grundlagen der Künstlichen Intelligenz

Modultyp: Elective Module
Moduldauer: 1 Term

Zugehörige Lehrveranstaltungen: Lecture and exercises
Sprache: English

Empfohlene Voraussetzungen: Knowledge in Grundlagen der Künstlichen Intelligenz / Foundations in Artificial Intelligence

Empfohlenes Fachterm: 2
ECTS-Punkte: 6

SWS: 3 Lecture + 1 Exercises
Angebotsfrequenz: only in the summer term

Arbeitsaufwand: 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Mathematik
- 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
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

The aim of this module is to give students a basic understanding of key concepts and standard techniques used in modal logics. After the module students should be able to implement and evaluate such techniques. Moreover students should then be able to understand current research papers and to start qualifying projects or theses on topics related to the lecture.

Inhalte Vorlesung / Content of the lecture

The term “modal logics” comprises a family of logics, which are used in quite different fields
in computer science (such as knowledge representation and reasoning, multi-agent systems, and formal verification). The lecture provides an in-depth introduction into standard techniques used in modal logics and provides an overview of closely related logics as well as their application. In particular, we will study the following topics:

- Uni- and multi-modal logics
- Expressiveness and computational complexity
- Tableaux-based decision procedures
- Epistemic logics
- Temporal and dynamic logics
- Description logics

Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Blackburn, van Benthem, Wolter, Handbook of Modal Logic, Elsevier, 2006</td>
</tr>
</tbody>
</table>
Einführung in die Multiagentensysteme / Introduction to Multiagent Systems

Nummer: Number 11LE13MO-1118

Modulverantwortlicher: Responsible person Prof. Dr. B. Nebel
Einrichtung: Organisational unit Chair Grundlagen der Künstlichen Intelligenz
Modultyp: Module Type Elective Module
Moduldauer: Module duration 1 Term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises
Sprache: Language English

Empfohlene Voraussetzungen: Recommended preconditions

The module has a strong focus on practical solutions to multi-agent systems. Therefore, programming skills in Java or C++ are mandatory. Furthermore, knowledge of concepts from the lecture Foundations of Artificial Intelligence (Grundlagen der Künstlichen Intelligenz), such as search methods, and probabilistic methods, is useful.

Empfohlenes Fachterm: Recommended term of study 2
ECTS-Punkte: ECTS-points 6
SWS: Term week hours 3 Lecture + 1 Exercises
Angebotsfrequenz: Regular cycle only in the summer term
Arbeitsaufwand: Workload 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

This module will address theoretical and practical aspects of multiagent systems. The rationale behind modeling problems in terms of agents in computer science and robotics will be explained. We will see how this approach is different from and relates to other programming paradigms, and which types problems can be solved using agent architectures. More specifically, the following topics will be included:
- Agent architectures
## Inhalte Vorlesung / Content of the lecture

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

Topics of this course are:
- Agent architectures
- Agent planning
- Methods of communication
- Game Theory
- Common sensing and world-modeling
- Distributed decision making
- Cooperation and coordination

## Inhalte Übung / Content of the exercises

Für die Zulassung zur Klausur müssen 50% der erreichbaren Punkte aus den Exercisesen und Projekten erreicht werden.

## Zu erbringende Prüfungsleistung / Examination result

written or oral examination

## Zu erbringende Studienleistung / Course Achievement

Um zur Abschlussprüfung zugelassen zu werden, muss die zu diesem Modul gehörige Lehrveranstaltung Exercises erfolgreich absolviert werden. Welche Leistung der Studierenden zu erbringen hat, wird in der Inhaltsbeschreibung der Exercises detailliert beschrieben und ebenso zu Beginn der Lehrveranstaltung vom Dozierenden mitgeteilt.

## Benotung / Grading

The module grade is calculated from the result of the final examination.
### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

### Literatur / Literature

**Modul / Module**

**Einführung in Embedded Systems / Introduction to Embedded Systems**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-910</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Becker, Prof. Dr. C. Scholl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Rechnerarchitektur, Chair Betriebssysteme</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Modulduauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Technische Informatik</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachterm:: Recommended term of study**

| 3 |

**ECTS-Punkte: ECTS-points**

| 6 |

**SWS: Term week hours**

| 3 Lecture + 1 Exercises |

**Angebotsfrequenz: Regular cycle**

| only in the winter term |

**Arbeitsaufwand: Workload**

| 180 Hours |

| (64 Full-time attendance course of study + 116 Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Mandatory Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering

Elective Module for students of the study program
- Lehramt an Gymnasien in Informatik, Hauptfach
- Lehramt an Gymnasien in Informatik, Erweiterungshauptfach
- Lehramt an Gymnasien in Informatik, Hauptfach in Verbindung mit Bildende Kunst und Musik
- Master of Science in Embedded Systems Engineering - Personal Profile
- Master of Science in Informatik - Cyber-Physical Systems

**Lernziele / Educational objectives**

The students have a basic understanding of the specific properties of embedded systems. They know the elementary design concepts for these systems as well as criteria for the partitioning in hardware or software. They know the component properties of an embedded system and understand the resulting demands for interfaces as well as for the entire system. They are able to assess the specific restrictions resulting from the physical laws of the surrounding system and can systematically integrate these into the design process. Finally,
they are aware how the specific software technology on the one hand and hardware design methods on the other hand can be combined to create a powerful design methodology respecting requirements for dimensions, reaction times, costs and energy consumption of the resulting system.

Inhalte Vorlesung / Content of the lecture

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.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

Literatur / Literature

Modul / Module

Entscheidungsprozeduren / Decision Procedures

Nummer: Number
11LE13MO-1209

Modulverantwortlicher: Responsible person
Prof. Dr. A. Podelski

Einrichtung: Organisational unit
Chair Softwaretechnik

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 Term

Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

Sprache: Language
English

Empfohlene Voraussetzungen: Recommended preconditions
Knowledge in logics

Empfohlenes Fachterm: Recommended term of study
2

ECTS-Punkte: ECTS-points
6

SWS: Term week hours
3 Lecture + 1 Exercises

Angebotsfrequenz: Regular cycle
only in the summer term

Arbeitsaufwand: Workload
180 Hours
(56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

Lernziele / Learning target

The students should know, for which theory fragments satisfiability is decidable. They should learn the most important algorithms that decide satisfiability. They should also be able to use existing tools to prove their formulas or the correctness of their programs.

Inhalte Vorlesung / Content of the lecture

Decision Procedures are the basis for program verification: The task of program verification is to give a formal proof that a program meets its specification. This amounts to determining the truth value of a logical formula. A decision procedure is an algorithm that can for a certain type of formulas decide whether the formula is true or false. We will investigate decision procedures for different logics. Starting with propositional logic we will investigate
decision procedures for logics with integers, reals, recursive structures (lists and trees), arrays, etc.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

### Literatur / Literature

Wird zu Beginn der Lehrveranstaltung bekannt gegeben.
Formale Methoden für Java / Formal Methods for Java

Modul / Module

Nummer: Number 11LE13MO-1210

Modulverantwortlicher: Responsible person Prof. Dr. A. Podelski

Einrichtung: Organisational unit Chair Softwaretechnik

Modultyp: Module Type Elective Module

Moduldauer Module duration 1 Term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises

Sprache: Language English

Empfohlene Voraussetzungen: Recommended preconditions Knowledge in Programming, Algorithms and Datastructures, Logics and Softwaretechnik / Software Engineering

Empfohlenes Fachterm:: Recommended term of study 3

ECTS-Punkte: ECTS-points 6

SWS: Term week hours 3 Lecture + 1 Exercises

Angebotsfrequenz: Regular cycle only in the winter term

Arbeitsaufwand: Workload 180 Hours (64 Full-time attendance course of study + 116 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

• Bachelor of Science in Embedded Systems Engineering
• 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
  o Zuverlässige Eingebettete Systeme
  o Personal Profile
• Master of Science in Informatik
  o Cyber-Physical Systems

Lernziele / Learning target

Die Studierenden sollen einen Überblick über die verschiedenen Arten der Verifikationswerkzeuge besitzen. Sie sollen abschätzen können, was diese Werkzeuge leisten und sie verwenden können, um Programme zu verifizieren. Sie sollen auch in der Lage sein interaktive Theorembeweiser zu verwenden.

Inhalte Vorlesung / Content of the lecture

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

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
Modulhandbuch M.Sc. Informatik – Fortgeschrittene Computergraphik / Advanced Computer Graphics

Fortgeschrittene Computergraphik / Advanced Computer Graphics

Nummer: Number
11LE13MO-1106

Modulverantwortlicher: Responsible person
Prof. Dr. M. Teschner

Einrichtung: Organisational unit
Chair Graphische Datenverarbeitung

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 Term

Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

Sprache: Language
English

Empfohlene Voraussetzungen: Recommended preconditions
• Programming skills
• Knowledge in Algorithms and Data Structures, Linear Algebra and Analysis
• Knowledge in Image Processing and Computer Graphics

Empfohlenes Fachterm: Recommended term of study
2
ECTS-Punkte: ECTS-points
6

SWS: Term week hours
2 Lecture + 2 Exercises

Angebotsfrequenz: Regular cycle
only in the summer term

Arbeitsaufwand: Workload
180 Hours
(66 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
• Bachelor of Science in Embedded Systems Engineering
• 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
  o Robotics and Computer Vision
  o Personal Profile
• Master of Science in Informatik
  o Kognitive technische Systeme

Lernziele / Learning target
The module offers deeper insights into generative computer graphics. Various models, data structures, numerical techniques and algorithms for all components of the raytracing concept for image generation are covered. The students learn a variety of relevant techniques. They also learn how to analyze the characteristics of the approaches and how to compare them.
Inhalte Vorlesung / Content of the lecture

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.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

Literatur / Literature

- Dutre, Bala, Bekaert: Advanced Global Illumination, A K Peters, 2006
- Pharr, Humphreys: Physically Based Rendering, Elsevier, 2010
**Funktionale Programmierung / Functional Programming**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1216</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. P. Thiemann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Programmiersprachen</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

Fun and interest in programming and learning and applying new programming concepts and languages. Further recommended:
- Courses "computer science I" and "Mathematics for Computer Scientists II" successfully completed
- own laptop

Prior knowledge of Haskell is not necessary.

**Empfohlenes Fachterm: Recommended term of study**

<table>
<thead>
<tr>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
</tr>
<tr>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
</tr>
</tbody>
</table>

**Arbeitsaufwand: Workload**

180 Hours
(67 Full-time attendance course of study + 113 Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

**Lernziele / Learning target**

- Develop an alternative, non-procedural view of algorithms and data structures
- Familiarity with the functions and data of higher order
- Knowledge of basic and advanced functional programming techniques
- Independent development of medium-sized functional programs
Inhalte Vorlesung / Content of the lecture

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

Inhalte Übung / Content of the exercises

Participants must edit each task on each sheet to be admitted to the examination. If the useful processing of a task fails, an appropriate justification must be placed.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>The basis for the first third of the course textbook Programming in Haskell by Graham Hutton, which is also in the TF library.</td>
</tr>
</tbody>
</table>
Modul / Module

Grundlagen von Programmiersprachen / Essentials of Programming Languages

Nummer: Number
11LE13MO-1222

Modulverantwortlicher: Responsible person
Prof. Dr. P. Thiemann

Einrichtung: Organisational unit
Chair Programmiersprachen

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 Term

Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

Sprache: Language
English

Empfohlenes Fachterm: Recommended term of study
2

ECTS-Punkte: ECTS-points
6

SWS: Term week hours
3 Lecture + 1 Exercises

Angebotsfrequenz: Regular cycle
only in the summer term

Arbeitsaufwand: Workload
180 Hours
(66 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

Lernziele / Learning target

Students have developed an understanding for the abstraction facilities that a programming language can provide.
They have mastered methods for modeling syntax and semantics of programming languages.
Students are aware of tools that support such modeling and they are able to apply them to selected problems.

Inhalte Vorlesung / Content of the lecture

- Abstract and concrete syntax
- Lambda calculus and functional programming
- imperative programming and objects
Operational semantics
Types and logic
Reasoning with contextual equivalence

Content of the exercises
Participants must edit each task on each sheet to be admitted to the examination. If the useful processing of a task fails, an appropriate justification must be placed.

Examination result
written or oral examination

Course achievement
The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Grading
The module grade is calculated from the result of the final examination.

Weight of examination result
- 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.

Literature
- B.C. Pierce. Types and Programming Languages. MIT Press, 2002
- S. Krishnamurthi. Programming Languages: Application
### Handlungsplanung / Artificial Intelligence Planning

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1102</th>
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<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Nebel</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Grundlagen der Künstlichen Intelligenz / Foundations of Artificial Intelligence</td>
</tr>
<tr>
<td>Empfohlenes Fachterm:: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours</td>
</tr>
<tr>
<td>(56 Full-time attendance course of study + 124 Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

### Lernziele / Learning target

Students are made familiar with the theory and the basic algorithms of AI planning to an extent that allows them to understand current research literature in the field of AI planning, to put it into context, and to actively participate in AI planning research.
## Inhalte Vorlesung / Content of the lecture

The lecture offers a detailed introduction into theoretical and algorithmic foundations of modern AI planning systems. In more detail, the following topics are covered:

- Formalization of AI planning
- Planning as search: progression and regression
- Satisficing heuristic search planning with delete-relaxation heuristics
- Optimal heuristic search planning with abstraction heuristics
- Nondeterministic and probabilistic planning
- Theoretical complexity of AI planning

Moreover, presumably at least one of the following additional topics will be covered:

- Computation and use of invariants
- Optimal planning as model checking with binary decision diagrams (BDDs)
- Planning as satisfiability

## Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects.

## Zu erbringende Prüfungsleistung / Examination result

written or oral examination

## Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

## Benotung / Grading

The module grade is calculated from the result of the final examination.

## Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

**Literatur / Literature**

- Rintanen: Introduction to Automated Planning. Lecture Notes for the SS 2005 course. Albert-Ludwigs-Universität-Freiburg, 2005
**Modul / Module**

**Informationswiedergewinnung / Information Retrieval**

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>Number</th>
<th>11LE13MO-1304</th>
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<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Responsible person</td>
<td>Prof. Dr. H. Bast</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Moduldauer</td>
<td>Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen:</td>
<td>Recommended preconditions</td>
<td>Basic knowledge in algorithms and data structures, basic programming skills.</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachterm: Recommended term of study**

<table>
<thead>
<tr>
<th>3</th>
</tr>
</thead>
</table>

**ECTS-Punkte: ECTS-points**

| 6 |

**SWS: Term week hours**

<table>
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<tr>
<th>2 Lecture + 2 Exercises</th>
</tr>
</thead>
</table>

**Angebotsfrequenz: Regular cycle**

| only in the winter term |

**Arbeitsaufwand: Workload**

<table>
<thead>
<tr>
<th>180 Hours</th>
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</thead>
</table>

(64 Full-time attendance course of study + 116 Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

**Lernziele / Learning target**

Students should understand the foundations of information systems, in particular search engines. They should be able to apply this knowledge in practice. This concerns algorithmic aspects (e.g., index data structures), quality aspects (e.g. ranking of search results) and user interfaces (e.g. AJAX programming).

**Inhalte Vorlesung / Content of the lecture**

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.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Bewertung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.

**Literatur / Literature**

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 .
Modulhandbuch M.Sc. Informatik – Ingenieurswissenschaft trifft auf
Biologie / Engineering meets Biology

Modul / Module

Ingenieurwissenschaft trifft auf Biologie / Engineering meets Biology

Nummer: 11LE13MO-PM-03

<table>
<thead>
<tr>
<th>Modulverantwortlicher:</th>
<th>Prof. Dr. O. Ronneberger</th>
</tr>
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<tbody>
<tr>
<td>Einrichtung:</td>
<td>Chair Bildverarbeitung</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer:</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Lecture and exercises</td>
</tr>
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<td>Sprache:</td>
<td>English</td>
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</table>

Empfohlenes Fachterm::

<table>
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<th>Recommended term of study</th>
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<tbody>
<tr>
<td>ECTS-Punkte:</td>
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<tr>
<td>Term week hours</td>
<td>2 Lecture + 3,4 Exercises</td>
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</table>

<table>
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<tr>
<th>Angebotsfrequenz:</th>
<th>Regular cycle</th>
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<td>only in the winter term</td>
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Arbeitsaufwand:

<table>
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<tr>
<th>Workload</th>
<th>180 Hours</th>
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</thead>
<tbody>
<tr>
<td>(86,5 Full-time attendance course of study + 93,5 Self-study)</td>
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</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Interdisciplinary Track
- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme

Lernziele / Learning target

Dieses gemeinsame Modul für Studierende der Biologie und der Ingenieurwissenschaften soll dazu anregen, die Methoden der jeweils anderen Disziplin kennen zu lernen und mit denjenigen der eigenen Disziplin zu kombinieren.

Die Studierenden können

- die Prinzipien der Synthetischen Biologie erklären.
- können genetische Netzwerke designen and analysieren.
- den Prozess der Bildaufnahme erklären and einfache Bildanalyseaufgaben durchführen.
- können neuronale Netzwerke beschreiben and neurophysiologische Messverfahren anwenden.
- elementare Prinzipien, Vorgehensweisen, momentane Begrenzungen and Perspektiven der Neurotechnologie beschreiben and erklären.
- ethische and sicherheitsrelevante Aspekte der Synthetischen Biologie and Neurotechnologie benennen and erläutern.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

### Literatur / Literature

Lecture handout and Skript zu den Exerciseyen werden in den Veranstaltungen verteilt.
# Komplexitätstheorie / Computational Complexity

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1320</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. C. Schindelhauer</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Rechnernetze and Telematik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

- Introduction to Programming
- Computer Science II: Algorithms and Datastructures
- Computer Science III: Theoretical Computer Science
- Algorithm Theory
- Graph Theory

**Empfohlenes Fachterm: Recommended term of study**

<table>
<thead>
<tr>
<th>Term week hours</th>
<th>3 Lecture + 1 Exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
</tbody>
</table>

**Arbeitsaufwand: Workload**

| 180 Hours |
| (56 Full-time attendance course of study + 124 Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteile Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme
- Master of Science in Mathematik

**Lernziele / Learning target**

The students should be able to learn and apply know the basic methodology of complexity theory. You will be introduced to current research topics and be able to classify them. Students will be able to prove basic theorems of complexity theory themselves.

---

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Inhalte Vorlesung / Content of the lecture

First, basics of complexity theory are repeated: Countable, enumerability, machine models, formal language classes, Goedelization, P, NP, completeness, computability. Then a selection of advanced topics will be discussed: hierarchies, simulations, oracle classes, alternating Turing machines, circuit complexity. Finally, selected topics from the following fields: Average complexity theory, quantum computing, Kolmogorov complexity, interactive complexity classes, randomization.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.

Literatur / Literature

- Papadimitriou, Christos H. Computational complexity. John Wiley and Sons Ltd., 2003
Modul / Module

Maschinelles Lernen / Machine Learning

Nummer: Number 11LE13MO-1103

Modulverantwortlicher: Responsible person N.N.
Einrichtung: Organisational unit Chair Maschinelles Lernen and Natürlichsprachliche Systeme

Modultyp: Elective Module Module Type
Moduldauer: Module duration 1 Term

Zugehörige Lehrveranstaltungen: Lecture and exercises Connected events
Sprache: Language English

Empfohlene Voraussetzungen: Knowledge in Grundlagen der Künstlichen Intelligenz / Foundations of Artificial Intelligence

Empfohlenes Fachterm: Recommended term of study 2 ECTS-Punkte: ECTS-points 6

SWS: Term week hours 3 Lecture + 1 Exercises Angebotsfrequenz: Regular cycle only in the summer term
Arbeitsaufwand: Workload 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  o Robotics and Computer Vision
  o Verteilte Systeme
  o Personal Profile
- Master of Science in Informatik
  o Informationssysteme
  o Kognitive technische Systeme

Lernziele / Learning target

Understanding of the basic concepts of machine learning, ability to think on different levels of abstraction, knowledge of exemplary implementations of learning algorithms, ability to independently identify connections of the concepts presented.
### Inhalte Vorlesung / Content of the lecture

Characterization of supervised, unsupervised and reinforcement learning, concept learning, decision trees, neural networks, probabilistic methods, committee techniques, reinforcement learning.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

### Literatur / Literature

- Mitchell: Machine Learning
- Murphy: Machine Learning – A Probabilistic Perspective
**Modul / Module**

**Maschinelles Lernen in Lebenswissenschaften / Machine Learning ind Life Science**

<table>
<thead>
<tr>
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<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. R.</td>
</tr>
<tr>
<td>Responsible person</td>
<td>Backofen</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Bioinformatik</td>
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<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduauer: Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**
Knowledge in machine learning and basic knowledge in molecular biology. Specialisation course in Bioinformatics II is helpful.

**Empfohlenes Fachterm: Recommended term of study**
3

**ECTS-Punkte: ECTS-points**
6

**SWS: Term week hours**
2 Lecture + 2 Exercises

**Angebotsfrequenz: Regular cycle**
only in the winter term

**Arbeitsaufwand: Workload**
180 Hours
(64 Full-time attendance course of study + 116 Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme

**Lernziele / Learning target**

The aim of this module is to introduce the basic techniques and types of machine learning models employed in modern molecular biology research.

**Inhalte Vorlesung / Content of the lecture**

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.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.

**Literatur / Literature**

The course material is based on influential publications both in the Machine Learning and/or Bioinformatics literature:

- P Baldi, S Brunak, Y Chauvin, C.A.F Andersen, H Nielsen, Assessing the accuracy of prediction algorithms for classification: an overview, Bioinformatics 2000
- T Fawcett, An introduction to ROC analysis, Pattern Recognition Letters 2006
- T Dietterich, Approximate statistical tests for comparing supervised classification learning algorithms, Neural Computation 1998
- D Jiang, C Tang, A Zhang, Cluster analysis for gene expression data: A survey, IEEE transactions on knowledge and data engineering 2004
- S.C Madeira, A.L Oliveira, Biclustering algorithms for biological data analysis: a survey, IEEE Transactions on computational Biology and Bioinformatics 2004
- A Krause, J Stoye, Large scale hierarchical clustering of protein sequences, BMC bioinformatics 2005
- X.W. Chen, Prediction of protein-protein interactions using random decision forest framework, Bioinformatics 2005
## Modul / Module

**Maschinelles Lernen und Optimierung für Algorithmendesign / Machine Learning and Optimization for Algorithm Design**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1122</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Dr. F. Hutter</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Grundlagen der Künstlichen Intelligenz</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen: Mandatory preconditions</td>
<td>Basic skills in Python</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Foundations of artificial intelligence; machine learning</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachterm: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours (64 Full-time attendance course of study + 116 Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
  - Cyber-Physical Systems
  - Informationssysteme
  - Kognitive technische Systeme

### Lernziele / Learning target

Students learn the foundations of automatic algorithm design based on methods from machine learning and optimization. They can explain and apply methods from algorithm configuration and algorithm portfolios to new problems, and can statistically analyze the performance of algorithms.
In particular, they can apply these methods to solve hard combinatorial problems (SAT, TSP, Planning...) more effectively.

Inhalte Vorlesung / Content of the lecture

The lectures are partitioned in 6 modules:
- Introduction to NP-Hard Problems,
- Methods for solving combinatorial problems,
- Empirical Evaluation of Algorithms,
- Statistical Models of the Empirical Hardness of NP-Hard Problems,
- Algorithm Configuration,
- Algorithm Portfolios

Inhalte Übung / Content of the exercises

The exercises follow the lectures. There will be at least one exercise for each module, in which the students independently implement the lecture material. In the end there is a large project (80h), in which the students apply all aspects of the course to a new problem domain. This project will be presented in the first part of the final exam.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination
In preparation for the written or oral exam, students work on a project, which they present in the first 15 minutes of the exam. In the second 15 minutes they answer questions about further course material.

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benoitung / Grading

The module grade is calculated from the result of the final examination.
<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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.</td>
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<tr>
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<tr>
<td>• 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.</td>
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</tr>
</tbody>
</table>
# Modellbildung und Systemidentifikation

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-2080</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
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<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>Englisch</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

- Mathematik I für Ingenieure und Informatiker / Mathematics I für Engineers and Computer Scientists
- Mathematik II für Ingenieure / Mathematics II für Engineers
- Differentialgleichungen / Differential Equations
- Systemtheorie und Regelungstechnik / Systems Theory and Feedback Control

**Empfohlenes Fachsemester:: Recommended term of study**

| 3 |

**ECTS-Punkte: ECTS-points**

| 6 |

**SWS: Semester week hours**

| 2 Lecture + 2 Exercises |

**Angebotsfrequenz: Regular cycle**

| Only in winter term |

**Arbeitsaufwand: Workload**

| 180 Hours |

**(64 Full-time attendance course of study + 116 Self-study)**

## Verwendbarkeit der Veranstaltung / Usability of the module

Mandatory Module for students in the study program

- Master of Science in Embedded Systems Engineering

Elective Module for students in the study program

- Master of Science in Informatik
  - Cyber-Physical Systems
  - Kognitive technische Systeme
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
### Lernziele / Learning target

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.

### Inhalte Vorlesung / Content of the lecture

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.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Lecture manuscript
- Lecture manuscript "System Identification" by J
Modul / Module

Netzwerkalgorithmen / Network Algorithms

Nummer: Number 11LE13MO-1313
Modulverantwortlicher: Responsible person Prof. Dr. F. Kuhn
Einrichtung: Organisational unit Chair Algorithmen und Komplexität
Modultyp: Module Type Elective Module
Moduldauer Module duration 1 Term
Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises
Sprache: Language English

Empfohlenes Fachterm:: Recommended term of study 2
ECTS-Punkte: ECTS-points 6
SWS: Term week hours 3 Lecture + 1 Exercises
Angebotsfrequenz: Regular cycle only in the summer term
Arbeitsaufwand: Workload 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme

Lernziele / Learning target

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.

Inhalte Vorlesung / Content of the lecture

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
<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
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</table>

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<tbody>
<tr>
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</table>

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</table>
## Modul / Module

### Numerische Optimierung / Numerical Optimization

<table>
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<th>Nummer: Number</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
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<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>4 Lecture + 2 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in Winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (96 hours Full-time attendance course of study + 84 Hours Self-study)</td>
</tr>
</tbody>
</table>

#### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Robotics and Computer Vision
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile

#### Lernziele / Learning target

Students understand important optimization methods used in practice for solution of convex and nonlinear programming problems and can independently apply the acquired knowledge.
### Inhalte Vorlesung / Content of the lecture

The course is divided into four major parts:

1. **Fundamental Concepts of Optimization:** Definitions, Types, Convexity, Duality
2. **Unconstrained Optimization and Newton Type Algorithms:** Stability of Solutions, Gradient and Conjugate Gradient, Exact Newton, Quasi-Newton, BFGS and Limited Memory BFGS, and Gauss-Newton, Line Search and Trust Region Methods, Algorithmic Differentiation
3. **Equality Constrained Optimization Algorithms:** Newton Lagrange and Generalized Gauss-Newton, Range and Null Space Methods, Quasi-Newton and Adjoint Based Inexact Newton Methods
4. **Inequality Constrained Optimization Algorithms:** Karush-Kuhn-Tucker Conditions, Linear and Quadratic Programming, Active Set Methods, Interior Point Methods, Sequential Quadratic and Convex Programming, Quadratic and Nonlinear Parametric Optimization

### Inhalte Übung / Content of the exercises

Theoretical and computer exercises accompany the lecture to deepen the understanding. Successful participation/solution of at least 50% of the weekly exercise sheets.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Zu erbringende Studienleistung / Course achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade...
of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

### Modul / Module

**Optimale Steuerung und Estimation / Optimal Control and Estimation**

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-5241</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Systemtheorie</td>
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<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**
The module is self contained and can be followed by all students with sufficient mathematical background. Thus, it is recommended not only to master and advanced bachelor students of engineering, but also to students of computer science, mathematics, and physics, that want to obtain a basic understanding of optimization and control. Having heard a basic systems and control course (e.g. Systemtheorie und Regelungstechnik) and an optimization course (e.g. „Convex and Nonlinear Optimization“) is an advantage, but not necessary.

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>3</th>
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</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>4 Lecture 2 Übung</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours</td>
</tr>
<tr>
<td></td>
<td>(84 Hours Full-time attendance course of study + 96 Hours Self-study)</td>
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### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Cyber.Physical Systems
  - Kognitive Technische Systeme
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
### Lernziele / Learning target

Aim of this self contained module is to provide the participants with a working knowledge of modern control theory as it is needed for use in engineering applications, with a focus on optimal control and estimation. At the end of the module the students shall have full understanding of how to use the linear quadratic regulator (LQR), the Kalman filter, Lyapunov and Ricatti Equations, dynamic programming, constrained optimal control, moving horizon estimation (MHE) and model predictive control (MPC).

### Inhalte Vorlesung / Content of the lecture

Focus of the course is state space control in discrete time. We start by discussing discrete time linear systems, their basic stability properties, time varying systems, linearization of nonlinear systems. We then enter optimal control, covering linear quadratic optimal control, linear quadratic regulation (LQR) control and Kalman filtering, Lyapunov and Riccati Equations, Dynamic Programming, Constrained Optimal Control, Moving Horizon Estimation (MHE) and Model Predictive Control (MPC). The course will be accompanied by weekly exercises with exercise questions and computer exercises using the environment MATLAB. In the last four weeks of the course (July), the participants will start to work, during the exercise sessions, on self chosen optimal control and estimation application projects, whose results will finally be presented to all course participants at the end of the semester.

### Inhalte Übung / Content of the exercises

Students have to complete 50% of the practical exercises to get the admission for the final module exam.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
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- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Literatur / Literature

Modulhandbuch M.Sc. Informatik – Optimierendes Lernen / Reinforcement Learning

Modul / Module

Optimierendes Lernen / Reinforcement Learning

<table>
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<tr>
<th>Nummer: Number</th>
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<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
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<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Maschinelles Lernen und Natürlichsprachliche Systeme</td>
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<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Artificial Intelligence and Machine Learning</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachterm: Recommended term of study | 3 |
| ECTS-Punkte: ECTS-points | 6 |
| SWS: Term week hours | 3 Lecture + 1 Exercises |
| Angebotsfrequenz: Regular cycle | only in the winter term |
| Arbeitsaufwand: Workload | 180 Hours (64 Full-time attendance course of study + 116 Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme

Lernziele / Learning target

- Comprehension of the fundamental concepts of Reinforcement Learning
- Ability to think on different levels of abstraction
- Knowledge of exemplary implementations of learning algorithms
- Ability to independently identify connections of the concepts presented
- Skills for the practical application
## Inhalte Vorlesung / Content of the lecture

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.

## Zu erbringende Prüfungsleistung / Examination result

written or oral examination

## Benotung / Grading

The module grade is calculated from the result of the final examination.

## Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

## Literatur / Literature

- Sutton, Barton: Reinforcement Learning – An Introduction.
### Module / Module

**Peer-to-Peer Netzwerke / Peer-to-Peer Networks**

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE13MO-1314</th>
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<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. C. Schindelhauer</td>
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<td>Lecture and exercises</td>
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<tr>
<td>Sprache:</td>
<td>English</td>
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<tr>
<td>Empfohlene Voraussetzungen:</td>
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<td>Empfohlenes Fachterm:</td>
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<tr>
<td>ECTS-Punkte:</td>
<td>6</td>
</tr>
<tr>
<td>SWS:</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz:</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>180 Hours (64 Full-time attendance course of study + 116 Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme

### Lernziele / Learning target

Students understand the advantages of different peer-to-peer network architectures. They can find appropriate network structures. They can classify existing peer-to-peer networks and analyse their communication structures and classify them. Students can apply anonymization techniques and performance enhancement.

### Inhalte Vorlesung / Content of the lecture

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 result

**Zu erbringende Prüfungsleistung**  
written or oral examination

### Grading

**Bemutung**  
The module grade is calculated from the result of the final examination.

### Weight of examination result

**Gewichtung der Prüfungsleistung**

- 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.
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- 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.

### Literature

**Literatur**

- Shen, X.; Yu, H.; Buford, J.; Akon, M. (Eds.): Handbook of Peer-to-Peer Networking, Springer 2010
Modul / Module

Prinzipien der Wissensrepräsentation / Knowledge Representation

Nummer: Number
11LE13MO-1104

Modulverantwortlicher: Responsible person
Prof. Dr. B. Nebel

Einrichtung: Organisational unit
Chair Grundlagen der Künstlichen Intelligenz

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 Term

Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

Sprache: Language
English

Empfohlene Voraussetzungen: Recommended preconditions
Knowledge in Grundlagen der Künstliche Intelligenz / Foundations of Artificial Intelligence

Empfohlenes Fachsemester: Recommended term of study
3

ECTS-Punkte: ECTS-points
6

SWS: Term week hours
3 Lecture + 1 Exercises

Angebotsfrequenz: Regular cycle
only in the winter term

Arbeitsaufwand: Workload
180 Hours
(64 Full-time attendance course of study + 116 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
• Bachelor of Science in Embedded Systems Engineering
• 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
  o Robotics and Computer Vision
  o Verteilte Systeme
  o Personal Profile
• Master of Science in Informatik
  o Informationssysteme
  o Kognitive technische Systeme

Lernziele / Learning target

The goal of the module is to enable students to understand logic-based knowledge representation formalisms and their associated inference services. Based on that they will learn how to extend existing KR systems and how to develop new ones. In particular, the course provides the skills for understanding current research literature in this field.
### Inhalte Vorlesung / Content of the lecture

This course gives an introduction to logic based knowledge representation formalisms. We cover in particular the following topics:
- Foundations: Formal logic and complexity theory
- Modal logic: Systems and proof techniques
- Non-montonic logics
- Description logic and the semantic web
- Qualitative temporal and spatial representations and reasoning

### Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

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- 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.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>R. J. Brachman and Hector J. Levesque, Knowledge Representation and Reasoning, Morgan Kaufman, 2004</td>
</tr>
</tbody>
</table>
Programmanalyse / Static Program Analysis

Modulverantwortlicher: Prof. Dr. P. Thiemann
Einrichtung: Chair Programmiersprachen
Modultyp: Elective Module
Moduldauer: 1 Term

Zugehörige Lehrveranstaltungen:
- Lecture and exercises
- Sprache: English

Empfohlene Voraussetzungen:
Knowledge in Informatik III - Theoretische Informatik and Graphentheorie

Empfohленes Fachterm:
- 2

ECTS-Punkte: 6

SWS:
- 3 Lecture + 1 Exercises

Angebotsfrequenz: only in the summer term

Arbeitsaufwand:
- 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

Lernziele / Learning target
Knowledge of basic modeling techniques and methods of static program analysis as well as methods for implementing them. Application of these methods to different language paradigms, knowledge of important analysis techniques and of the transformations that are enabled by them. Students should be advanced towards current research problems in this area.

Inhalte Vorlesung / Content of the lecture
- Semantics, fixed point theory, abstract interpretation, constraints, types, effects, type inference. Application: data flow analysis, intraprocedural analysis, interprocedural analysis
fixed point algorithms, analysis frameworks.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
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<tr>
<td>• 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.</td>
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<td>• 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.</td>
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<td>• 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.</td>
</tr>
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<td>• 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.</td>
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<tr>
<td>• 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.</td>
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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>• Additionally original literature.</td>
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**Programmverifikation / Programm Verification**

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<td>Modulverantwortlicher:</td>
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<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
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<td>Moduldauer:</td>
<td>1 Term</td>
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<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache:</td>
<td>English</td>
</tr>
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</table>

| Empfohlenes Fachterm: | 3 |
| ECTS-Punkte: | 6 |
| SWS: | 3 Lecture + 1 Exercises |
| Angebotsfrequenz: | only in the winter term |
| Arbeitsaufwand: | 180 Hours (64 Full-time attendance course of study + 116 Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program:
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

**Lernziele / Learning target**

Often computers are used in embedded, networked, safety critical applications. The cost of failure is high. In this module we introduce the basis of automatic tools for ensuring that a system does not have bad behaviours. We start with a short introduction to propositional logic and first-order reasoning. We then go on to establish a setting for the verification of programs, whose correctness is specified by a kind of program comments. In this setting, the correctness of the program is reduced to the validity of logical formulas. The validity is proven automatically by a new generation of powerful reasoning engines. Finally, we connect verification with static analysis methods that have been developed originally in compiler optimization and which are formalized by Patrick and Radhia Cousot’s framework of abstract interpretation.
In this lecture we introduce the basis of automatic tools for ensuring that a system does not have bad behaviours. In the lecture, we start with a short introduction to propositional logic and first-order reasoning. We then go on to establish a setting for the verification of programs, whose correctness is specified by a kind of program comments. In this setting, the correctness of the program is reduced to the validity of logical formulas. The validity is proven automatically by a new generation of powerful reasoning engines. Finally, we connect verification with static analysis methods that have been developed originally in compiler optimization and which are formalized by Patrick and Radhia Cousot's framework of abstract interpretation. Example of a verification problem; Technical documentation, for example of device driver programs for Windows and Linux operating systems, contains 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. We can formalize such rules, for example by a finite automaton. Below a small program for which we would like to know whether it obeys the rule 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). The rule can be formalized by the automaton shown below (the red state is the accepting state of the automaton the automaton accepts exactly the words that correspond to a bad behaviour). Is the program correct? Today tools exist that can answer this question automatically.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.
**Reversible Logik and Quantumcomputer / Reversible Logic and Quantum Computing**

| Modulverantwortlicher: Responsible person | Prof. Dr. C. Scholl |
| Modultyp: Module Type | Elective Module |
| Modulnummer: Number | 11LE13MO-1221 |
| Einrichtung: Organisational unit | Chair Betriebssysteme |
| Modulverantwortlicher: Responsible person | Prof. Dr. C. Scholl |
| Modultyp: Module Type | Elective Module |
| Modulnummer: Number | 11LE13MO-1221 |
| Einrichtung: Organisational unit | Chair Betriebssysteme |
| Zugehörige Lehrveranstaltungen: Connected events | Lecture and exercises |
| Sprache: Language | English |
| Empfohlenes Fachterm: Recommended term of study | 3 |
| ECTS-Punkte: ECTS-points | 6 |
| SWS: Term week hours | 3 Lecture + 1 Exercises |
| Angebotsfrequenz: Regular cycle | only in the winter term |
| Arbeitsaufwand: Workload | 180 Hours |
| (64 Full-time attendance course of study + 116 Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program:
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

**Lernziele / Learning target**

The students learn how quantum circuits can be used to describe quantum algorithms. They learn in detail how a desired functionality can be realized in terms of a reversible circuit which is part of the quantum circuit. This strengthens their knowledge on the design flow for digital systems. For the description of algorithms for the synthesis of reversible circuits basics from symmetric groups will be taught.

**Inhalte Vorlesung / Content of the lecture**

- quantum algorithms
- quantum circuits
- reversible functions
- reversible circuits
- design flow for reversible circuits
- synthesis algorithms
- symmetric groups

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
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- 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.

**Literatur / Literature**

Not required:
- Matthias Homeister: Quantum Computing verstehen
- Michael A. Nielsen and Isaac L. Chuang: Quantum Computing and Quantum Information
RNA Bioinformatik / RNA Bioinformatics

Nummer: 11LE13MO-1318

Modulverantwortlicher: Prof. Dr. R. Backofen

Einrichtung: Chair Bioinformatik

Modultyp: Elective Module

Modulaufer: 1 Term

Zugehörige Lehrveranstaltungen: Lecture and exercises

Sprache: English

Empfohlene Voraussetzungen:
- Basic knowledge of Bioinformatics and molecular biology
- Fundamental knowledge in algorithms

Empfohlenes Fachterm::

<table>
<thead>
<tr>
<th>Term week hours</th>
<th>ECTS-Punkte: ECTS-points</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Lecture + 2 Exercises</td>
<td>6</td>
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</table>

Angebotsfrequenz: only in the summer term

Arbeitsaufwand: 180 Hours
(56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

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.

**Inhalte Vorlesung / Content of the lecture**

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

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

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<table>
<thead>
<tr>
<th>Literatur / Literature</th>
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Modul / Module

Roboter-Kartierung / Robot Mapping

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<thead>
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<th>Nummer: Number</th>
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<td>Prof. Dr. W. Burgard</td>
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<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Autonome Intelligente Systeme</td>
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<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Moduldauer Module duration</td>
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<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
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<td>Sprache: Language</td>
<td>English</td>
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<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Einführung in die Mobile Robotik / Introduction to Mobile Robotics</td>
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<td>Empfohlenes Fachterm: Recommended term of study</td>
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<td>ECTS-Punkte: ECTS-points</td>
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Verwendbarkeit der Veranstaltung / Usability of the module

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- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme

Lernziele / Learning target

The students should be able to understand, characterize, and implement different approach to robot mapping and the simultaneous localization and mapping problem. This includes parametric and non-parametric filters, optimization-based approaches as well as techniques for addressing data association problems. The students will get practical experience with mapping systems and implement the basic methods.

Inhalte Vorlesung / Content of the lecture

The lecture will cover different topics and techniques in the context of environment modeling with mobile robots. This includes techniques such as the family of Kalman filters, information...
filters, particle filters, graph-based approaches, least-squares error minimization, techniques for place recognition and appearance-based mapping, data association as well as information-driven approaches for observation processing. The exercises and homework assignments will also cover practical hands-on experience with mapping techniques, as basic implementations will be part of the homework assignments.

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<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
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<tbody>
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<tbody>
<tr>
<td>• Thrun et al., Probabilistic Robotics, MIT Press, 2005</td>
</tr>
<tr>
<td>• Springer Handbook on Robotics, Chapter on Simultaneous Localization and Mapping</td>
</tr>
<tr>
<td>• Grisetti et al., A Tutorial on Graph-based SLAM, 2009</td>
</tr>
<tr>
<td>Further material will be available via the course website</td>
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</table>
### Module / Module

**Sicherheit im Geschäftsprozessmanagement / Security in Business Process Management**

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<td>Prof. Dr. G. Müller</td>
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<td>Institut für Informatik and Gesellschaft – Telematik</td>
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### Usability of the module / Verwendbarkeit der Veranstaltung

Elective Module for students of the study program
- 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
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme

### Learning target / Lernziele

Business process management is of paramount importance in enterprise information systems. This lecture presents the foundations of business process management in the context of information security. Considering processes in their three possible incarnations, namely process models, runtime process instances and process logs, the lecture introduces the corresponding analysis and requirements formalization techniques and tools to automate the analysis.

### Content of the lecture / Inhalte Vorlesung

- Business process management.
- Business process modeling.
- Petri nets for process and requirements modeling.
- Security models for access control/authorization.
- Process mining.
- Tools: WoPED, ProM, Disco, Nitro, SecSy, jBPM

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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### Literatur / Literature

**Module / Module**

**Simulation in Computergraphik / Simulation in Computer Graphics**

**Number:** 11LE13MO-1113

**Modulverantwortlicher:** Prof. Dr. M. Teschner

**Einrichtung:** Chair Graphische Datenverarbeitung

**Modultyp:** Elective Module

**Moduldauer:** 1 Term

**Zugehörige Lehrveranstaltungen:** Lecture and exercises

**Sprache:** English

**Empfohlene Voraussetzungen:**
- Programming skills
- Knowledge in algorithms and data structures, linear algebra and analysis.

**Empfohlenes Fachterm:** 3

**ECTS-Punkte:** 6

**SWS:** 2 Lecture + 2 Exercises

**Angebotsfrequenz:** only in the winter term

**Arbeitsaufwand:** 180 Hours

(64 Full-time attendance course of study + 116 Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
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- Master of Science in Embedded Systems Engineering
  - Robotics and Computer Vision
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme
- Master of Science in Mathematik

**Lernziele / Learning target**

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.
### Inhalte Vorlesung / Content of the lecture

The course addresses various aspects of the dynamics of mass-point systems, rigid objects and fluids. In the context of fluids, grid- and particle-based approaches are covered. The course further addresses techniques to detect collisions and to handle contacts. Here, bounding-volume hierarchies, space-subdivision techniques and image-based techniques are discussed.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

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### Gewichtung der Prüfungsleistung / Weight of examination result

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### Literatur / Literature

Software Design, Modellierung and Analyse in UML / Software Design, Modelling and Analysis in UML

<table>
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<th>Number:</th>
<th>11LE13MO-1215</th>
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<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prod. Dr. A. Podelski</td>
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<td>Einrichtung:</td>
<td>Chair Softwaretechnik</td>
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<td>Connected events:</td>
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<td>Language:</td>
<td>English</td>
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<td>Recommended term of study:</td>
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</tr>
<tr>
<td>ECTS-points:</td>
<td>6</td>
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<td>3 Lecture + 1 Exercises</td>
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<td>Angebotsfrequenz:</td>
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Verwendbarkeit der Veranstaltung / Usability of the module

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  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme

Lernziele / Learning target

Approaches to the definition of formal semantics for complex visual formalisms, studied on the example of the Unified Modelling Language (UML) and its natural language semantics descriptions; basic knowledge of model-based software development, i.e. In particular the ability to formalise requirements and design aspects in UML and to understand such formalisations.
### Inhalte Vorlesung / Content of the lecture

Notion of models; usage of UML for documentation and modelling; Object Constraint Language; syntax and semantics of class diagrams for the description of structure; syntax and semantics of state machines and sequence diagrams as examples for constructive and reflective descriptions of behaviour (in the context of the OMG standard documents); concepts inheritance and meta-modelling; the exercises use contemporary tools for UML modelling, simulation, and code-generation.

### Zu erbringende Prüfungsleistung / Examination result

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### Literatur / Literature

Will be announced at the beginning of the course.
Module / Module

Spieltheorie / Game Theory

Nummer: Number 11LE13MO-1117
Modulverantwortlicher: Responsible person Prof. Dr. B. Nebel
Einrichtung: Organisational unit Chair Grundlagen der Künstlichen Intelligenz
Modultyp: Module Type Elective Module
Moduldauer: Module duration 1 Term
Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises
Sprache: Language English

Empfohlenes Fachterm: Recommended term of study 2
ECTS-Punkte: ECTS-points 6
SWS: Term week hours 3 Lecture + 1 Exercises
Angebotsfrequenz: Regular cycle only in the summer term
Arbeitsaufwand: Workload 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
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  o Verteilte Systeme
  o Personal Profile
• Master of Science in Informatik
  o Informationssysteme
  o Kognitive technische Systeme

Lernziele / Learning target

After attending the module, students should be able to model simple strategic decision situations according to the game theory and to analyze them with regard to solutions (Nash equilibria, subgame perfect equilibria). Moreover, the students should be able to employ simple mechanisms.

Inhalte Vorlesung / Content of the lecture

Game theory is about rational decision making to further ones own objectives. In particular, it is about interactions and conflicts between the objectives of different players, i.e., about the question how the knowledge about other players' objectives influences ones own behavior. In the lecture, we study strategic and extensive games and discuss formalizations.
and solution concepts as well as algorithms for the computation of such solutions. In addition, the course is concerned with the mechanism design problem, i.e., with the question of how the rules of a social system should be designed in order to incentivize all participants to behave in a way that maximizes social welfare.

**Inhalte Übung / Content of the exercises**

For admission to the exam students must attain 50% of all points reachable in the assignments and projects.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Zu erbringende Studienleistung / Course Achievement**

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

**Benotung / Grading**

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<thead>
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<tr>
<td>• Osborne, Rubinstein, A Course in Game Theory, The MIT Press, Cambridge, MA, 1994</td>
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<tr>
<td>• Nisan, Roughgarden, Tardos, Vazirani (Hrsg.), Algorithmic Game Theory, Cambridge University Press, 2007</td>
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</table>
### Modul / Module

**Statistische Mustererkennung / Statistical Pattern Recognition**

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<td>Einrichtung: Organisational unit</td>
<td>Chair Musterkennung und Bildverarbeitung</td>
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### Verwendbarkeit der Veranstaltung / Usability of the module

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  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme

### Lernziele / Learning target

After taking the module, students should know about the most relevant pattern recognition techniques and the basic concepts of statistical learning. They should be able to read and understand related scientific literature. Moreover, they can apply the learned techniques to solve learning problems in various application domains. They should develop basic skills in working with Matlab.

### Inhalte Vorlesung / Content of the lecture

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 help deepen the understanding of the material.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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.</td>
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</tr>
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<td>• 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.</td>
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</tbody>
</table>
### Systeminfrastruktur für Data Science / System Infrastructure for Data Science

**Nummer: Number**

<table>
<thead>
<tr>
<th>Modulverantwortlicher: Responsible person</th>
<th>Einrichtung: Organisational unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. Dr. P. Fischer</td>
<td>Chair Web Science</td>
</tr>
</tbody>
</table>

**Modultyp:** Elective Module  
*Moduldauer: Module duration*  
1 Term

**Zugehörige Lehrveranstaltungen:** Lecture and exercises  
*Sprache: Language*  
English

**Empfohlene Voraussetzungen:** Knowledge in Datenbanken und Informationssysteme / Databases and Information Systems

**Empfohlenes Fachterm:**  
Recommended term of study  
ECTS-Punkte: ECTS-points  
6

**SWS:**  
Term week hours  
3 Lecture + 1 Exercises  
Angebotsfrequenz: Regular cycle  
only in the winter term

**Arbeitsaufwand:**  
Workload  
180 Hours  
(64 Full-time attendance course of study + 116 Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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  
  o Verteilte Systeme  
  o Personal Profile
- Master of Science in Informatik  
  o Informationssysteme  
  o Kognitive technische Systeme

**Lernziele / Learning target**

Students will develop and understanding of fundamental architectural options for designing and implementing scalable, expressive and responsive infrastructures for data science. This understanding comes from two directions: From a high-level point of view, students will be able to understand what systems exist and how they can be used. From a bottom-up perspective, students will gain a detailed insight and hand-on experience on the techniques used.
Inhalte Vorlesung / Content of the lecture

The course covers the fundamentals of different data infrastructure systems, among them classical databases, main-memory databases, data stream systems and cloud computing frameworks. To do so, the course provides details on the foundations of information system architecture, among them data storage, indexing, query processing, operator models and optimization. On this basis, it provides further insights how design assumptions change when such systems are used in contexts which require extreme scalability, very short response times or complex analytical operations.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.

Literatur / Literature

The classical data management areas are covered well in the following books:
- Kemper and Eickler. Datenbanksysteme. Eine Einführung. Oldenbourg-Verlag. (in German)

Modern techniques are mostly available in research papers, which are provided during the lecture.
## Modul / Module

**Test and Zuverlässigkeit / Test and Reliability**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1202</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Becker</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Rechnerarchitektur</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

| Voraussetzungen: Recommended preconditions | Knowledge in Technische Informatik and Rechnerarchitektur / Computer Architecture |

| Empfohlenes Fachterm: Recommended term of study | 2 |
| ECTS-Punkte: ECTS-points | 6 |
| SWS: Term week hours | 3 Lecture + 1 Exercises |
| Angebotsfrequenz: Regular cycle | only in the summer term |
| Arbeitsaufwand: Workload | 180 Hours |
| (56 Full-time attendance course of study + 124 Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

### Lernziele / Learning target

The students are familiar with basic problems concerning test of digital circuits, understand corresponding algorithmic techniques, and know how to apply and possibly adapt them to new requirements. They are capable to integrate “Design for Testability” into a concrete design and judge advantages/disadvantages of these measures. The challenges of “the new technologies” are aware to them and state-of-the-art approaches to cope with these challenges can be assessed.
Inhalte Vorlesung / Content of the lecture

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.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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Literatur / Literature

Verifikation eingebetteter Systeme / Verification of embedded Systems

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1204</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Becker, Prof. Dr. C. Scholl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Rechnerarchitektur, Chair Betriebssysteme</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in technical computer science. Knowledge of the lecture &quot;Verification of embedded systems&quot; is useful for understanding, but not a prerequisite.</td>
</tr>
<tr>
<td>Empfohlenes Fachterm: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours (64 Full-time attendance course of study + 116 Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

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- Lehramt an Gymnasien in Informatik major subject in combination with Visual Arts or Music
- Master of Science in Embedded Systems Engineering
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical System

Lernziele / Learning target

Embedded systems consist of a digital control unit, but interact with continuous quantities like temperature, velocity and time. Beyond the question merely regarding functional correctness, often properties like the expected life-time, the average performance or the reliability are of central interest. For this, effects which are stochastic by nature have to be taken into account (e.g. communication via unreliable channels, the finite life-time of components, etc.). The students know the formalisms which can be used to model such systems. They are able to apply algorithms for the automatic analysis of such systems regarding a number of
different relevant properties and understand how these algorithms can be implemented efficiently. The students understand the problems that can occur if these techniques are applied to practically relevant systems and know ways to circumvent or solve these problems.

Inhalte Vorlesung / Content of the lecture

In this lecture we present formalisms for modeling and analysis of probabilistic systems:

- Discrete-time and continuous-time Markov chains
- Markov reward models
- Markov decision processes

For these classes of models we discuss algorithms which can be used to automatically check a variety of properties, e.g.: "The probability to reach, within the usual period of operation, a safety-critical state is at most 0.00001.", "The average energy consumption is on the long run, 5.8 W.", "On average, 10 tries are necessary until a message has been transmitted successfully."

We consider Markov models from the perspective of computer science with a focus on algorithms for their analysis. The necessary foundations which go beyond the contents of introductory lectures on mathematics and technical computer science (as taught in the curriculum of ESE/Computer Science) are introduced in the lecture.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

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Gewichtung der Prüfungsleistung / Weight of examination result

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- 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.

Literatur / Literature

Christel Baier, Joost-Pieter Katoen: Principles of Model Checking The MIT Press 2008
Verteilte Systeme / Distributed Systems

Number: 11LE13MO-1312

Modulverantwortlicher: Prof. Dr. C. Schindelhauer, Prof. Dr. L. Lausen

Einrichtung: Chair Rechnernetze and Telematik, Chair Datenbanken und Informationssysteme

Modultyp: Elective Module

Moduldauer: 1 Term

Zugehörige Lehrveranstaltungen: Lecture and exercises

Sprache: English

Empfohlene Voraussetzungen: Knowledge in Datenbanken und Informationssysteme / Data Bases and Information Systems

Empfohlenes Fachterm: 2

ECTS-Punkte: 6

SWS: 3 Lecture + 1 Exercises

Angebotsfrequenz: only in the summer term

Arbeitsaufwand: 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
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- Lehramt an Gymnasien in Informatik major subject in combination with Visual Arts or Music
- Master of Science in Embedded Systems Engineering
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme

Lernziele / Learning target

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.
Inhalte Vorlesung / Content of the lecture

After an introduction into distributed systems, the following major topics are discussed.

- System models
- Networks and Communications
- Time and global states
- Consistency and coordination
- Distributed Transactions
- Replication
- Modeling of distributed applications

Furthermore, current issues, which may originate from the following areas, are presented.

- Mobile Distributed Systems
- Web-based Distributed Systems
- Distributed multi-threading
- Peer-to-peer networks

Zu erbringende Prüfungsleistung / Examination result

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Benotung / Grading

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Gewichtung der Prüfungsleistung / Weight of examination result

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- 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.

Literatur / Literature

- Additional literature will be presented in the lecture
Modul / Module

Zufallsgesteuerte Algorithmen / Randomized Algorithms

<table>
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<th>Nummer: Number</th>
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<tbody>
<tr>
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<td>Prof. Dr. H. Bast</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Algorithmen und Datenstrukturen</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in stochastics</td>
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</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachterm: Recommended term of study</th>
<th>2</th>
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</thead>
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<tr>
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<td>Angebotsfrequenz: Regular cycle</td>
<td>nur im Sommersemester</td>
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<td>180 Hours</td>
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</table>

Verwendbarkeit der Veranstaltung / Usability of the module

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- 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
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme

Lernziele / Learning target

Students should know basic techniques and applications for randomization and should get an intuition where randomized algorithms are favourable compared to deterministic strategies.
They should understand tools for analyzing randomized algorithms in theory and practice.

Inhalte Vorlesung / Content of the lecture

In the course, fundamental concepts for randomization are taught (Las Vegas, Monte Carlo algorithms). Based on applications in various areas such as sorting, searching, testing,
computational geometry, AI and graph theory, techniques for applying randomization are introduced and analyzed. The focus lies on showing how randomized algorithms can improve the problem complexity in theory and practice. Moreover randomized on-line algorithms and the probabilistic method are motivated and applied to several problem classes.

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<td>• 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.</td>
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<td>• 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.</td>
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<td>• 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.</td>
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<td>• 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.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>The lecture will not follow a specific book; nevertheless standard text books for randomized algorithms will cover large portions of the content, e.g. Randomized Algorithms [Rajeev Motwani, Prabhakar Raghavan]. Additional literature in the form of papers will be announced during the course.</td>
</tr>
</tbody>
</table>
Elective part

The elective part is divided in the Application Area and the Specialization Area. In the Application Area there is a range of different application fields. Students have to choose one of the application fields and have to complete the modules of this field with a total volume of 18 ECTS.

In Specialization in Computer Science (Specialization modules) students have to complete Specialization Modules and Seminars with a total volume of 32 ECTS. The Specialization Modules and Seminars are offered in 3 different specialization areas:
- Cyber-Physical Systems
- Informationssysteme / Information Systems
- Kognitive technische Systeme / Kognitive Technical Systems

Students have to select 1 area.
Students have to complete 2 Seminars. Minimum 1 Seminar must be part of the selected specialization area.

Application Area

The elective part is divided in the Application Area and the Specialization Area. In the Application Area there is a range of different application fields. Students have to choose one of the application fields and have to complete modules of this field with a total volume of 18 ECTS.

Application Area Archaeological Sciences

In the Application Area "Archaeological Sciences" students have to complete modules with a volume of 18 ECTS.

<table>
<thead>
<tr>
<th>Module / Part Module</th>
<th>Course Achievement</th>
<th>SL</th>
<th>PL</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grundlagenmodul I</td>
<td></td>
<td>SL</td>
<td>PL</td>
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<tr>
<td>- Vorlesung / Lecture</td>
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<td></td>
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<td>- Seminar / Seminar</td>
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<tr>
<td>Grundlagenmodul II</td>
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<tr>
<td>- Vorlesung / Lecture</td>
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<tr>
<td>- Vorlesung / Lecture</td>
<td></td>
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</tr>
</tbody>
</table>

Auswahl aus den Fachrichtungen Urgeschichtliche Archäologie, Vorderasiatische Archäologie, Klassische Archäologie, Provinzialrömische Archäologie, Christliche Archäologie und Byzantische Kunstgeschichte, Frühgeschichtliche Archäologie und Archäologie des Mittelalters

The current module descriptions are not yet available.
Application Area Bioinformatics

In the Application Area "Bioinformatics" students have to complete modules with a volume of 18 ECTS.

<table>
<thead>
<tr>
<th>Module / Part Module</th>
<th>Course Achievement</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioinformatik I / Bioinformatics I</td>
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<td>6</td>
</tr>
<tr>
<td>Bioinformatik II / Bioinformatics II</td>
<td>PL</td>
<td>6</td>
</tr>
<tr>
<td>Specialization Module in Bioinformatics</td>
<td>PL</td>
<td>6</td>
</tr>
</tbody>
</table>

Bioinformatik I / Bioinformatics I

Number: 11LE13MO-1309
Modulverantwortlicher: Prof. Dr. R. Backofen
Einrichtung: Chair Bioinformatik
Modultyp: Elective Module
Moduldauer: 1 Term
Zugehörige Lehrveranstaltungen: Lecture and exercises
Sprache: English

Empfohlene Voraussetzungen:
- Basic knowledge in molecular biology
- Basic knowledge in algorithms

Empfohlenes Fachterm: 2
ECTS-Punkte: 6

SWS: 2 Lecture + 2 Exercises
Angebotsfrequenz: only in the summer term

Arbeitsaufwand: 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  o Verteilte Systeme
  o Personal Profile
- Master of Science in Informatik
  o Informationssysteme
  o Kognitive technische Systeme
  o Fachfremder Wahlbereich “Bioinformatik”
### Lernziele / Learning target

This module is an introduction to major topics in the field of bioinformatics with a special focus on sequence analysis. In the course we revise fundamental principles in biology 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 course, students will become familiar with applications of Markov models in Bioinformatics and be able to compute phylogenetic trees.

### Inhalte Vorlesung / Content of the lecture

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

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

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

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
Modulhandbuch M.Sc. Informatik – Bioinformatik II / Bioinformatics II

Bioinformatik II / Bioinformatics II

Nummer: 11LE13MO-1310
Modulverantwortlicher: Prof. Dr. R. Backofen
Einrichtung: Chair Bioinformatik
Modultyp: Elective Module
Moduldauer: 1 Term
Zugehörige Lehrveranstaltungen: Lecture and exercises
Sprache: English

Empfohlenes Fachterm: 3 ECTS-Punkte: 6
SWS: 2 Lecture + 2 Exercises Angebotsfrequenz: only in the winter term
Arbeitsaufwand: 180 Hours (64 Full-time attendance course of study + 116 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
• Bachelor of Science in Embedded Systems Engineering
• 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
  o Verteilte Systeme
  o Personal Profile
• Master of Science in Informatik
  o Informationssysteme
  o Kognitive technische Systeme
  o Fachfremder Wahlbereich “Bioinformatik”

Lernziele / Learning target

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.
### Inhalte Vorlesung / Content of the lecture

- **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
  - Protein threading
- **RNA structure prediction**
  - Nussinov algorithm
  - Zuker algorithm
- **Energy Landscapes**
  - Monte-Carlo sampling
  - Abstractions
  - Folding dynamics

### Zu erbringende Prüfungsleistung / Examination result

- written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.W. Mount: Bioinformatics - Sequence and Genome Analysis Cold Spring Harbor</td>
</tr>
</tbody>
</table>
Algorithmische Grundlagen der Bioinformatik / Algorithmic Foundations of Bioinformatics

Nummer: 11LE13MO-1308

Modulverantwortlicher: Prof. Dr. S. Schuierer
Einrichtung: Institut für Informatik

Modultyp: Elective Module
Moduldauer: 1 Term

Zugehörige Lehrveranstaltungen: Lecture
Sprache: German

Empfohlene Voraussetzungen: Knowledge in algorithms and data structures

Empfohlenes Fachterm: 2
ECTS-Punkte: 6

SWS: 2 Lecture
Angebotsfrequenz: only in the summer term

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme

Lernziele / Learning target

Die Studierenden haben Verständnis des Entwurfs und der Analyse von Zeichenkettenalgorithmen in der Bioinformatik. Sie können mit den gängigen Ansätzen zur Analyse umgehen.

Inhalte Vorlesung / Content of the lecture

- Suffixbäume
- Editierdistanz
- Multiples Zeichenkettenalignment
- Suchheuristiken
- Hidden Markov Modelle für die Alignierung von Zeichenketten

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.

### Literatur / Literature

Algorithms on Strings, Trees and Sequences: Computer Science and Computational Biology von Dan Gusfield von Cambridge University Press
## Maschinelles Lernen in Lebenswissenschaften / Machine Learning in Life Science

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1112</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. R. Backofen</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Bioinformatik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldaeuere Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehoerige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in machine learning and basic knowledge in molecular biology. Specialisation course in Bioinformatics II is helpful.</td>
</tr>
<tr>
<td>Empfohlenes Fachterm:: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Term week hours</td>
<td>2 Lecture + 2 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitaufwand: Workload</td>
<td>180 Hours (64 Full-time attendance course of study + 116 Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme

### Lernziele / Learning target

The aim of this module is to introduce the basic techniques and types of machine learning models employed in modern molecular biology research.

### Inhalte Vorlesung / Content of the lecture

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.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
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- 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.

**Literatur / Literature**

The course material is based on influential publications both in the Machine Learning and/or Bioinformatics literature:

- P Baldi, S Brunak, Y Chauvin, C.A.F Andersen, H Nielsen, Assessing the accuracy of prediction algorithms for classification: an overview, Bioinformatics 2000
- T Fawcett, An introduction to ROC analysis, Pattern Recognition Letters 2006
- T Dietterich, Approximate statistical tests for comparing supervised classification learning algorithms, Neural Computation 1998
- D Jiang, C Tang, A Zhang, Cluster analysis for gene expression data: A survey, IEEE transactions on knowledge and data engineering 2004
- S.C Madeira, A.L Oliveira, Biclustering algorithms for biological data analysis: a survey, IEEE Transactions on computational Biology and Bioinformatics 2004
- A Krause, J Stoye, Large scale hierarchical clustering of protein sequences, BMC bioinformatics 2005
- X.W. Chen, Prediction of protein-protein interactions using random decision forest framework, Bioinformatics 2005
RNA Bioinformatics

Number: 11LE13MO-1318

Modulverantwortlicher: Prof. Dr. R. Backofen

Einrichtung: Chair Bioinformatik

Modultyp: Elective Module

Moduldauer: 1 Term

Zugehörige Lehrveranstaltungen: Lecture and exercises

Sprache: English

Empfohlene Voraussetzungen: Basic knowledge of Bioinformatics and molecular biology, Fundamental knowledge in algorithms

Empfohlenes Fachterm: 2 ECTS-Punkte: 6

SWS: 2 Lecture + 2 Exercises Angebotsfrequenz: only in the summer term

Arbeitsaufwand: 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program:
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

The goal of this module is to get a deeper understanding of the essential algorithms and methods for RNA sequence/structure analysis going beyond the topics covered in Bioinformatics 1 and 2. Students will learn about fundamental algorithms and methods for sequence and structure analysis of the biological macromolecule RNA. Students will be able to predict optimal RNA secondary structure and to explain the methods. At the end of the course, they can use probabilistic analysis of structure by partition function approaches, and thus compute base pair probabilities. Furthermore, participants will be able to compare and align RNAs according to their sequence and structural information. This will be possible using techniques for the alignment of folded RNA as well as for the simultaneous operations of alignment and folding. As special topics,
students will be able to explain fundamental concepts of and methods for RNA-RNA-interaction prediction, as well as the algorithmic treatment of pseudoknots.

<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
</tr>
<tr>
<td>Structure prediction</td>
</tr>
<tr>
<td>• Nussinov algorithm</td>
</tr>
<tr>
<td>• Zuker algorithm</td>
</tr>
<tr>
<td>• McCaskill algorithm</td>
</tr>
<tr>
<td>Comparative RNA analysis:</td>
</tr>
<tr>
<td>• Plan A: first align, then fold</td>
</tr>
<tr>
<td>• Plan C: first fold, then align</td>
</tr>
<tr>
<td>• Plan B: simultaneous alignment and folding</td>
</tr>
<tr>
<td>Overview of RNA related tasks and algorithms</td>
</tr>
<tr>
<td>• RNA-RNA interactions</td>
</tr>
<tr>
<td>• Pseudoknot prediction - Eddy algorithm</td>
</tr>
<tr>
<td>• Binding sites of RNA-binding proteins</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
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<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
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</tbody>
</table>
### Literature

Application Area Biology
In the Application Area "Biology" students have to complete modules with a volume of 18 ECTS.

<table>
<thead>
<tr>
<th>Module / Part Module</th>
<th>Course Achievement SL Examination PL</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computational Neuroscience</td>
<td>PL</td>
<td>18</td>
</tr>
</tbody>
</table>

The current module descriptions are not yet available.
Application Area Cognitive Technical Sciences

In the Application Area "Cognitive Technical Sciences" students have to complete modules with a volume of 18 ECTS.

<table>
<thead>
<tr>
<th>Module / Part Module</th>
<th>Course Achievement</th>
<th>SL Examination</th>
<th>PL</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seminar I</td>
<td>PL</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Seminar II</td>
<td>PL</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Project Seminar</td>
<td>PL</td>
<td></td>
<td>10</td>
<td></td>
</tr>
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</table>

The current module descriptions are not yet available.
Application Area Mathematics

In the Application Area "Mathematics" students have to complete modules with a volume of 18 ECTS.

<table>
<thead>
<tr>
<th>Module / Part Module</th>
<th>Course Achievement</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module I</td>
<td>PL</td>
<td>9</td>
</tr>
<tr>
<td>Module II</td>
<td>SL</td>
<td>9</td>
</tr>
</tbody>
</table>

The students have to select 2 Module out of a huge variety of modules from the Department of Mathematics.

The current module descriptions are not yet available.
Application Area Medicine

In the Application Area "Medicine" students have to complete modules with a volume of 18 ECTS.

<table>
<thead>
<tr>
<th>Module / Part Module</th>
<th>Course Achievement</th>
<th>ECTS</th>
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</thead>
<tbody>
<tr>
<td>Medizinische Informatik</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Themen der Medizinischen Informatik</td>
<td>PL</td>
<td>3</td>
</tr>
<tr>
<td>- Mikrosystemtechnik in der Medizin</td>
<td>PL</td>
<td>3</td>
</tr>
<tr>
<td>Grundlage des menschlichen Organismus</td>
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<td></td>
</tr>
<tr>
<td>- Struktur, Funktion und Fehlfunktion des menschlichen Organismus für Fortgeschrittene</td>
<td>PL</td>
<td>5</td>
</tr>
<tr>
<td>- Innere Medizin für Zahnmediziner</td>
<td>SL</td>
<td>3</td>
</tr>
<tr>
<td>- Allgemeine Chirurgie für Zahnmediziner</td>
<td>SL</td>
<td>1,5</td>
</tr>
<tr>
<td>Grundlagen der Pathologie (Wahlmodul)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Allgemeine Pathologie für Zahnmediziner</td>
<td>SL</td>
<td>3</td>
</tr>
<tr>
<td>- Pathologisch-histologischer Kurs für Zahnmediziner</td>
<td>SL</td>
<td>1,5</td>
</tr>
<tr>
<td>Humangenetik für Studierende der Molekular Medizin (Wahlmodul)</td>
<td>SL</td>
<td>1,5</td>
</tr>
<tr>
<td>Geschichte, Theorie und Ethik der Medizin (Wahlmodul)</td>
<td>SL</td>
<td>1,5</td>
</tr>
<tr>
<td>Pharmakologie und Toxikologie für Zahnmediziner (Wahlmodul)</td>
<td>SL</td>
<td>1,5</td>
</tr>
<tr>
<td>Mikrobiologie für Pharmazeuten (Wahlmodul)</td>
<td>PL</td>
<td>3</td>
</tr>
<tr>
<td>Seminar Wissenschaftliches Denken und Handeln (Wahlmodul)</td>
<td>SL</td>
<td>3</td>
</tr>
<tr>
<td>Projekt an einem medizinischen Lehrstuhl (Wahlmodul)</td>
<td>SL</td>
<td>6</td>
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</tbody>
</table>

The current module descriptions are not yet available.
Application Area Microsystems Engineering
In the Application Area "Microsystems Engineering" students have to complete modules with a volume of 18 ECTS.

Modul / Module

Analyse- und Messmethoden für Dünnschichten und die Nanoskala / Thin Film Analysis and Nanoscale Measurement Technologies

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5117</th>
</tr>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Zacharias</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Nanotechnology</td>
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<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Moduldauer Module duration</td>
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</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester:: Recommended term of study | 5 |
| ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 lecture |
| Angebotsfrequenz: Regular cycle | Only in the winter term |
| Arbeitsaufwand: Workload | 90 hours (32 Hours Full-time attendance course of study + 58 Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Sensors and actuators
  - Personal Profile

Lernziele / Learning target
The module gives an overview of all state-of-the-art measurement and analysis methods for
thin films and nanoscopic structures. Special emphasis will be placed on the prospects and drawbacks of each method as well as on typical limits and potential measurement artifacts. Educational objective is to enable students to find a suitable and appropriate method to measure or detect a certain material property of interest.

### Inhalte Vorlesung / Content of the lecture

The treated measurement and analysis techniques include optical, electrical, chemical and structural methods which detect and probe material properties like morphology/shape, film thickness, crystallinity, chemical composition, trace impurities, bonding configurations, bandgap, etc. Namely methods like AFM, SEM / TEM, APT, SIMS, XPS, SE, PL, FTIR, Raman, XRD, C-V / I-V, RBS and many more will be dealt with.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- Master of Science in Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
XPS, TEM, FTIR, UPS, SEM, AFM, SPR, GIR, ATR, STM?? Got it?
The performance of microsystems is often dominated by the nature of the surfaces involved. This course honours the great importance of surfaces and interfaces in microsystems engineering by introducing the most common techniques for surface analysis. Examples will be presented which are typical to various fields of microsystems engineering.
(Ellipsometry, XRR, Surface Plasmon Spectroscopy) of layers. General topics from the surface sciences such as adhesion, wetting, and adsorption processes are also presented together with the techniques.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Bewertung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Various materials are available on the website.
### Modul / Module

**Ausgewählte Problemstellung in Biosignalverarbeitung / Selected Problems in Biosignal Processing**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5303</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. U. Hofmann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Fakultät für Medizin</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended requirements**

Prerequisite to be able to follow this module is a thorough understanding of classical signal processing. Strongly recommended is the knowledge of one programming language like Python (preferably), Matlab (or Octave) or even IDL (not supported).

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture + 1 Übung</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
</tbody>
</table>

| Arbeitsaufwand: Workload | 90 hours (42 Hours Full-time attendance course of study + 48 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

### Lernziele / Learning target

Participants will learn to interpret and analyze biological signals of high bandwidth. They will
- gain a deep knowledge of feature extraction methods,
- utilize selected classification methods and
- decision making methods.
Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
**Modulhandbuch M.Sc. Informatik – Biobrennstoffzelle / Biofuel Cells**

**Modul / Module**

**Biobrennstoffzelle / Biofuel Cells**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5401</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. R. Zengerle</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair MEMS Applications</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>High school education in mathematics and natural sciences</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester:: Recommended term of study**

<table>
<thead>
<tr>
<th>4 oder 5</th>
<th>ECTS-Punkte:: ECTS-points</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>1 Lecture + 1 Seminar</td>
<td>Angebotsfrequenz: Regular cycle</td>
</tr>
<tr>
<td>Arbeitssaufwand: Workload</td>
<td>90 hours (28 oder 32 Hours Full-time attendance course of study + 58 oder 62 Hours Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile

**Lernziele / Learning target**

**Inhalte Vorlesung / Content of the lecture**

In der Vorlesung wird eine Einführung in elektrochemische Energiewandler und speziell in bioelektrochemische Systeme gegeben. Behandelt werden schwerpunktmäßig die Punkte theoretischer Hintergrund und Funktions-Prinzipien, Design, Anwendungsbeispiele, und Methoden zur Charakterisierung.

**Inhalte Seminar / Content of the seminar**

Im Seminar halten die Studierenden Vorträge zu aktuellen Themen aus den Bereichen Biobrennstoffzelle, Bioenergie und regenerative Energieversorgung. Im praktischen Teil werden Biobrennstoffzellen aufgebaut und elektrochemisch charakterisiert. Dieser Teil wird mit einer Auswertung und Diskussion der erhaltenen Ergebnisse abgeschlossen. Um zur Abschlussprüfung zugelassen zu werden, muss die schriftliche Ausarbeitung erfolgreich bestanden sein.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Zu erbringende Studienleistung / Course Achievement**

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th><strong>Literatur / Literature</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Begleitend zur Lecture wird ein Skriptum zur Verfügung und regelmäßig aktualisiert.</td>
</tr>
</tbody>
</table>
# Biochiptechnologien / Biochip Technologies

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>Number</th>
<th>11LE50MO-5402</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer</td>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester**: Recommended term of study 4

**SWS**: Semester week hours 2 Lecture

**Arbeitsaufwand**: Workload 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)

**ECTS-Punkte**: ECTS-points 3

**Angebotsfrequenz**: Regular cycle Only in the summer term

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile

### Lernziele / Learning target

For modern Life sciences and molecular diagnostics Biochip technologies play a key role for miniaturization and parallelization of analysis. They combine different methods for microstructuring surfaces, for immobilizing biomolecules and read-out technologies. Here, all the aspects and tools for the development of modern bioanalytical surfaces and applications will be addressed in this lecture.

### Inhalte Vorlesung / Content of the lecture

This lecture includes:
- Surface modifications, techniques and components
### Zu erbringende Prüfungsleistung / Examination result

- written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Various materials are available on the website [http://www.cpi.uni-freiburg.de/](http://www.cpi.uni-freiburg.de/)
<table>
<thead>
<tr>
<th>Nummer:</th>
<th>11LE50MO-5315</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. R. Zengerle</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Chair MEMS Applications</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldaurer</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Lecture and Laboratory</td>
</tr>
<tr>
<td>Sprache:</td>
<td>German</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fachsemester::</td>
<td>ECTS-Punkte:</td>
</tr>
<tr>
<td>Recommended term of study</td>
<td>ECTS-points</td>
</tr>
<tr>
<td>SWS:</td>
<td>2 lecture + 2 exercises</td>
</tr>
<tr>
<td>Semester week hours</td>
<td>Angebotsfrequenz:</td>
</tr>
<tr>
<td></td>
<td>Regular cycle</td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>180 hours</td>
</tr>
<tr>
<td>Workload</td>
<td>(56 oder 64 hours Full-time attendance course of study + 116 oder 124 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

- Elective Module for students of the study program
  - Master of Science in Embedded Systems Engineering
    - Personal Profile
  - Master of Science in Informatik
    - Application area Mikrosystemtechnik
  - Master of Science in Mikrosystemtechnik
    - Life sciences: Biomedical engineering
    - Life sciences: Lab-on-a-chip
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Life sciences: Biomedical engineering
    - Life sciences: Lab-on-a-chip
    - Personal Profile

**Lernziele / Learning target**

Strategien zur Identifizierung und Bewertung neuer Anwendungen der Mikrosystemtechnik im Bereich Mikro- und Molekularbiologie aufgezeigt.
Laboratory „BioMST 1: Grundtechniken der Molekularbiologie:“

<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anhand ausgewählter Beispiele wird gezeigt, wie durch den Einsatz der Mikrosystemtechnik biotechnologische Probleme vorteilhaft gelöst werden können. Dabei wird Bezug genommen auf aktuelle Entwicklungen germaner und internationaler Forschungseinrichtungen sowie der Industrie. Ferner werden Strategien zur Identifizierung neuer Anwendungen der Mikrosystemtechnik im Bereich Biotechnologie aufgezeigt. Die Themen der LVA sind:</td>
</tr>
<tr>
<td>- Spektrum der Biotechnologie</td>
</tr>
<tr>
<td>- BioMST Roadmap</td>
</tr>
<tr>
<td>- Molekulare Biotechnologie</td>
</tr>
<tr>
<td>- Wissenschaftliche Grundlagen</td>
</tr>
<tr>
<td>- Instrumentierung &amp; Automatisierung</td>
</tr>
<tr>
<td>- Mikrobiologische Methoden</td>
</tr>
<tr>
<td>- Molekularbiologische Methoden</td>
</tr>
<tr>
<td>- Funktionsanalytik</td>
</tr>
<tr>
<td>- Gastvortrag aus der Industrie</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inhalte Praktikum / Content of the laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Das Laboratory ist als 4 tägiger Block ausgelegt. 4 Wochen vor dem Laboratory bekommt jeder Teilnehmer/in ein Thema zugeordnet, über das er/sie ein 15 minütiges Referat am ersten Tag hält ums so zum einen zu zeigen, dass auch ein biochemischer Stoff aufgearbeitet werden kann und um zugleich den anderen Kursteilnehmern/innen den Stoff aus eigener Sicht nahe zu bringen. Zu den einzelnen Versuchen sind Protokolle zu schreiben. Vor Beginn der Versuche wird eine Sicherheitsbelehrung durchgeführt um überhaupt im Biolabor arbeiten zu dürfen. Folgende Experimente werden durchgeführt:</td>
</tr>
<tr>
<td>- Zellkulturtechniken werden erlernt, um einerseits steril arbeiten zu können und andererseits etwas Erfahrung im Umgang und der Aufzucht von Bakterien und Zellen zu erhalten. Um zu wissen wie viele Zellen vorhanden sind, werden verschiedene Zellzählungsmethoden angewendet.</td>
</tr>
</tbody>
</table>
Eine weitere Standardtechnik ist der Immunoassay. Hierbei wird ein Protein, welches sich aus einem entsprechenden Gen ableitet, quantitativ nachgewiesen. Es wird sowohl die klassische Methode in der Mikrotiterplatte als auch in einem zentrifugalen System durchgeführt. Hierbei soll insbesondere in der Handhabung und im Nachweis der Unterschied zwischen DNA und Protein erlernt werden.

Als letzte Technik wird die Elektrophorese durchgeführt. Sie dient sowohl zum Nachweis von DNA als auch Proteinen. Hierbei soll der Umgang mit Gelen und wie man die erhaltenen Daten ausliest erlernt werden.

Fragen, Anregungen und Änderungswünsche sind jederzeit willkommen, da wir versuchen das Laboratory so zu gestalten, dass innerhalb kurzer Zeit ein maximales Verständnis für diese recht komplexen Techniken der Biologen erreicht werden kann.

Die Praktikumsnote setzt sich zusammen aus einem Kurzreferat zu einem Experimentalthema des Praktikums sowie der Erstellung eines Praktikumsberichtes.

### Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Begleitend zur Lecture wird ein Skriptum zur Verfügung gestellt und regelmäßig aktualisiert.
### BioMST 2 – Biotechnologische Aufgabenstellung für die Mikrosystemtechnik / BioMST 2 – Biotechnological Tasks for Microsystems Technology

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5317</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. R. Zengerle</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair MEMS Applications</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>german</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile

### Lernziele / Learning target


### Inhalte Vorlesung / Content of the lecture

Anhand ausgewählter Beispiele wird gezeigt, wie durch den Einsatz der Mikrosystemtechnik biotechnologische Probleme vorteilhaft gelöst werden können. Dabei wird Bezug genommen auf aktuelle Entwicklungen von Forschungseinrichtungen sowie der Industrie. Ferner werden Strategien zur Identifizierung neuer Anwendungen der Mikrosystemtechnik im Bereich Biotechnologie aufgezeigt. Die Themen der LVA sind:

- Bioverfahrenstechnik
- Bereiche und Aufgaben
- Bioverfahrensentwicklung
- UP-Stream Prozesse & Stoffumwandlung
- Down-Stream Prozesse Diagnostik
- Diagnostik
- Mikroorganismen in Lebensmitteln
- Bakterien & Viren als Krankheitserreger
- Klassisch Mikrobiologische Diagnostik
- Immun- und Nukleinsäurebasierte Diagnostik von Erregern
- Automatisierung, Miniaturisierung und Integration
- Systementwicklung, Validierung und QM

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Literatur / Literature

Begleitend zur Lecture wird ein Skriptum zur Verfügung gestellt und regelmäßig aktualisiert.
### Modul / Module

**Bionische Sensoren / Bionic Sensors**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5701</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. G. Urban</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Sensoren</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

#### Empfohlenes Fachsemester:: Recommended term of study

<table>
<thead>
<tr>
<th>ECTS-Punkte: ECTS-points</th>
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</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>1 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Arbeitssaufwand: Workload</th>
<th>90 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>(14 Hours Full-time attendance course of study + 76 Hours Self-study)</td>
<td></td>
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</table>

#### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile

#### Lernziele / Learning target

The aim of this module is a basic understanding of electrical, electrochemical and optical chemo- and biosensor principles as well as the basic knowledge of biological sensors. Principles of bioinspired system and the background of bionic learning from nature to realize microtechnological systems will be discussed. Basics of electrical charge transfer and information processes in biological systems will be presented.

#### Inhalte Vorlesung / Content of the lecture

The lecture bionic sensors deal with learning from nature to realize technical chemo- and biosensors. Topics are:
- Biological sensors/receptors
- Charge transfer and information processes in biology
- Chemosensor, introduction
- Basics of electrochemistry
- Electrochemical potentiometric sensors
- Electrochemical amperometric sensors
- Gas sensors
- Biosensors

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Bewertung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Bionische Sensoren - Laboratory / Bionic Sensors - Laboratory

Nummer: 11LE50MO-5702

Moduloberverantwortlicher: Prof. Dr. G. Urban
Einrichtung: Chair Sensoren
Modultyp: Elective Module
Moduldauer: 1 term
Zugehörige Lehrveranstaltungen: Laboratory
Sprache: English

Empfohlene Voraussetzungen: Kenntnisse der Inhalte in den Modulen Sensors, Bionic Sensors, BioMEMS

Empfohlenes Fachsemester: 3
ECTS-Punkte: 3
SWS: 3 Laboratory
Angebotsfrequenz: only in the winter term
Arbeitsaufwand: 90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  o Sensors and actuators
  o Personal Profile
- Master of Science in Informatik
  o Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Microsystems Engineering
  o Sensors and actuators
  o Personal Profile
- Master of Science in Mikrosystemtechnik
  o Sensors and actuators
  o Personal Profile

Lernziele / Learning target

Students should gain hands on experience with several types of sensors the theory of which has been presented in the lectures “Sensors and Actuators” as well as “Sensorik und Aktorik”, and explained deeper in “Bionic Sensors” and “BioMEMS”.

### Inhalte Praktikum / Content of the laboratory

Five experiments will be offered with selected types of sensors described in the lectures mentioned above. Students will work with the sensors, calibrate them, build up experiments and perform detection and measurements with the sensors under supervision of tutors.

### Zu erbringende Prüfungsleistung / Examination result

Each student will have to write at least one report about one of the experiments she/he participated; during each experiment a written test and continuous discussions will take place; practical skills of the students in accordance with the basic theory will be observed and graded.

### Benotung / Grading

The final module grade is determined from an average of the grades of the individual reports.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
## Biophysics of the cell

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<th>11LE50MO-5305</th>
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</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. A. Rohrbach</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Bio- and Nano-Photonik</td>
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<tr>
<td>Module Type</td>
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<tr>
<td>Module duration</td>
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</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>german</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>3 Lecture + 2 Übung</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (80 Hours Full-time attendance course of study + 100 Hours Self-study)</td>
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</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Physik
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile

### Lernziele / Learning target

This module gives a survey through modern cell biophysics, addresses state of the art scientific questions and presents modern investigation methods. This comprises classical but also novel physical methods and theories, which pushed the field of biophysics together with newest measurement technology. The applied physical methods do not only inspire biology and medicine, but also the physics of complex systems, which achieves an unequaled level of self-organisation and complexity inside living cells. This lecture is designed for physicists and engineers and provides a colorful mixture of physics, biology, chemistry, mathematics, and engineering that is illustrated with numerous pictures and animations.
### Inhalte Vorlesung / Content of the lecture

- Structure of the cell or the recipe for cell-biophysical science
- Diffusion and Fluctuation
- Sensing and Acting measurement principles
- Biological relevant forces
- Biophysics of proteins
- Polymerphysics
- Visco-elasticity and micro rheology
- Dynamics of the cytoskeleton
- Molecular motors
- Membrane physics

75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

### Inhalte Übung / Content of the exercises

The tutorials help the students to get a more in-depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this, the students should prepare weekly exercises and present them during the tutorial. Only difficult exercises are presented by the tutors.

75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the lecture and the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Joe Howard: Mechanics of Motor Proteins and the Cytoskeleton.
Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.
### Modul / Module

**CMOS-Integrierte Mikrosysteme / CMOS-Integrated Microsystems**

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<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5716</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Paul</td>
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<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Materialien</td>
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<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
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<td>Sprache: Language</td>
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<table>
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<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
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<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
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<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 exercises</td>
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<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
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<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (56 hours Full-time attendance course of study + 124 Hours Self-study)</td>
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### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - MEMS Processing
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - MEMS Processing
  - Personal Profile

### Lernziele / Learning target

The most successful microsystems to date have been based on silicon. Companies such as Bosch, Analog Devices, Texas Instruments, Sensirion, and other small and medium enterprises have built their success on this wise technological choice. The lecture deals with microsystems compatible with silicon foundry services and commercial silicon technologies, in particular CMOS technologies. It will offer a healthy mix of technology, physical sensor principles and operating techniques, and will be enriched with examples that made it into the market and others that have remained scientific visions. In tune with the progress of the lecture material, home-work will be assigned, with the presentation and discussion of
solutions by students during the course hours.

### Inhalte Vorlesung / Content of the lecture

- Introduction
- Basic technologies
- Magnetic sensors
- Radiation sensors
- Stress sensors
- Inertial sensors
- Thermal sensors
- Chemical sensors
- Material parameters
- System integration

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
## Module / Modul

### Computerunterstützte und mechanische Konstruktion / Computer-Aided and mechanic Design

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<th>Number:</th>
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<tr>
<td>Responsible person:</td>
<td>Prof. Dr. P. Woias</td>
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<td>Organisational unit:</td>
<td>Chair Konstruktion von Mikrosystemen</td>
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<td>Module duration:</td>
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<td>Lecture and exercises</td>
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<td>Language:</td>
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### Recommended term of study: 3 ECTS-points: 3

### Semester week hours: 1 Lecture + 1 Übung Angebotsfrequenz: Only in the winter term

### Workload: 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

### Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Personal Profile
### Lernziele / Learning target

- Kenntnisse der Vorgehensweise vom Konstruieren am PC
- Praktische Erfahrung mit CAD
- Berechnung und Auslegung einfacher mechanischer Bauelemente
- Verifikation der Auslegung durch mechanische Simulation im CAD System
- CAD Konstruktion eines komplexen Systems

### Inhalte Vorlesung / Content of the lecture


### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Dubbel: Taschenbuch für den Maschinenbau, K.-H. Grote, J. Feldhusen. 2011
Kabus: Mechanik und Festigkeitslehre, K. Kabus, 2013
Modul / Module

DNA Analytik / DNA Analysis

<table>
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<th>Number</th>
<th>11LE50MO-5404</th>
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<td>Modulverantwortlicher:</td>
<td>Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
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<tr>
<td>Einrichtung:</td>
<td>Organisational unit</td>
<td>Chair Chemie und Physik von Grenzflächen</td>
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<tr>
<td>Modultyp:</td>
<td>Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Moduldauer</td>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester:: Recommended term of study | 2 | ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture | Angebotsfrequenz: Regular cycle | Only in the summer term |
| Arbeitsaufwand: Workload | 90 hours (28 Full-time attendance course of study + 62 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Lab-on-a-chip
  - Personal Profile

Lernziele / Learning target

The key principles of DNA analysis are taught using standard and high tech applications to demonstrate the underlying mechanisms of DNA analysis. Starting with the biochemical role of the DNA the principles of enzymatic modification and physical detection of nucleic acids are covered. PCR is used as a demo application to introduce the key features of DNA analysis. From there on the areas of sequencing and DNA microarrays are covered as well as the use of databases to gain information about DNA sequences and how to design DNA primers and probes. The technical equipment to perform PCR, gel electrophoresis, microarray production and readout is also addressed. The lecture should give the student the theoretical background to understand, plan and perform DNA analysis research.
### Inhalte Vorlesung / Content of the lecture

This lecture includes:
- Structure and function of DNA
- Enzymes that process DNA
- DNA amplification (PCR)
- DNA detection (gel electrophoresis, ...)
- Application in forensic sciences
- DNA microarray overview

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the results of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Various materials are available on the website http://www.cpi.uni-freiburg.de/
# Drahtlose Sensorsysteme / Wireless Sensor Systems

<table>
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<tr>
<th>Nummer: Number</th>
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<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. L. Reindl</td>
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<td>Einrichtung: Organisational unit</td>
<td>Chair Electrical Instrumentation</td>
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<td>Elective Module</td>
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<td>Moduldauer Module duration</td>
<td>1 term</td>
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<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
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<td>Sprache: Language</td>
<td>English</td>
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</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 1 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
**Lernziele / Learning target**

With the help of microelectronics many everyday objects have to be connected to realize visions like Pervasive Computing and Ambient Intelligence. Miniaturized, self-powered wireless sensor nodes - also discussed as eGrain or Smart Dust - will make an important contribution to the networking of various objects. Miniaturized sensor nodes for wireless sensor networks represent a design problem, which is characterized by a high degree of functional complexity combined with a significant realization diversity.

**Inhalte Vorlesung / Content of the lecture**

In the first part of the lecture behavioral and technological degrees of freedom of a wireless sensor system are presented and discussed intensively. Based on this, special systems such as tire pressure sensors, torque sensors and wireless sensor nodes for a logistics scenario will be discussed in detail.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modulhandbuch M.Sc. Informatik – Elektrochemische Fertigungsverfahren in der Mikrotechnik / Electrochemical production technologies

Modul / Module

Elektrochemische Fertigungsverfahren in der Mikrotechnik / Electrochemical production technologies

Nummer: Number
11LE50MO-5602

Modulverantwortlicher: Responsible person
Prof. Dr. H. Reinecke

Einrichtung: Organisational unit
Chair Process Technology

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Lecture

Sprache: Language
english

Empfohlenes Fachsemester:: Recommended term of study
3

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
2 Lecture

Angebotsfrequenz: Regular cycle
Only in the winter term

Arbeitsaufwand: Workload
90 hours
(32 Hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  o Personal Profile
- Master of Science in Informatik
  o Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  o MEMS Processing
  o Personal Profile
- Master of Science in Microsystems Engineering
  o MEMS Processing
  o Personal Profile

Lernziele / Learning target

The aim of the module is to provide the in-depth theoretical foundations and the specific technical knowledge of the micro-electro-chemical processes as well as the methodology to benchmark the process with alternative technical methods.

Inhalte Vorlesung / Content of the lecture

- Electrochemical fundamentals (Galvanic and Corrosion Cell)
- Batteries and fuel cells
- Thermodynamics
- Nernst, Butler-Vollmer, Faraday, Porbaix
- Double layer models (Helmholtz, Gouy-Chapman Stern-Doppelschicht Grahame
Bockris-Müller-Devanathan Schmickler und Henderson Trasatti-Buzzanca Conway Marcus-Theory

- Electroplating, electrolyte compositions (Ni, Au, Cu, alloys), Material properties (stress, hardness, surface roughness), MST applications
- Electrochemical machining (ECM), electrolyte compositions, Technology and variants, MST applications
- Comparison and benchmark to Spark Erosion, Technology, process characteristics, MST applications and results

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
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- Master of Science in Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Accompanying the lecture, a script is provided and updated regularly.
Energiegewinnung / Energy Harvesting

**Nummer:** Number
11LE50MO-5703

**Modulverantwortlicher:** Responsible person
Prof. Dr. P. Woias

**Einrichtung:** Organisational unit
Chair Konstruktion von Mikrosystemen

**Modultyp:** Module Type
Elective Module

**Moduldauer:** Module duration
1 term

**Zugehörige Lehrveranstaltungen:** Connected events
Lecture and exercises

**Sprache:** Language
english

**Empfohlenes Fachsemester:** Recommended term of study
2

**ECTS-Punkte:** ECTS-points
5

**SWS:** Semester week hours
2 lecture + 2 exercises

**Angebotsfrequenz:** Regular cycle
Only in the summer term

**Arbeitsaufwand:** Workload
150 hours (56 hours Full-time attendance course of study + 94 Hours Self-study)

---

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Fachfremdes Wahlmodul Mikrosystemtechnik
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile

---

**Lernziele / Learning target**
The students shall learn the basic principles of (micro) energy harvesting. Several energy conversion techniques, energy storage concepts and power management strategies are described in detail. By this the students shall become able to estimate the energy generation of different harvesting techniques and to work on the design of energy autonomous embedded systems. The importance of the system-level design in these systems is, in general, a central objective in this class.

---

**Inhalte Vorlesung / Content of the lecture**
- Harmonical Oscillator (with bending beams)
- Piezoelectric Energy Harvesters
Electrodynamic Energy Harvesters
Electrostatic Energy Harvesters
Non-Resonant Generators
Thermoelectric Generators & Processes
Thermomechanic Generators
Capacitive Storages and Accumulators
Step-up Converters and Advanced Step-up Converter Design
Energy Harvesting Applications

Zu erbringende Prüfungsleistung / Examination result
written or oral examination

Benotung / Grading
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result
- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature
Energiespeicherung und Wandlung mittels Brennstoffzellen / Energy storage and conversion using fuel cells

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5203</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Reinecke</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Process Technology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile

Lernziele / Learning target

The aim of the module is to provide the in-depth theoretical fundamentals and specific skills for the storage and conversion of energy using fuel cells in micro-technical systems.

Inhalte Vorlesung / Content of the lecture

- Physikalisch chemische Grundlagen Brennstoffzellen
- Aufbau und Funktion von Brennstoffzellen
- Vorstellung unterschiedlicher Brennstoffzellentypen
- Physikalisch chemische Grundlagen der Wasserstoffspeicherung
Vorstellung von Wasserstoffspeichertypen und -mechanismen
Diskussion von Vor- und Nachteilen der Wasserstoffspeicher
Brennstoffzellensysteme im Automobil
PEM
DMFC
Miniatuirisierung von Brennstoffzellen
Mikrobrennstoffzelle
Chiptegierte Brennstoffzelle (P²Brenn)
Brennstoffzellenakkumulator
Miniatuirisierung der Wasserstofferzeugung
Einsatz von Brennstoffzellensystemen in der MST

Zu erbringende Prüfungsleistung / Examination result
written or oral examination

Benotung / Grading
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature
Zur Lecture wird ein Skriptum zur Verfügung gestellt und regelmäßig aktualisiert.

Modul / Module
**Energiewende / Energy Transition**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5802</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Elektrische Mess- und Prüfverfahren</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Seminar</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Winter or summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 or 32 hours Full-time attendance course of study + 58 or 62 hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Personal Profile

**Lernziele / Learning target**

Aus den Perspektiven Technik, Ökonomie und Geisteswissenschaften soll der Zusammenhang zwischen Informationstechnologien und der ökologischen Energiewende kritisch beleuchtet werden.

**Inhalte Vorlesung / Content of the lecture**

Ziel ist die Etablierung einer innovativen Lehrveranstaltung, die ein problemlösungsorientiertes Ausbildungskonzept für Studenten aus unterschiedlichen Fachbereichen anbietet. Konkret umfasst das vorgestellte Konzept drei Aspekte (1) Gastvorträge, (2) Gruppenarbeit und (3) Präsentierbares Handlungskonzept. Durch das eigenständige Erarbeiten in interdisziplinären Teams wird die Arbeitswelt praxisnah simuliert, die Begrenzungen und die Stärken der eigenen Fachdisziplin werden konkret am Problem erfahren und durch Einbeziehung anderer Disziplinen innovativer gelöst.

Veranstaltende Professoren:
- Prof. Becker, Lehrstuhl für Rechnerarchitektur
- Prof. Gander, Philosophisches Seminar und Husserl-Archiv
- Prof. Lausen, Institut für Informatik
- Prof. Müller, Institut für Informatik und Gesellschaft (koordinierend)
- Prof. Neumann, Lehrstuhl für Wirtschaftsinformatik
- Prof. Reindl, Lehrstuhl für elektrische Mess- und Prüfverfahren
- Prof. Schneider, Lehrstuhl für Kommunikationssysteme

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**Zu erbringende Prüfungsleistung / Examination result**

- written documentation
- oral examination

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**Benotung / Grading**

The final module grade is calculated 50% of the written documentation and 50% of the oral presentation.

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**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Ergebnisse wissenschaftlich präsentieren / Scientific writing and presentation

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5801</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Hanemann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Werkstoffprozess-technologien</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulverantwortlicher: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German or english</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester:: Recommended term of study | 2 |
| ECTS-Punkte: ECTS-points | 3 |
| SWŠ: Semester week hours | 2 Seminar |
| Angebotsfrequenz: Regular cycle | Only in summer term |
| Arbeitsaufwand: Workload | 90 hours |
| (28 hours Full-time attendance course of study + 58 hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Personal Profile

Lernziele / Learning target

Die Studierenden werden
- über die Bedeutung der Einhaltung der guten wissenschaftlichen Praxis informiert
- in die Lage versetzt, ein Labortagebuch (Laborjournal) und einfache wissenschaftliche Berichte zu schreiben
- über das Erstellen einer Master- bzw. Promotionsarbeit informiert
- in die Lage versetzt, einen wissenschaftlichen Vortrag (15 min), einen Kurzvortrag (3 min), ein wissenschaftliches Poster sowie ein Werbeposter zu erstellen und zu präsentieren.
### Inhalte Vorlesung / Content of the lecture

The following topics will be covered during the course:

- Ancient and current scientific malpractice
- Rules for safeguarding good scientific practice
- Laboratory journal, Scientific reports (from project reports to dissertation thesis)
- Lecture presentation
- Oral poster presentation (3 minutes lecture)
- Scientific poster presentation, "Advertisement" poster

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The final module grade is calculated from the presentation (50%), short presentation (20%), scientific poster (20%) and commercial poster (10%).

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Etische Aspekte der Neurotechnologie / Ethical Aspects of Neurotechnology

<table>
<thead>
<tr>
<th>Modulnummer:</th>
<th>11LE50MO-5320</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. U. Egert</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Chair Biomikrotechnik</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer:</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache:</td>
<td>German or english</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen:</td>
<td>Interesse an interdisziplinärer Aufbereitung aktueller Fragestellungen</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte:</td>
<td>3</td>
</tr>
<tr>
<td>SWS:</td>
<td>2 Seminar</td>
</tr>
<tr>
<td>Angebotsfrequenz:</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

## Usability of the Module
Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

## Learning target
**Inhalte Seminar / Content of the seminar**

Interdisziplinares Seminar zu ethischen und philosophischen Aspekten der Neurotechnologie.

Folgende Themenbereiche werden jeweils unter ethischen, neurowissenschaftlichen bzw. ingenieurwissenschaftlichen Gesichtspunkten bearbeitet:

1. Ethik der Neurowissenschaften als aktuelles Gebiet der Philosophie
2. Identität, Person und Persönlichkeit als Grundbegriffe der Ethik der Neurowissenschaften
3. Spezifische philosophische und ethische Aspekte folgender Anwendungsfelder:
   - Invasive und nicht-invasive Gehirn-Maschine-Schnittstellen
   - Neuroimaging- Emotionale Integration neuronaler Prothesen
   - Tiefe Hirnstimulation
   - Optogenetische Interaktion
   - Neuro-Enhancement
   - Zukunftstechnologien und deren Einsatz

**Zu erbringende Prüfungsleistung / Examination result**

mündliche Abschlussprüfung

**Benotung / Grading**

Die Modulnote errechnet sich zu 100% aus der mündlichen Abschlussprüfung.

**Gewichtung der Prüfungsleistung / Weight of examination result**


**Literatur / Literature**

- Script
The lab course includes topics as part of the HIGHWIND project (Simulation, Optimization and Control of High-Altitude Wind Power Generators). As the HIGHWIND project offers a large variety of project topics, students may be assigned topics meeting best their interests and academic background. Prior studies of "Modelling and System Identification" and/or "Optimal Control and Estimation" are recommended.

Empfohlene Fachsemester:: Recommended term of study
2 oder 3

ECTS-Punkte: ECTS-points
6

SWS: Semester week hours
4 Laboratory

Angebotsfrequenz: Regular cycle
Each term

Arbeitsaufwand: Workload
180 hours (56 oder 64 hours Full-time attendance course of study + 124 oder 116 hours Self-study)

Lernziele / Learning target
Aim of this module is to use the theoretical background for real applications in a scientific project. Finding creative solutions to problems as well as hands-on testing/verification of soft- and hardware will be part of the projects. The module will also offer experience of working in an international team.

**Inhalte Praktikum / Content of the laboratory**

Focus of the lab course is making a real flight control system work for small aerial vehicles equipped with a variety of sensing and actuation equipment. These vehicles might be remote controlled airplanes with IMUs and GPS or quadrotors, and they might be connected to the ground via a tether. The course will be accompanied by weekly meetings with one or more team members working on complementary projects addressing the same real world control problem. In the last two to three weeks of the lab course, when the main project aims are achieved, the participants will start to work on a short report for documentation and give a final oral presentation to share their findings with all team members.

**Zu erbringende Prüfungsleistung / Examination result**

Project work:
- A working project result
- project documentation and oral presentation

**Bewertung / Grading**

The final module grade is determined from an average of the grades of the project documentation and the presentation.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Fortgeschrittene Aufbau- und Verbindungstechnik / Advanced Assembly and Packaging Technology

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5601</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Wilde</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Aufbau- und Verbindungstechnik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>english</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Good knowledge of assembly and packaging technologies from the compulsory lecture</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - MEMS Processing
  - Personal Profile

### Lernziele / Learning target

It is the aim, that after this module the students will be able to understand advanced problems in the field of assembly and packaging. Furthermore it is intended that the students will have capabilities to resolve A&P-related research tasks for micro-systems. The employed methods will start with system concepts and comprise thermal, electrical and mechanical modelling and optimisation. As a basis the student will know the fundamental elements of A&P as well as the specific technologies for interconnection, assembly and protection. Also, the students will become familiar with the materials, their processing and
properties. In this way they have the abilities for own research on micro-systems.

### Inhalte Vorlesung / Content of the lecture

The contents of teaching are mainly based on actual research projects in the chair Aufbau- und Verbindungstechnik.

**Organization of the lecture:**
- Introduction
- Thermal management using novel materials
- Packaging of MEMS pressure sensors
- Fatigue analysis of soldered joints
- Adhesive bonding of power electronics
- Computation of packaging stress in Hall sensors
- Concepts for sensors for mechanical properties
- High-temperature packaging
- Materials modelling in A&P
- Reliability modelling in A&P

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- **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 2011:** 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 Microsystems Engineering, Academic regulations of 2009:** 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 Mikrosystemtechnik, Academic regulations of 2009:** The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
**Modul / Module**

**Fortgeschrittene Eingebettete Systeme Laboratory / Advanced Embedded Systems Laboratory**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5223</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. L. Reindl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Electrical Instrumentation</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Students require basic knowledge of VHDL, good knowledge of C and should be familiar with the basic usage of Linux.</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>4 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (56 hours Full-time attendance course of study + 124 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile

**Lernziele / Learning target**

The goal is to provide students with the necessary practical background for hardware software codesign.

**Inhalte Praktikum / Content of the laboratory**

...
This course concentrates on hardware-software-co-design, such as combining FPGA-based hardware with high level operating systems running on ARM cores. Students will learn implementing basic hardware structures in VHDL and later proceed to control that hardware directly from high level applications running on the additional ARM core. Students will work either in small groups or on their own.

**Zu erbringende Prüfungsleistung / Examination result**

For each experiment, a lab report is required. The final grade is determined from an average of the grades of the individual reports. All experiments must be performed and a lab report written.

**Benotung / Grading**

The module grade will be determined from the average of the grades of each report.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Modul / Module

**Fortgeschrittene Siliziumtechnologie / Advanced Silicon Technology**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5112</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Paul</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Materialien der Mikrosystemtechnik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>english</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in Microsystems technology and semiconductor physics</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - MEMS Processing
  - Personal Profile

### Lernziele / Learning target

This module provides a more detailed description of silicon technologies exceeding the modules in Microsystemtechnology I and II. The basics in silicon technologies will be accomplished by the most recent results found in literature. Whenever possible, we will organize a visit of the Micronas GmbH in Freiburg and their CMOS Fab.
### Inhalte Vorlesung / Content of the lecture

Substrate materials, oxidation, diffusion, implantation, polysilicon and epitaxy, silisides, metallisation, dielectric layers, SiGe, strained silicon, low- und high-k-dielectrics, photo lithography (immersion lithography, phase shift mask, EUV, chemical-mechanical polishing, process integration, CMOS-compatible micro mechanics.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Chang/Sze: ULSI Technology, Wiley
- Semiconductor International: monatliche Technologie-Zeitschrift
Fortgeschrittene Themen in Mikrooptik / Advanced topics in Micro-Optics

**Modul / Module**

**Fortgeschrittene Themen in Mikrooptik / Advanced topics in Micro-Optics**

<table>
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<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5231</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Mikrooptik</td>
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<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehorige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in physics, mathematics and micro-optics</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester: Recommended term of study | 2 |
| ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture |
| Angebotsfrequenz: Regular cycle | Only in the summer term |
| Arbeitsaufwand: Workload | 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Personal Profile

**Lernziele / Learning target**

In this module we consider topics in micro-optics in greater depth than is possible in the introductory course Micro-optics, which is a prerequisite.
At the completion of the course, the successful student should possess:
- the ability to understand and analyze multi-lens and thick lens systems
- an understanding of the basics of numerical modeling as well as characterization
techniques for optics
• the ability to understand the structure and function of some important optical instruments
• an awareness of the most important devices and effects in MOEMS, nano-optics and tunable optics
• the ability to understand and apply these concepts in microsystems applications

Inhalte Vorlesung / Content of the lecture
A variety of optical topics with relevance to microsystems engineering is considered. Whereas advanced techniques in geometrical optics analysis, optical modeling instruments, and interferometry apply to macro as well as micro-optical systems, the later topics, including MOEMS and optofluidics, are of prime importance in optical microsystems and their applications.
Table of contents:
• Advanced geometric optics
• Optics modeling
• Optical instruments
• Interferometry
• Optics characterization
• Optical multilayers
• MOEMS
• Tunable optics
• Optofluidics

Zu erbringende Prüfungsleistung / Examination result
oral presentation

Benotung / Grading
The module grade will be determined from the grade of the presentation.

Gewichtung der Prüfungsleistung / Weight of examination result
• 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade
of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- E. Hecht: Optics
- B. Saleh & M. Teich: Fundamentals of Photonics
- L. Novotny & B. Hecht: Principles of Nano-optics
- W. Smith: Modern Optical Engineering
- S. Gaponenko: Introduction to Nanophotonics
Fortgeschrittenes Praktikum für Mikrocontroller / Advanced Laboratory in Microcontroller

Nummer: Number
11LE50MO-5233-2

Modulverantwortlicher: Responsible person
Prof. Dr. L. Reindl

Einrichtung: Organisational unit
Chair Electrical Instrumentation

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Laboratory

Sprache: Language
English

Empfohlene Voraussetzungen: Recommended preconditions
- Knowledge of the course and laboratory in Micro-controller
  The skills are inspected by an entry test!

Empfohlenes Fachsemester: Recommended term of study
2

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
4 Laboratory

Angebotsfrequenz: Regular cycle
Only in the summer term

Arbeitsaufwand: Workload
90 hours
(56 hours Full-time attendance course of study + 34 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module
Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  o Circuits and Systems
  o Personal Profile
- Master of Science in Informatik
  o Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  o Circuits and Systems
  o Personal Profile
- Master of Science in Microsystems Engineering
  o Circuits and Systems
  o Personal Profile

Lernziele / Learning target
- Work with microcontroller as a central component
- Tasks targeted in the corresponding areas divide hardware, software and HIDs with consideration of the issues, ergonomics, noise immunity, reliability, and efficiency of the overall design.

Inhalte Vorlesung / Content of the lecture
On one µC board several experiments will be executed. The base is a MSP430. Use of existing libraries or creation of your own libraries for existing sensors and interfaces. Other topics are: interrupt security-related hardware, watchdog usage, interfaces, and bus systems.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written or oral examination</td>
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<table>
<thead>
<tr>
<th>Benotung / Grading</th>
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<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
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</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
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</thead>
<tbody>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
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</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Mikrocontrollertechnik Am Beispiel der MSP430-Familie: Matthias Sturm</td>
</tr>
<tr>
<td>• Das MSP430 Mikrocontroller Buch: Marian Walter, Stefan Tappertzhofen</td>
</tr>
<tr>
<td>• Halbleiter-Schaltungstechnik: Tietze, Schenk; Gamm</td>
</tr>
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</table>
### Modul / Module

**Gassensorik / Gas Sensors**

<table>
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<th>Nummer: Number</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Wöllenstein</td>
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<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Dünnschicht-Gassensorik</td>
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<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile

### Lernziele / Learning target


### Inhalte Vorlesung / Content of the lecture

ebenso ab, wie applikationsspezifische Sonderlösungen. Folgende wichtige Grundlagen für die Gassensorik werden diskutiert:

- Wechselwirkung Gas-Halbleiter, Adsorption, Elektrische Auswirkungen von adsorbierten Gasen
- Wärmeleitung u. –kapazität, Paramagnetismus von Gasen
- Schwingungs- und Rotationsspektren im IR, Druck- und Dopplerverbreiterung, Linienformen
- Interferometer, Schwarzkörperstrahlung, Elektrochemie

Folgende Bauelemente und Messsysteme werden vorgestellt:

- Metalloxidgassensoren, Lambdasonde, Gassensitive Feldeffekttransistoren
- Wärmeleitfähigkeitsensoren, Pelistoren
- Paramagnetischer Sauerstoffsensor
- Optische Systeme (Laserspektrometer, Filterphotometer, Photoakustik, Wellenleiter), Fourier Transformations Infrarot Spektrometer
- Elektrochemische Sensoren, Elektronische Nasen

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Begleitend zur Lecture wird ein Folien-Skriptum zur Verfügung gestellt.
Grundlagen der Elektrostimulation / Fundamentals of electrical stimulation

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5306</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Stieglitz</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Biomedical Microtechnology</td>
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<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>english</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester: Recommended term of study

| 3 | ECTS-Punkte: ECTS-points |
| 3 |

SWS: Semester week hours

| 2 Lecture | Angebotsfrequenz: Regular cycle |
| Only in the winter term |

Arbeitsaufwand: Workload

| 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

Lernziele / Learning target

Objective of the module is to impart knowledge of the medical and biological as well as the physicochemical and technical fundamentals during electrical stimulation of nerve and muscle that are mandatory for any engineer to understand the biological processes and to design and develop technical aids and processes in the field of neural prostheses and neuromodulation.

The module teaches the students the theoretical background with respect to effects, hazards and damaging mechanisms of electrical stimulation in the peripheral and central nervous system as well as the electrochemical processes that have to be taken into account in neuro-technical interfaces.
Inhalte Vorlesung / Content of the lecture

The lecture introduces biological-medical as well as physico-technical aspects during electrical stimulation of nerves and muscles. The following topics will be covered:

- Overview of the history of electrical stimulation
- Anatomy and physiology of nerves and muscles
- Description of electrical excitation of nerve cells
- Electrical fields and electrochemical processes at electrodes
- Methods of selective nerve stimulation
- Effects of chronic electrical stimulation of nerve and muscle
- Limits of safe electrical stimulation
- System theory and control aspects in neural prosthetics
- Simulation of nerve excitation
- Design of stimulators for electrical stimulation
- Characteristic parameters for different applications in electrical stimulation.

The learning targets and objectives will be summarized at the end of each lecture and a comprehensive summary will take place at the end of the course to repeat the most important objectives and facilitate preparation of the oral examinations.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Actual copies of the slides will be delivered accompanying to the lectures.

Literature:
- Horch, K.W., Dhillon, G.S. (Hrsg.): Neuroprosthetics – Theory and Practice. (Series on Bioengineering & Biomedical Engineering – Vol. 2)
- River Edge: World Scientific Computing, 2004
# Modul Handbuch M.Sc. Informatik – Halbleitertechnologie / Semiconductor Technology and Devices

## Modul / Module

### Halbleitertechnologie / Semiconductor Technology and Devices

<table>
<thead>
<tr>
<th>Nummer: Number</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Zacharias</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachsemester: Recommended term of study

<table>
<thead>
<tr>
<th></th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

### Lernziele / Learning target

The module is specifically designed for the international master not familiar with Clean Room processes. It is a lecture which gives the basic knowledge in equipments and processes used in a Si Clean Room. In addition, the lesson will give an overview and some basic physics about typical devices like pn- junctions, solar cells, and photodetectors.

### Inhalte Vorlesung / Content of the lecture

Mandatory knowledge for Si technology will be provided including wafer processing, wet and dry etching, CVD growth processes, doping, metallization, CMOS process, and others.

### Zu erbringende Prüfungsleistung / Examination result
### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- **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 2011:** 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 Microsystems Engineering, Academic regulations of 2009:** 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 Mikrosystemtechnik, Academic regulations of 2009:** The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Module

**Hardware-Entwicklung mit der Finite-Elemente-Methode / Hardware Design with the Finite-Element-Method**

<table>
<thead>
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<th>Number</th>
<th>11LE50MO-5503</th>
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<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. J. Wilde</td>
</tr>
<tr>
<td>Organisational unit</td>
<td>Chair Aufbau- und Verbindungstechnik</td>
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<tr>
<td>Modultyp:</td>
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<tr>
<td>Moduldauer</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache:</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen:</td>
<td>Knowledge in Assembly and Packaging Technology or Aufbau- und Verbindungstechnik</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte:</td>
<td>5</td>
</tr>
<tr>
<td>SWS:</td>
<td>4 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz:</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>150 hours (64 hours Full-time attendance course of study + 86 hours Self-study)</td>
</tr>
</tbody>
</table>

### Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Personal Profile

### Learning target

It is the aim, that after this module, the student will know the fundamental physical problems in electronic hardware based on own numerical investigations. The student will have elementary capabilities to solve praxis-relevant design problems in assembly and packaging of MEMS using a professional finite-element-system. He/she will know how experiments can be replaced by simulation and what the necessary input data are. He/she will be able to work with the Finite-Element-Code and to modify complex existing models. Furthermore it is expected that the student will have improved capabilities in the analysis of industrial problems and on reporting of the corresponding results.
<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graded protocols and a written or oral exam related to the protocols</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is determined from an average of the grades of the individual reports.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
# Innovations- und Technologiemanagement / Innovation Theory and Technology Management

**Nummer: Number**
11LE50MO-5805

<table>
<thead>
<tr>
<th>Modulverantwortlicher: Responsible person</th>
<th>Prof. Dr. L. Reindl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Elektrische Mess- und Prüfverfahren</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester:: Recommended term of study**

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>2 Lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in winter term</td>
</tr>
</tbody>
</table>

| Arbeitsaufwand: Workload | 90 hours (32 hours Full-time attendance course of study + 58 hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Personal Profile

**Lernziele / Learning target**

Inhalte Vorlesung / Content of the lecture

- Innovationstheorie: Was ist Innovation? Wie kommt Innovation zustande? Welche Innovationsprozesse gibt es und wie funktionieren sie?
- Ethik und Recht: Was ist vor rechtlichem Hintergrund zu beachten? Welche ethischen Fragen sind zu beachten? Was kann Technologie, was darf sie?

Zu erbringende Prüfungsleistung / Examination result

Es ist eine Hausarbeit mit mindestens 7 Seiten zu erstellen. Hausarbeitsthemen werden durch den Dozenten vorgeschlagen, die Studierenden können jedoch in Abstimmung mit dem Dozenten auch eigene Themen vorschlagen und bearbeiten.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- Heinz Strebel (Hg): "Innovations- und Technologiemanagement" (UTB 2007);
- Hans Dieter Seghezzi: "Integriertes Qualitätsmanagement" (Hanser München, Wien 1996);
- Pero Micic: "Das ZukunftsRadar" (GABAL Offenbach 2006);
- Hans Lenk, Günter Ropohl (Hg.): "Technik und Ethik" (Reclam Stuttgart 1993);
- Bruno Latour: "Ein Versuch, das 'Kompositionistische Manifest' zu schreiben" (Heise 2010);
- Thomas Lenk, Stephan Zelewski (Hg.): "ECOVIN Enhancing Competitiveness in Small and Medium Enterprises via Innovation" (Mai
2000, ISB-N 3-922602-71-1

[Mehr Literaturhinweise folgen im Verlauf der Vorlesung]
**Modul / Module**

**Keramiktechnologie in der Mikrotechnik / Ceramic technology in microsystems**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5103</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Hanemann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair WerkstoffProcess Technology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>german</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in &quot;Keramische Werkstoffe der Mikrotechnik&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

**Lernziele / Learning target**

in der Mikrotechnik sehr wichtige Materialklasse zu wecken.

<table>
<thead>
<tr>
<th>Inhalte Praktikum / Content of the laboratoryecture</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>graded protocols</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The final module grade is determined from an average of the grades of the individual reports.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikroystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
# Keramische Werkstoffe der Mikrotechnik / Ceramic Materials for Microsystems

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5102</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Hanemann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair WerkstoffProcess Technology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

## Empfohlene Voraussetzungen: Recommended preconditions

Kenntnisse der Werkstoffwissenschaft, z.B. Zustandsdiagramme, physikalische Eigenschaften verschiedener Materialklassen, Kristallsysteme, thermodynamische Eigenschaften und Kinetik kristalliner und nichtkristalliner Festkörper.

## Empfohlenes Fachsemester: Recommended term of study

| 2 |

## ECTS-Punkte: ECTS-points

| 3 |

## SWS: Semester week hours

| 2 Lecture |

## Angebotsfrequenz: Regular cycle

| Only in the summer term |

## Arbeitsaufwand: Workload

| 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study) |

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

## Lernziele / Learning target

Ziel des Moduls ist es, die technologischen und physikalischen Grundlagen der keramischen Werkstoffe und die zugehörigen Prozessierungsmethoden zu vermitteln. Mikrosystemtechnisch relevante Aspekte der keramischen Werkstoffe und ihrer Prozessierungsmethoden sollen aufgezeigt werden.
### Inhalte Vorlesung / Content of the lecture


### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Begleitend zur Lecture wird ein Skriptum und werden Handzettel der Lecturesfolien zur Verfügung gestellt.
## Lattice Gas Methoden / Lattice Gas Methods

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5504</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Simulation</td>
</tr>
<tr>
<td>Nummer: Number</td>
<td>11LE50MO-5504</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>It is advantageous but not necessary to be familiar with the basic topics of the course &quot;Simulation&quot;</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 hours (56 hours Full-time attendance course of study + 124 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Personal Profile

### Lernziele / Learning target

**Lecture:**
The students will learn the basic theoretical descriptions of the Lattice Gas and of the Lattice Boltzmann method and their derivation from kinetic theory. The students will understand the application of these two methods to the computational tasks for the simulation of fluid flow.

**Practical exercises:**
The students will learn to apply the Lattice Gas method as well as Lattice Boltzmann method.
to special problems in fluid dynamics. They will be assigned to implement the methods into an algorithm, estimate the computational cost for a given problem, and they will learn to elaborate the result obtained by the simulation and give a detailed interpretation of the fluid flow phenomena under investigation.

### Inhalte Vorlesung / Content of the lecture

The lectures will cover the following topics:

- From classical mechanics to statistical mechanics
- Concepts of thermodynamics
- Formal classical transport theory
- The Boltzmann transport equation (BTE)
- Methods for solving the BTE
- Simple Lattice Gas Method
- Lattice Boltzmann Method

### Inhalte Übung / Content of the exercises

This exercise will accompany the topics given in the course on Advanced Topics in Simulation: Lattice Gas Methods. The exercises will focus on problems to be solved with the software tool Mathematica. The students will be assigned with a project to be solved by Mathematica. To pass the exercises, students have to pass minimum 50 % of the exercises sheets.

### Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literature / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Sauro Succi: The lattice Boltzmann equation for fluid dynamics and beyond, Oxford University Press, 2001, Fakultätsbibliothek Ang, Wiss, Frei 91: AB/3.0/89</td>
</tr>
<tr>
<td>• Dieter A. Wolf-Gladrow, Lattice gas cellular automata and lattice Boltzmann models, Springer-Verlag, 2000</td>
</tr>
</tbody>
</table>
### Modul / Module

#### Leistungselektronik: Systeme und Konzepte / Power Electronics and Concepts

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5218</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Optoelektronik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile

### Lernziele / Learning target

The students will be enabled to understand materials, concepts, functioning, and design of modern power devices, circuits, and converter systems. This includes the understanding of basic concepts of power conversion (AC theory), of passive and active semiconductor devices, high-voltage operation, converter-, and control concepts, device protection, and aspects of system and power network theory. The students will be competent to analyse and design passive and active power devices such as MOSFET, Insulated Gate Bipolar IGBT, Junction FETs (JFET), thyristors, and circuits, full converter functions, integration, and analyze full system concepts. Circuits and system concepts for power conversion, such as half and full bridges, aspects high voltage operation, and design for robustness are presented, and several examples are discussed in detail.
Inhalte Vorlesung / Content of the lecture

The lecture Power electronics: Devices and concepts deals with the fundamentals and concepts of power devices and circuits. It comprises three parts: fundamental power conversion-concepts with focus on DC-DC and –AC conversion, more complex power circuitry, and actual power conversion systems. At the interface of modern electronics, circuit design, and control theory, advanced analysis and characterisation techniques are introduced in order to bridge the gap from modern power conversion to the understanding of systems and network systems with all aspects of power conversion. The methodologies of power-analysis, design of circuits, complex power flow, their modelling and their characterisation are introduced along with the demonstration of their relevance to real power-components and -systems. Typical applications include DC-DC conversion for server systems, photovoltaic power conversion, and high-voltage windcraft systems.

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- N. Mohan, Power Electronics, A first course, John Wiley and Sons, 2012
- Further literature for systems are presented during the lecture
### Modul / Module

**Lithographie für Microsystems Engineers/ Litography for Microsystems Engineers**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5608</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Reinecke</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Process Technology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>
| Empfohlene Voraussetzungen: Recommended preconditions | Knowledge of the modules  
  - MST Technologies and Processes  
  - Cleanroom Laboratory |
| Empfohlenes Fachsemester: Recommended term of study | 2 |
| ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture |
| Angebotsfrequenz: Regular cycle | Only in the summer term |
| Arbeitsaufwand: Workload | 90 hours  
  (28 hours Full-time attendance course of study + 62 hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program  
- Master of Science in Informatik  
  - Application area Mikrosystemtechnik  
- Master of Science in Microsystems Engineering  
  - MEMS Processing  
  - Personal Profile

### Lernziele / Learning target

At the end of the block seminar the students should have learned the basic knowledge to perform a simple troubleshooting for photoresist processing in a cleanroom environment and should be able to choose the appropriate technique for the realization of micro- or nanostructures.

### Inhalte Vorlesung / Content of the lecture

The purpose of this block course is to deepen the existing knowledge of lithography for micro structures (gained by the lecture “MST- Technologies and Processes”) and to learn the basics of alternative state-of-the-art lithography techniques such as nanoimprinting (UV-NIL, HEL, etc.), interference lithography, contact printing. The students will be introduced to a more profound knowledge of the working principles of modern photo resists used in Microsystems Technology. The necessary equipment and tools for lithography are also
covered (mask-aligner, photo mask, microscope, etc.).

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
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<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
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<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
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</thead>
<tbody>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Marc Madou &quot;Fundamentals of Microfabrication&quot;</td>
</tr>
<tr>
<td>• Hand-Outs to the single subjects will be provided at the block seminar.</td>
</tr>
</tbody>
</table>
Magnetische Mikrosysteme / Magnetic Microsystems

Modul / Module

Magnetische Mikrosysteme / Magnetic Microsystems

Nummer: Number

11LE50MO-5206

Modulverantwortlicher: Responsible person

Prof. Dr. U. Wallrabe

Einrichtung: Organisational unit

Chair Mikroaktorik

Modultyp: Module Type

Elective Module

Moduldauer: Module duration

1 term

Zugehörige Lehrveranstaltungen: Connected events

Lecture

Sprache: Language

English

Empfohlene Voraussetzungen: Recommended preconditions

Basic knowledge in Physics, Electrical Engineering, Engineering Mechanics and Microsystems Technologies and Processes

Empfohlenes Fachsemester: Recommended term of study

3

ECTS-Punkte: ECTS-points

3

SWS: Semester week hours

2 Lecture

Angebotsfrequenz: Regular cycle

Only in the winter term

Arbeitsaufwand: Workload

90 hours

(32 Hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Personal Profile

Lernziele / Learning target

The purpose of this module is to give an overview of the diverse microsystems having as a chief operating principle the magnetic interactions. Several features specific to magnetic microsystems will be highlighted during the lecture: generation of stable forces without power supply, levitation, remote actuation, electrical generation, high energy density. A special attention will be paid to the building blocks of magnetic microsystems: various technologies to build microcoils, processing of active magnetic materials, and integration of micro-magnets in magnetic microsystems. Several applications will be reviewed, among
them: magnetic resonance imaging and spectroscopy at the microscale, motors, generators, electromagnetic microbearings to eliminate friction and wear.

Inhalte Vorlesung / Content of the lecture

A brief introduction/reminder of magnetism will be given at the beginning of the lecture covering: magnetic fields and sources of magnetic fields, electromagnetic induction, magnetism and matter.

MEMS processes specific to magnetic microsystems will be reviewed in detail:
- microcoil fabrication techniques for:
  - planar microcoils – spiral and loop coils
  - 3D microcoils – rectangular cross-section, axis parallel to the substrate
  - 3D microcoils – circular cross-section, axis perpendicular to the substrate
  - other techniques
- processing of thin magnetic layers: deposition, lamination
- integration of magnetic materials in magnetic microsystems

The third part of the lecture will be dedicated to investigate several magnetic microsystems with specific functionalities. Among them, but not limited to:
- Magnetic resonance. Imaging (MRI) and spectroscopy (NMR)
- Basics
- MRI and NMR at the microscale. The general problem
- Design of MR micro-detectors:
  - Microcoils: planar, 3D
  - Planar microslot waveguide
  - The stripline as an NMR micro-detector
- Electromagnetic levitation. Electromagnetic microbearings
- Device: design and fabrication
- Theory: device characterization
- Electromagnetic energy harvesting
- Eddy current applications
- Proximity sensing and crack detection
- Damping (experiment)
- Scanning mirror using Lorentz force and magnetostatic force

Zu erbringende Prüfungsleistung / Examination result

At the beginning of the lecture the students will be presented with a list of topics in connection with the general purpose of the lecture. Each student will have to choose one topic and make a relevant literature review centered on that topic. This literature review will be than presented in an oral presentation followed by a discussion.

Benotung / Grading

The module grade is calculated from the results of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Begleitend zur Lecture werden die verwendeten Folien zur Verfügung gestellt.
Mechanische Eigenschaften und Degradationsmechanismen / Mechanical Properties and Degradation Mechanisms

<table>
<thead>
<tr>
<th>Modulverantwortlicher:</th>
<th>Prof. Dr. C. Eberl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache:</td>
<td>English</td>
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<tr>
<td>Empfohlenes Fachsemester:</td>
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</tr>
<tr>
<td>SWS:</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>90 hours</td>
</tr>
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</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

Lernziele / Learning target

The goal is to learn how materials properties and their impact on functionality and performance of micro systems. You will learn about the physical mechanisms in structural and functional materials as well as damage evolution during the applications lifetime. Based on the physical understanding you can evaluate microsystem designs, improve their lifetime and performance. This allows specifying materials and systems closer to their performance limit.
**Inhalte Vorlesung / Content of the lecture**

Introduction: physical mechanisms  
Fundamentals in stress and strain as well as anisotropic properties  
Fundamentals in mechanics of beams and membranes explained in examples  
Micro- and nanostructured materials in micro systems  
Small scale characterization of mechanical properties  
- Intrinsic stresses  
- Elastic and plastic behavior  
- Adhesion properties  
Physical principles and loading conditions in functional materials for actors and sensors

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.  
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- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- L.B. Freund and S. Suresh: „Thin Film Materials“  
Modul / Module

Mikroakustik / Microacoustics

Nummer: Number 11LE50MO-5207

Modulverantwortlicher: Responsible person Prof. Dr. L. Reindl
Einrichtung: Organisational unit Chair Electrical Instrumentation

Modultyp: Module Type Elective Module
Moduldauer Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises
Sprache: Language English

Empfohlenes Fachsemester: Recommended term of study 3
ECTS-Punkte: ECTS-points 3

SWS: Semester week hours 2 lecture + 1 exercises
Angebotsfrequenz: Regular cycle Only in the winter term

Arbeitsaufwand: Workload 90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Sensors and actuators
  - Personal Profile

Lernziele / Learning target

Students will gain an understanding of the structure, operation and applications of microacoustic devices. You will learn the basic methods for designing, modeling, for the optimization and for the production of these components. You know the functioning of bulk acoustic wave oscillators, surface acoustic wave components, as well as membrane and Bragg reflector-based thin film components. You will be able to design and analyze simple "Finite Impulse Response" and "Infinite Impulse Response" filter. Students know the applications of microacoustic components in wireless communications and in sensor technology.
**Inhalte Vorlesung / Content of the lecture**

The Micro Acoustics deals with the generation and manipulation of high-frequency (electro-) mechanical waves which enables the realization of high-frequency filters, sensors and actuators. The generation and manipulation is carried out via planar microstructures on piezoelectric materials on which these waves are performed.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
The seminar micro acoustic offers the opportunity to work independently on a topic of micro acoustic and to present the results in a final presentation. As part of this work there will be built up based knowledge in specific areas of micro acoustic, and a scientific way of working is trained as well. The independent literature review is an integral part of the seminar paper. There is a personal attention of the seminar participants, which is essentially limited to the clarification of concrete, subject-specific issues. The seminar concludes with an oral exam in the form of the final presentations, which are followed by a brief discussion.
### Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Mikrofluidik II: Mikrofluidische Plattformen / Microfluidics II: Platforms

<table>
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<tr>
<th>Nummer: Number</th>
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<tbody>
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<td>Prof. Dr. R. Zengerle</td>
</tr>
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<td>Einrichtung: Organisational unit</td>
<td>Chair MEMS Applications</td>
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<td>Elective Module</td>
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<td>Moduldauer: Module duration</td>
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</tr>
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<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
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<tr>
<td>Sprache: Language</td>
<td>german</td>
</tr>
<tr>
<td>Empfohlende Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Micro-fluidics</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester: Recommended term of study 2 ECTS-Punkte: ECTS-points 3
SWS: Semester week hours 2 Lecture Angebotsfrequenz: Regular cycle Only in the summer term
Arbeitsaufwand: Workload 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Lab-on-a-chip
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Lab-on-a-chip
  - Personal Profile

Lernziele / Learning target


Zu erbringende Prüfungsleistung / Examination result

written or oral examination
### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Students will receive a handout that will be updated on a regular basis.
Modulhandbuch M.Sc. Informatik – Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components

Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components

Nummer: 11LE50MO-5604

Modulverantwortlicher: Prof. Dr. T. Hanemann
 Einrichtung: Chair Werkstoffprozesstechnik

Modultyp: Elective Module
 Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture
 Sprache: English

Empfohlenes Fachsemester: 3
 ECTS-Punkte: 3

SWS: 2 Lecture
 Angebotsfrequenz: Only in the winter term

Arbeitsaufwand: 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - MEMS Processing
  - Personal Profile

Lernziele / Learning target

Besides silicon and the established MEMS/MOEMS technology polymer materials and the related micropereplication technologies are becoming more and more important for the realization and commercial success of new microcomponents and microsystems. New nanostructuring methods like 2-photon-stereolithography and others are at the threshold of leaving the laboratory status and entering market. The course will cover the large variety of polymer materials, their fundamental chemical and physical properties and the derived microstructuring and replication possibilities. Direct and indirect micro- and nanostructuring methods like deep X-ray lithography, stereolithography, laser machining, nanoimprinting and others as well as the large family of replication methods like hot embossing and injection molding will be described in detail. Master and tooling fabrication methods like electroplating, electro discharge machining as well as mechanical and laser micromachining will be presented and discussed intensely. A large number of application examples and case
studies dealing with the accessible geometries, feasibility, and process characteristics will be used for the presentation of the polymer microfabrication importance.

### Inhalte Vorlesung / Content of the lecture

**Contents:**
- Polymers: Fundamental chemical and physical properties
- Fabrication of molding tools: Fabrication principles and characteristics
- Rapid Prototyping in microsystem technology
- Polymer replication techniques: Reaction Molding, UV-Embossing, Hot Embossing and Injection Molding: Principles, equipment, applications and case studies
- From micro to nano: Nanoimprinting, soft lithography, nanostereolithography and other new developments

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Mikrosystemtechnik in der Medizin / Microsystems technology in Medicine

**Nummer:** 11LE50MO-5307

**Modulverantwortlicher:** PD Dr. M. Boeker

**Einrichtung:** Fakultät für Medizin

**Modultyp:** Elective Module

**Moduldauer:** 1 term

**Zugehörige Lehrveranstaltungen:** Seminar

**Sprache:** German

**Empfohlene Voraussetzungen:** Grundlegende physikalische Kenntnisse

**Empfohlenes Fachsemester:**

<table>
<thead>
<tr>
<th>Fachsemester</th>
<th>ECTS-Punkte</th>
<th>Arbeitssaufwand</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung**

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Personal Profile

**Lernziele**

Wichtige Anwendungen der Mikrosystemtechnik in der Medizin beschreiben können:

- Computergestützte Bildanalyse
- Patch-Clamp Verfahren
- Klinische Anwendung beim Mammakarzinom
- Cochlea-Implantat
- Sehprothesen
- Diagnostik und Therapie von Herzrhythmusstörungen
- Volumetrische Bildgebung in der Radiologie
### Inhalte Vorlesung / Content of the lecture

Dozenten aus verschiedenen Fachbereichen der Medizin stellen wichtige und aktuelle Themen der Mikrosystemtechnik in der Medizin vor: Sehprothesen, Cochlea-Implantate, minimal invasive Gefäßtherapien, computergestützte Tumordiagnostik, klinische Anwendungen beim Brustkrebs, Diagnostik und Therapie von Herzrhythmusstörungen und Verfahren der Bildanalyse in der bildgebenden Diagnostik. Dabei stellen die Dozenten insbesondere eine Verbindung zwischen den medizinisch-biologischen Gegebenheiten im menschlichen Organismus und der technischen Herangehensweise an ein spezifisches medizinisches Problem her, ohne dass besondere medizinische Kenntnisse vorausgesetzt werden.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modellbildung und Systemidentifikation / Modelling and System Identification</strong></td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Nummer: Number</th>
<th>11LE50MO-2080</th>
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<tbody>
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<td>Prof. Dr. M. Diehl</td>
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<td>Einrichtung: Organisational unit</td>
<td>Chair Systemtheorie</td>
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<td>Elective Module</td>
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<td>Modulduer: Module duration</td>
<td>1 term</td>
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<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**
- Knowledge of:
  - Mathematik I für Ingenieure und Informatiker / Mathematics I for Engineers and Computer Scientists
  - Mathematik II für Ingenieure / Mathematics II for Engineers
  - Differentialgleichungen / Differential Equations
  - Systemtheorie und Regelungstechnik / Systems Theory and Feedback Control

**Empfohlenes Fachsemester: Recommended term of study**
- 3

**ECTS-Punkte: ECTS-points**
- 6

**SWS: Semester week hours**
- 2 lecture + 2 exercises

**Angebotsfrequenz: Regular cycle**
- Only in the winter term

**Arbeitsaufwand: Workload**
- 180 hours (64 hours Full-time attendance course of study + 116 hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Mandatory Module for students of the study program
- Master of Science in Embedded Systems Engineering

Elective Module for students of the study program
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Kognitive technische Systeme
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
### Lernziele / Learning target

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.

### Inhalte Vorlesung / Content of the lecture

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.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Lecture manuscript
- Lecture manuscript "System Identification" by J
Modul / Module

Mold Flow Simulation für Replikationsprozesse / Mold Flow Simulation for Replication Processes

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5605</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Reinecke</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Process Technology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>english</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester:: Recommended term of study 3 ECTS-Punkte:: ECTS-points 3

SWS: Semester week hours 2 Lecture Angebotsfrequenz: Regular cycle Only in the winter term

Arbeitsaufwand: Workload 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - MEMS Processing
  - Personal Profile

Lernziele / Learning target

The module is focusing on the theoretical concepts and algorithm of process simulation for micro replication. Design Rules for Micro- Nano replication will be formulated. Gate and runner Balancing, cavity design and the influence on crystallisation, shrinkage and warpage will be studied. Experimental results obtained under different processing conditions will be simulated by state of the art software tools.

Inhalte Vorlesung / Content of the lecture

- Design of Material for Products
- Thermoset and rubber
- Amorphous polymer
- Semi crystalline polymer
- Process and Technology
- Mould and process Control
- Injection Moulding-Micro Injection Moulding
- Extrusion
- Thermoforming
- Fundamental Model for replication
- Thermal
- Mechanical
- Viscoelastic
- Rheology
- Filling, Compression, Packing and Cooling
- The downscaling of replication
- Wall Slip
- Turbulent Flow
- Process Instabilities (Air bubbles, vacuoles)
- Shear Thinning and Heat conduction and heat transfer
- Training on Software tools for simulation
- Material Characterisation
- Mould Model-Machine Model
- Meshing

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Accompanying the lecture is a script made available and updated regularly.
**Modul / Module**

**Nanobiotechnologie / Nanobiotechnology**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5308</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Ambacher</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Verbindungshalbleiter</td>
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<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
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</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

**Lernziele / Learning target**


**Inhalte Vorlesung / Content of the lecture**

Zu den Themen der Nanobiotechnologie gehört die Diskussion von organischen

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Physiologie des Menschen, R.F. Schmidt, F. Lang, G. Thews, Springer Medizin Verlag Heidelberg 2005
Modul / Module

Nanomaterialien / Nanomaterials

Nummer: Number
11LE50MO-5104

Modulverantwortlicher: Responsible person
Prof. Dr. M. Zacharias

Einrichtung: Organisational unit
Chair Nanotechnologie

Modultyp: Module Type
Elective Module

Moduldauer Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Lecture

Sprache: Language
English

Empfohlene Voraussetzungen: Recommended preconditions
Basiswissen in Festkörperphysik

Empfohlenes Fachsemester: Recommended term of study
4

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
2 Lecture

Angebotsfrequenz: Regular cycle
Only in the summer term

Arbeitsaufwand: Workload
90 hours
(28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

Lernziele / Learning target

The aim of the module is to give an introduction into modern methods for bottom-up approaches for nanomaterials. The bottom-up growth will be discussed on selected examples. Methods of functionalizing nanomaterials and surfaces will be presented. The lecture will also include some basic knowledge on size effects and high resolution characterization methods. Overall the module gives instructions in nanoscaled growth as well as in understanding the basic material properties of such bottom-up grown nanomaterials. In addition, the module will develop basic theoretical understanding for material effects on the nanoscale and will
give a deeper understanding of state of the art nanomaterial growth as well as future developments.

### Inhalte Vorlesung / Content of the lecture

After a short introduction on basics of bottom-up growth the lecture will summarize the state of the art knowledge in nanomaterials growth. Highly relevant examples from research will be discussed in detail developing the knowledge of material growth as well as basic understanding in selected growth techniques. The bottom-up growth will be discussed on selected examples which include: carbon nanotubes, Si nanoclusters and nanocrystals, Si nanowires, ZnO nanowires, colloidal methods for II-VI nanoclusters, nanobiological systems. The lecture will also include some basic knowledge on size effects and high resolution characterization methods. At the end methods of functionalizing nanomaterials and surfaces will be taught.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Nanomaterialien in Anwendungen: Umweltaspekte und Nanotoxizität / Nanomaterials in Applications: Environmental Aspects and Nanotoxicity

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5318</th>
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</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>N.N.</td>
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<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Nanotechnologie</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>english</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester:: Recommended term of study | 2 |
| ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture |
| Angebotsfrequenz: Regular cycle | Only in the winter term |
| Arbeitsaufwand: Workload | 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Informatik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Materials
  - Personal Profile

## Lernziele / Learning target

The aim is to learn what nanomaterials are and where they are utilized. Especially differences to bulk materials in context of utilization and toxicity will be discussed. The students should be able after the course to contribute in public discussions about "nanotoxicity" and "nanomaterials" a scientific viewpoint and balanced opinion. Furthermore the lecture should stimulate the scientific potential as well as the awareness of risks of nanomaterials in future research efforts of the students in the framework of Bachelor, Master and PhD theses.
### Inhalte Vorlesung / Content of the lecture

- Introduction to nanomaterials and aspects of toxicity
- Applications of colloidal metal and semiconductor nanoparticles
- Applications of nanocarbon compounds
- Applications of other nano(composite) and nanohybrid materials
- Nanomaterial drugs and drug carrier systems
- Environmental aspect of (nano)materials
- Interaction of nanomaterials with organism; Uptake and fate of nanomaterials
- Nanotoxicity legislation aspects

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Nano – Laboratory / Nano - Laboratory

Nummer: Number 11LE50MO-5105

Modulverantwortlicher: Responsible person Prof. Dr. M. Zacharias

Einrichtung: Organisational unit Chair Nanotechnologie

Modultyp: Module Type Elective Module

Moduldauer Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Laboratory

Sprache: Language English

Empfohlene Voraussetzungen: Recommended preconditions Students must have passed either the module Nanomaterials or the module Nanotechnology.

Empfohlenes Fachsemester: Recommended term of study

ECTS-Punkte: ECTS-points 3

SWS: Semester week hours 2 Laboratory

Angebotsfrequenz: Regular cycle Only in the winter term

Arbeitsaufwand: Workload

90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

Lernziele / Learning target

Educational objective is a demonstration of applied nanotechnology using standard methods of semiconductor thin film technology. The students will apply nanolithographic methods, grow nanostructures via self-organization and get introduced in standard characterization methods (PL, SEM, EDX). Overall, the lab course provides insight into fundamental research on nanostructures and demonstrates how basic properties of materials change at the nanoscale.
**Inhalte Praktikum / Content of the laboratory**

- Fabrication of size-controlled silicon quantum dots
- Atomic layer deposition (ALD) of ZnO thin films
- Gold nanodots/lines via phase shift nanolithography
- ZnO nanowire growth via vapor-solid (VS) method
- SnO2 nanowire growth via ionic-liquid assisted vapor-liquid-solid method (VLS)
- Photoluminescence spectroscopy of Si and ZnO nanostructures
- Imaging and elemental analysis of nanostructures using scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDX)

**Zu erbringende Prüfungsleistung / Examination result**

1. Multiple choice test at the beginning, which has to be passed to continue with the lab course.
2. Presentation and oral exam at the end of the lab course.

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Nanotechnologie / Nanotechnology

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5106</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Zacharias</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Nanotechnologie</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basiswissen in Festkörperphysik</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester: Recommended term of study

| 2 oder 3 |
| ECTS-Punkte: ECTS-points | 3 |

SWS: Semester week hours

| 2 Lecture |
| Angebotsfrequenz: Regular cycle | Each term |

Arbeitsaufwand: Workload

| 90 hours |
| 28 or 32 hours Full-time attendance course of study + 58 or 62 hours Self-study |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - MEMS Processing
  - Personal Profile

Lernziele / Learning target

The aim of the module is to give an introduction into modern methods for the growth of nanomaterials as well as to learn the principles of high resolution investigation (SEM, TEM, HRTEM, STM, AFM, and SNOM). Methods of nanodeposition such as atomic layer deposition (ALD), methods of low dimensional growth (such as molecular beam epitaxy) and methods of self organization are summarized and presented based on selected examples. The today status of nanolithography (porous nano templates, nanosphere lithography, and
interference lithography) will be discussed in detail. The module gives instructions in basic knowledge of nanoscaled growth as well as in understanding the basics in high resolution structural investigation techniques of nanostructures. In addition, the module will develop a basic theoretical understanding for size effects on the nanoscale and will give a deeper understanding of state of the art nanotechnology as well as future developments.

**Inhalte Vorlesung / Content of the lecture**

After a short introduction in nanotechnology the lecture will start with discussing different size effects from point of physics as well as applications. After that the methods and equipments used for defined growth of nanostructures and nanolayers will be presented and advantages and disadvantages of the various methods will be demonstrated on selected examples. Quantum structures based on III-V semiconductors representing the modern status of optoelectronic LED and laser devices, silicon nanocrystal based structures, nanotubes (carbon, spinel), and photonics crystals are used as example for applications of nanostructures in optics and electronics. In relation to our own research methods for spatially arranged nanowire growth are discussed. The lectures will also include knowledge on the development of nanodevices (memories, nanosensors, nanolaser) and the basic structural, optical and electronic investigation.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Befragung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modul / Module

Neurophysiologie – Laboratory / Neurophysiology - Laboratory

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5316</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. U. Hofmann</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>english</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Prerequisite to become eligible for this course is the participation in the exercises in &quot;Implant manufacturing technologies&quot; or participation in the seminar „Neuroprosthetics“ in the last winter semester.</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester:: Recommended term of study 2  
ECTS-Punkte: ECTS-points 3  
SWS: Semester week hours 3 Laboratory Angebotsfrequenz: Regular cycle Only in the summer term  
Arbeitsaufwand: Workload 90 hours (42 Hours Full-time attendance course of study + 48 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

Lernziele / Learning target

Participants will gain first hand experiences into neuroscientific and electrophysiologically verifiable paradigms to natural signal processing in the rat brain in vivo. Participants will get in depth insight into the current knowledge of the somatosensory system, the visual system and the motor system. In addition, the rat’s learning and orientation system will be introduced in depth as well. Signal processing methods will be presented and for later use in exercises substantiated. Participants will learn a respectful and honorable handling of living beings, even if they are „only“ lab rats. Students will gain first hand experience with multisite electrophysiological recordings from anesthetized and freely moving animals. Signals acquired during these day long experiments will be analyzed according to state of the art and results will be presented as
Inhalte Vorlesung / Content of the lecture

Students will in three neurophysiological paradigms (two acute, one freely behaving) under experienced supervision participate. Students will get in depth and first hand insight into the current knowledge of the somatosensory system, the visual system and the motor system. In addition, the rat’s learning and orientation system will be introduced as well. Signal processing methods will be presented and for later use in exercises substantiated. They will gain hands on experience with in vivo animal electrophysiology with micro devices and collect data for subsequent home based analysis. Their analysis results will be presented as final teaching experience.

Zu erbringende Prüfungsleistung / Examination result

Written reports and presentation

Benotung / Grading

The final module grade is calculated from the tests during the experiments (1/3) plus the grade from the oral presentation (2/3).

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- diverse journal papers like:
Neuroprosthetics is an emergent field of biomedical engineering aiming at developing devices to replace or augment non functional sensory or motor paths of humans resulting from disease or trauma.

The participating student will be instructed on the basic neuromedical concepts, and the targeted medical deficits, both needed to evaluate current clinical neuroprostheses and critically assess devices under development.

The student will gain well funded knowledge on clinical applications and technologies and will have to face the more biological and ethical aspects of these devices and treatment options as well.
The module aims at active involvement by independent webbased information acquisition, oral presentation of findings and internet based reporting.

**Inhalte Vorlesung / Content of the lecture**

Introductory lessons contain:
- Basic concepts of neuroscience
- Interfacing the nervous system
- Modelling approaches for CNS applications
- Neuroethical aspects

Student covered topics will contain:
- Cochlea Implant - Deafness
- Retina Implant - Blindness
- Deep Brain Stimulation - Parkinson’s Disease
- Spinal Cord Stimulation - Chronic Pain Syndrome
- Vagal Nerve Stimulation - Epilepsy
- Functional Electrical Stimulation - Drop Foot Syndrome
- Human Machine Interfacing - BCI and BMI
- Foreign Body Reaction

**Zu erbringende Prüfungsleistung / Examination result**

- 40 % on the presentation
- 40 % on the topic website
- 20 % active involvement

**Benotung / Grading**

The final module grade is calculated 40 % on the presentation, 40% on the topic website and 20 % active involvement.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**
• Farina, D., Jensen, W., Akay, M., Eds. (2013). INTRODUCTION TO NEURAL ENGINEERING FOR MOTOR REHABILITATION, IEEE
Modul / Module

Neurowissenschaften für Ingenieure / Neuroscience for Engineers

Nummer: Number 11LE50MO-5319
Modulverantwortlicher: Responsible person Prof. Dr. U. Egert
Einrichtung: Organisational unit Chair Biomikrotechnik
Modultyp: Module Type Elective Module
Moduldauer Module duration 1 term
Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises
Sprache: Language English

Empfohlenes Fachsemester:: Recommended term of study 2
ECTS-Punkte: ECTS-points 3
SWS: Semester week hours 2 lecture + 1 exercises
Angebotsfrequenz: Regular cycle Only in the summer term
Arbeitsaufwand: Workload 90 hours
(42 Hours Full-time attendance course of study + 48 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module
Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life sciences: Biomedical engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life sciences: Biomedical engineering
  - Personal Profile

Lernziele / Learning target
The aim of this module is to convey an understanding of fundamental neuroscientific concepts, methods, processes and structures that define or influence the function of technical components in biomedical applications.

Inhalte Vorlesung / Content of the lecture
The lecture series conveys the foundations of various neuroscientific processes, structures and measuring techniques. We emphasize processes that
• influence the generation and properties of signals measurable with neuronal systems,
• influence the usability of MST components, such as sensors and implants,
• are relevant for typical fields of application of MST components, e.g. implantable sensors, prostheses, neurotechnology, etc..
In the course of the lectures we will present an overview of central neuroscientific concepts, tools and applications.
Main topics are:
• Structure of the nervous systems
• Biophysics of electrical potentials
• Neuronal networks and their signals
• Sensory systems
• Foundations of learning and memory
• Interaction with neuronal networks

Zu erbringende Prüfungsleistung / Examination result
written or oral examination

Benotung / Grading
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result
• 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature
Literature will be presented during the lecture
Nichtlineare Modell-Praediktive Regelung / Nonlinear Model Predictive Control

Number: 11LE50MO-5225

Modulverantwortlicher: Prof. Dr. M. Diehl

Einrichtung: Chair Systemtheorie

Modultyp: Elective Module

Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture and exercises

Sprache: English

Empfohlene Voraussetzungen:
Undergraduate mathematics (e.g. Mathematik 1 und 2) and basic systems and control knowledge (e.g. Systemtheorie und Regelungstechnik and/or Optimal Control and Estimation). The course is self contained and can be followed by all students with sufficient background in mathematical systems and control theory. It is recommended not only to master students of engineering, but also to students of computer science, mathematics, and physics. An optimization course (e.g. „Applied Convex and Nonlinear Optimization“ or „Optimal Control and Estimation“) is an advantage, but not necessary.

Empfohlenes Fachsemester: 3

ECTS-Punkte: 3

SWS: 2 lecture + 1 exercises

Angebotsfrequenz: Only in the winter term

Arbeitsaufwand: 90 hours (48 Hours Full-time attendance course of study + 42 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  o Circuits and Systems
  o Design and Simulation
  o Personal Profile
- Master of Science in Informatik
  o Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  o Circuits and Systems
  o Design and Simulation
  o Personal Profile
- Master of Science in Microsystems Engineering
  o Circuits and Systems
  o Design and Simulation
## Lernziele / Learning target

Aim of this module is to give both theoretical background and hands-on practical knowledge in theory and numerics for nonlinear model predictive control (NMPC). In particular, participants shall become able to formulate and to numerically solve NMPC problems with the help of modern computing tools.

## Inhalte Vorlesung / Content of the lecture

The course covers all topics relevant for the theory and numerical solution of nonlinear model predictive control (NMPC) problems. It starts by recalling concepts from systems theory in continuous and discrete time as well as concepts from nonlinear optimization with equalities and inequalities, and the computation of derivatives. The major focus of the course is on the stability theory of NMPC and what impact it can have in control engineering practice. A second focus is on the numerical solution of nonlinear model predictive control and moving horizon estimation problems.

## Inhalte Übung / Content of the exercises

All lecture topics are accompanied by intensive computer exercises, for which we use the computational optimization environments Python and CasADi (both open-source), and participants are recommended to bring a laptop. At the end of the course, each participant will also start to work on a self chosen application problem and the results will be presented in a short report and presentation towards end of the course, after the written exam.

## Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

## Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

## Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Numerische Optimierung / Numerical Optimization

Number: 11LE50MO-5243

Modulverantwortlicher: Prof. Dr. M. Diehl
Einrichtung: Chair Systemtheorie

Modultyp: Elective Module
Modulverantwortlicher: Prof. Dr. M. Diehl
Einrichtung: Chair Systemtheorie

Modulverantwortlicher: Prof. Dr. M. Diehl
Einrichtung: Chair Systemtheorie

Zugehörige Lehrveranstaltungen: Lecture and exercises
Sprache: English

Empfohlene Voraussetzungen: Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses

Empfohlenes Fachsemester:: 3
ECTS-Punkte: 6

SWS: 4 Lecture + 2 Exercises
Angebotsfrequenz: Only in Winter term

Arbeitsaufwand: 180 hours (96 hours Full-time attendance course of study + 84 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Robotics and Computer Vision
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile

Lernziele / Learning target

Students understand important optimization methods used in practice for solution of convex and nonlinear programming problems and can independently apply the acquired knowledge.

Inhalte Vorlesung / Content of the lecture
The course is divided into four major parts:

5. Fundamental Concepts of Optimization: Definitions, Types, Convexity, Duality
6. Unconstrained Optimization and Newton Type Algorithms: Stability of Solutions, Gradient and Conjugate Gradient, Exact Newton, Quasi-Newton, BFGS and Limited Memory BFGS, and Gauss-Newton, Line Search and Trust Region Methods, Algorithmic Differentiation
8. Inequality Constrained Optimization Algorithms: Karush-Kuhn-Tucker Conditions, Linear and Quadratic Programming, Active Set Methods, Interior Point Methods, Sequential Quadratic and Convex Programming, Quadratic and Nonlinear Parametric Optimization

Inhalte Übung / Content of the exercises

Theoretical and computer exercises accompany the lecture to deepen the understanding. Successful participation/solution of at least 50% of the weekly exercise sheets.

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Zu erbringende Studienleistung / Course achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Literatur / Literature

- Stephen Boyd and Lieven Vandenberghe, Convex Optimization, Cambridge Univ. Press, 2004
Modulhandbuch M.Sc. Informatik – Numerische Optimierung / Numerical Optimization - Projekt

Modul / Module

Numerische Optimierung / Numerical Optimization - Projekt

<table>
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<tr>
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<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Systemtheorie</td>
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<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Moduldauer Module duration</td>
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<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlene Voraussetzungen: Recommended preconditions

Numerical Optimization Lecture (participation in the project is only possible for participants of the lecture)

Empfohlenes Fachsemester: Recommended term of study

3 ECTS-Punkte: ECTS-points

3 Angebotsfrequenz: Regular cycle

Only in winter term

Arbeitsaufwand: Workload

90 hours (90 hours Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile

Lernziele / Learning target

Students can independently program, analyse and apply optimization methods for continuous optimization problems.

The project work consists of a computer implementation of one ore more self-chosen optimization methods and the application to one or more application problems. The focus could be more on the algorithmic side, e.g. on comparing different algorithm variants, or more on the modelling side, e.g. formulating and solving on interesting optimization problem.

The project results are a documented computer code, a project report, and a public presentation.
### Zu erbringende Prüfungsleistung / Examination result

written documentation of the project results  
Result of the project and the basis for the project grade is a documented computer code, a report and a brief public presentation in the lecture at the end of the semester.

### Zu erbringende Studienleistung / Course achievement

The students have to participate in the course "Numerische Optimierung / Numerical Optimization - Lecture" in order to be admitted to the final module exam.

### Benotung / Grading

The module grade is calculated as 100% of the written report of the project.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Numerische Verfahren der Optimalen Steuerung / Numerical Optimal Control

Nummer: 11LE50MO-5242

Modulverantwortlicher: Prof. Dr. M. Diehl
Einrichtung: Chair Systemtheorie

Modultyp: Elective Module
Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture and exercises
Sprache: English

Empfohlene Voraussetzungen: Undergraduate mathematics (e.g. Mathematik 1 und 2) and basic systems and control knowledge (e.g. Systemtheorie und Regelungstechnik and/or Optimal Control and Estimation). An optimization course (e.g. „Optimal Control and Estimation“) is an advantage, but not necessary.

Empfohlenes Fachsemester: 3
ECTS-Punkte: 3

SWS: 2 lecture + 2 exercises
Angebotsfrequenz: Only in the winter term

Arbeitsaufwand: 90 hours (64 hours Full-time attendance course of study + 26 Hours Self-study)

Verwendbarkeit der Veranstaltung

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile

Lernziele

Aim of this intensive course is to give both theoretical background and hands-on practical knowledge in numerical methods to solve optimal control problems for offline and embedded
applications such as linear and nonlinear model predictive control. In particular, participants shall become able to formulate and to numerically solve optimal control problems with help of modern computing tools.

**Inhalte Vorlesung / Content of the lecture**

The course covers all topics relevant for the formulation and practical solution of embedded optimal control problems (OCP). It starts by recalling concepts from numerical simulation of ordinary differential equation models (ODE) and differential algebraic equations (DAE) as well as concepts from convex and nonlinear optimization. The major focus of the course is on direct approaches, in particular on direct collocation, direct single and direct multiple shooting. A second focus is on important application classes such as parameter and state estimation and nonlinear model predictive control (NMPC) and embedded optimization algorithms. The course also treats several implementation details such as the choice of discretization schemes and quadratic programming (QP) solvers. All lecture topics are accompanied by intensive computer exercises, for which we use the computational optimization environments Python, CVXPY and CasADi (all open-source), and participants are recommended to bring a laptop. In the second week of the course, each participant will also start to work on a self chosen application problem and the results will be presented in a short report and presentation towards at end of the course, after the written exam.

**Inhalte Übung / Content of the exercises**

The computer exercises are integral parts of the summer course on numerical optimal control. They consist of guided exercises that are intensively supervised but not graded, and a final project, where students work in small groups on a freely chosen application problem. The project results are presented at the end of the course to all participants, and a jury consisting of teachers grades the results and presentation.

**Zu erbringende Prüfungsleistung / Examination result**

- Written or oral examination
- Graded exercises/practical exercises

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

**Benotung / Grading**

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

**Modul / Module**

**Oberflächenanalyse – Laboratory / Surface Analysis Laboratory**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5311</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
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<td>Einrichtung: Organisational unit</td>
<td>Chair for Chemistry and Physics of Interfaces</td>
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<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
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<td>Sprache: Language</td>
<td>English</td>
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</tbody>
</table>

**Empfohelnes Fachsemester:: Recommended term of study**

- 2

**ECTS-Punkte:: ECTS-points**

- 3

**SWS:: Semester week hours**

- 2 Laboratory

**Angebotsfrequenz:: Regular cycle**

- Only in the summer term

**Arbeitsaufwand:: Workload**

- 90 hours
  - (28 Hours Full-time attendance course of study + 62 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Informatik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

**Lernziele / Learning target**

Microsystems – especially those for microfluidics – are dominated by their surfaces due to their surface to volume ratio. This strong influence of surfaces is also important for devices e.g. sensors that are in contact with biological fluids. Surface analytical methods are, hence, often at the center of research questions in microsystems engineering. The Surface Analysis Laboratory introduces selected methods in this field and discusses strengths and limitations of each technique. It concentrates on surface analytical questions which are relevant for the life sciences.
| Topic 1: Determination of the layer thickness and roughness of biocompatible coatings |
|---|---|
| Experiment 1: Using ellipsometry and x-ray reflectometry to determine the thickness of hydrogel coatings |

| Topic 2: Wetting of surfaces – Surface free energies |
|---|---|
| Experiment 2: Measurement of the contact angles of test liquids in various surfaces; Determination of the surface free energy using the Zisman method |
| Experiment 3: Generation and characterization of microarrays on various surfaces |

| Topic 3: Proteins / peptides on surfaces |
|---|---|
| Experiment 4: Measurement of the adsorption of blood proteins on surfaces using Surface Plasmon Resonance |
| Experiment 5: Characterization of the structure of protein layers using Fourier Transform Infrared Spectroscopy |

| Topic 4: DNA at surfaces |
|---|---|
| Experiment 6: Visualisation of DNA on mica using the Atomic Force Microscope |

### Examination result

Before each experiment there will be an oral examination and for each experiment the student has to submit a written laboratory report.

### Grading

The module grade will be determined from the average of the grades of the oral examinations and the laboratory reports.

### Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literature

- Script
Modul / Module

Optik-Laboratory Grundlagen / Basic Optics Laboratory

<table>
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<tr>
<th>Nummer:</th>
<th>11LE50MO-5213</th>
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<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Chair Mikrooptik</td>
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<td>Moduldauer:</td>
<td>1 term</td>
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<td>Zugehörige Lehrveranstaltungen:</td>
<td>Laboratory</td>
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<td>Sprache:</td>
<td>English</td>
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<tr>
<td>Empfohlene Voraussetzungen:</td>
<td>Basic knowledge in physics and mathematics; Knowledge in Micro-optics</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester: | 2 |
| ECTS-Punkte: | 3 |
| SWS: Semester week hours | 2 Laboratory |
| Angebotsfrequenz: | Only in the summer term |

| Arbeitsaufwand: | 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Personal Profile

Lernziele / Learning target

The Basic Optics Laboratory provides an opportunity for hands-on experimentation on the topics introduced in the Micro-optics course. As a result, the students will develop expertise in the design, assembly and characterization of optical systems and become experienced in making optical measurements.

At the completion of the course, the successful student should possess:
- the ability to analyze measurement data and estimate errors;
- the ability to apply error propagation methods;
the ability to assemble and align optical systems;
• a basic understanding of optical design methods;
• the ability to apply optical measurement techniques;
• the ability to apply analytical and graphical techniques for analyzing optical images.

Inhalte Praktikum / Content of the laboratory

One laboratory experiment has been conceived for each of the important topics addressed in the Micro-optics course; a different experiment is performed each week of the laboratory course. The topics addressed include geometric, reflective, diffractive and fiber optics as well as Fourier optics, interference, diffraction and polarization. To allow adequate representation and analysis of the measured experimental data, the course begins with a compact mini-lecture on data analysis.

Table of contents:
• Statistics and data analysis
• Error propagation
• Focal length of lenses
• Focal length of lens systems
• Construction of a microscope
• Diffraction from gratings
• Newton’s rings
• Fiber optics
• Construction of an interferometer
• Polarization

Zu erbringende Prüfungsleistung / Examination result

For each experiment, a lab report is required. The final grade is determined from an average of the grades of the individual reports. All experiments must be performed and a lab report written.

Benotung / Grading

The final module grade is determined from an average of the grades of the individual reports.

Gewichtung der Prüfungsleistung / Weight of examination result

• 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the
calculation of the overall grade.

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<tr>
<td><strong>In German:</strong></td>
</tr>
<tr>
<td>• E. Hecht: Optik</td>
</tr>
<tr>
<td>• Walcher: Laboratory der Physik</td>
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<tr>
<td>• Westphal: Physikalisches Laboratory</td>
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<td>• Geschke: Physikalisches Laboratory</td>
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<td><strong>In English:</strong></td>
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<tr>
<td>• H. Zappe: Fundamentals of Micro-optics</td>
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<tr>
<td>• E. Hecht: Optics</td>
</tr>
<tr>
<td>• B. Saleh &amp; M. Teich: Fundamentals of Photonics</td>
</tr>
<tr>
<td>• S. Sinziger &amp; J. Jahns: Microoptics</td>
</tr>
<tr>
<td>• W. Smith: Modern Optical Engineering</td>
</tr>
<tr>
<td>• P. Hariharan: Basics of interferometry</td>
</tr>
<tr>
<td>• R.R. Shannon: The art and science of optical design</td>
</tr>
<tr>
<td>• D. Malacara: Optical shop testing</td>
</tr>
<tr>
<td>• W.J. Smith: Practical optical system layout</td>
</tr>
</tbody>
</table>
**Modul / Module**

**Optik-Laboratory Grundlagen und Fortgeschritten / Basic and Advanced Optics Laboratory**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5217</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Chair Mikrooptik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in physics and mathematics; Knowledge in Micro-optics</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester: Recommended term of study**

<table>
<thead>
<tr>
<th>2 and 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

**SWS: Semester week hours**

<table>
<thead>
<tr>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each term</td>
</tr>
</tbody>
</table>

**Arbeitsaufwand: Workload**

<table>
<thead>
<tr>
<th>180 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>(60 Hours Full-time attendance course of study + 300 Hours Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Personal Profile

**Lernziele / Learning target**

**Basic Optics Laboratory:**
The Basic Optics Laboratory provides an opportunity for hands-on experimentation on the topics introduced in the Micro-optics course. As a result, the students will develop expertise in the design, assembly and characterization of optical systems and become experienced in making optical measurements.

At the completion of the course, the successful student should possess:
• the ability to analyze measurement data and estimate errors
• the ability to apply error propagation methods
• the ability to assemble and align optical systems
• a basic understanding of optical design methods
• the ability to apply optical measurement techniques
• the ability to apply analytical and graphical techniques for analyzing optical images

**Advanced Optics Laboratory:**

The Advanced Optics Laboratory Course provides an opportunity for hands-on experimentation on topics introduced in the different optics courses at IMTEK. The course is based on the curriculum of the 'Optics Lab Course I' which is a prerequisite. As a result, the students will develop advanced expertise in the design, assembly and characterization of modern optical systems and become experienced in understanding physics in optical systems.

At the completion of the course, the successful student should possess:

• the ability to design optical systems
• the ability to assemble and align complex optical systems
• the ability to analyze the properties of optical systems
• an insight into modern optical experiments
• advanced knowledge in analyzing experimental results
• an understanding of physics in modern optical setups

**Inhalte Praktikum / Content of the laboratory**

**Basic Optics Laboratory:**

One laboratory experiment has been conceived for each of the important topics addressed in the Micro-optics course; a different experiment is performed each week of the laboratory course. The topics addressed include geometric, reflective, diffractive and fiber optics as well as Fourier optics, interference, diffraction and polarization. To allow adequate representation and analysis of the measured experimental data, the course begins with a compact mini-lecture on data analysis.

Table of contents:

• Statistics and data analysis
• Error propagation
• Focal length of lenses
• Focal length of lens systems
• Construction of a microscope
• Diffraction from gratings
• Newton’s rings
• Fiber optics
• Construction of an interferometer
• Polarization

**Advanced Optics Laboratory:**

This advanced Optics Lab Course provides an opportunity for hands-on experimentation on topics introduced in the different optics courses at IMTEK. The course is based on the knowledge acquired in the 'Basic Optics Laboratory' which is a prerequisite. As a result, the students will develop advanced expertise in the design, assembly and characterization of optical systems and become experienced in understanding physics in optical systems.

At the completion of the course, the successful student should possess:

• the ability to design optical systems
• the ability to assemble and align complex optical systems
• the ability to analyze the properties of optical systems
- an insight into modern optical experiments
- advanced knowledge in analyzing experimental results
- an understanding of physics in optical setups

Table of contents:
- Anamorphic imaging
- Dynamically addressable gratings
- Whispering gallery resonators
- Michelson interferometer and coherence
- Three dimensional light distribution in a 6f system
- Diode pumped solid state laser

### Zu erbringende Prüfungsleistung / Examination result

For each experiment, a lab report is required. The final module grade is determined from an average of the grades of the individual reports of both courses. All experiments must be performed and a lab report written.

### Benotung / Grading

The final module grade is determined from an average of the grades of the individual reports in both courses.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

**In German:**
- E. Hecht: Optik
- Walcher: Laboratory der Physik
- Westphal: Physikalisches Laboratory
- Geschke: Physikalisches Laboratory

**In English:**
- E. Hecht: Optics
- B. Saleh & M. Teich: Fundamentals of Photonics
- S. Sinziger & J. Jahns: Microoptics
- W. Smith: Modern Optical Engineering
- P. Hariharan: Basics of interferometry
- R.R. Shannon: The art and science of optical design
- D. Malacara: Optical shop testing
- W.J. Smith: Practical optical system layout
<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Optimale Steuerung und Estimation / Optimal Control and Estimation</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5241</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Systemtheorie</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**
The module is self contained and can be followed by all students with sufficient mathematical background. Thus, it is recommended not only to master and advanced bachelor students of engineering, but also to students of computer science, mathematics, and physics, that want to obtain a basic understanding of optimization and control. Having heard a basic systems and control course (e.g. Systemtheorie und Regelungstechnik) and an optimization course (e.g. „Convex and Nonlinear Optimization“) is an advantage, but not necessary.

**Empfohlenes Fachsemester: Recommended term of study**
- 3

**ECTS-Punkte: ECTS-points**
- 6

**SWS: Semester week hours**
- 4 Lecture 2 Übung

**Angebotsfrequenz: Regular cycle**
- Only in the winter term

**Arbeitsaufwand: Workload**
- 180 hours (84 Hours Full-time attendance course of study + 96 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**
- Elective Module for students of the study program
  - Master of Science in Embedded Systems Engineering
    - Circuits and Systems
    - Design and Simulation
    - Personal Profile
  - Master of Science in Informatik
    - Cyber.Physical Systems
    - Kognitive Technische Systeme
    - Application area Mikrosystemtechnik
  - Master of Science in Mikrosystemtechnik
    - Circuits and Systems
    - Design and Simulation
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Circuits and Systems
    - Design and Simulation
    - Personal Profile
Lernziele / Learning target

Aim of this self contained module is to provide the participants with a working knowledge of modern control theory as it is needed for use in engineering applications, with a focus on optimal control and estimation. At the end of the module the students shall have full understanding of how to use the linear quadratic regulator (LQR), the Kalman filter, Lyapunov and Riccati Equations, dynamic programming, constrained optimal control, moving horizon estimation (MHE) and model predictive control (MPC).

Inhalte Vorlesung / Content of the lecture

Focus of the course is state space control in discrete time. We start by discussing discrete time linear systems, their basic stability properties, time varying systems, linearisation of nonlinear systems. We then enter optimal control, covering linear quadratic optimal control, linear quadratic regulation (LQR) control and Kalman filtering, Lyapunov and Riccati Equations, Dynamic Programming, Constrained Optimal Control, Moving Horizon Estimation (MHE) and Model Predictive Control (MPC). The course will be accompanied by weekly exercises with exercise questions and computer exercises using the environment MATLAB. In the last four weeks of the course (July), the participants will start to work, during the exercise sessions, on self chosen optimal control and estimation application projects, whose results will finally be presented to all course participants at the end of the semester.

Inhalte Übung / Content of the exercises

Students have to complete 50% of the practical exercises to get the admission for the final module exam.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literature / Literature</th>
</tr>
</thead>
</table>
## Modul / Module

### Optimization

### Nummer:  Number
11LE13MO-720

### Modulverantwortlicher:  Responsible person
Prof. Dr. F. Kuhn und Prof. Dr. T. Brox

### Einrichtung:  Organisational unit
Chair Algorithmen und Komplexität und Bildverarbeitung und Computergraphik

### Modultyp:  Module Type
Elective Module

### Moduldauer  Module duration
1 term

### Zugehörige Lehrveranstaltungen:  Connected events
Lecture and exercises

### Sprache:  Language
German

### Empfohlene Voraussetzungen:  Recommended preconditions
Kenntnisse aus den Modulen
- Einführung in die Programmierung
- Informatik II – Algorithmen und Datenstrukturen
- Fortgeschrittene Programmierung
- Mathematik I für Ingenieure und Informatiker
- Mathematik II für Informatiker

### Empfohlenes Fachsemester:  Recommended term of study
4

### ECTS-Punkte:  ECTS-points
3

### SWS:  Semester week hours
1 Lecture + 1 Übung

### Angebotsfrequenz:  Regular cycle
only in the summer term

### Arbeitsaufwand:  Workload
90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module

- Mandatory Module for students of the study program
  - Bachelor of Science in Informatik

- Elective Module for students of the study program
  - Bachelor of Science in Embedded Systems Engineering
  - Bachelor of Science in Mikrosystemtechnik
  - Master of Science in Embedded Systems Engineering
    - Design and simulation
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Design and simulation
    - Personal Profile
  - Master of Science in Mikrosystemtechnik
    - Design and simulation
    - Personal Profile
**Lernziele / Learning target**

Die Studierenden lernen, welche Optimierungsprobleme es gibt und wie sie gelöst werden können. Sie sollen die Schwierigkeit von Optimierungsproblemen analysieren und einschätzen lernen und in die Lage versetzt werden, die besprochenen Optimierungsverfahren in Anwendungsfällen einzusetzen.

**Inhalte Vorlesung / Content of the lecture**


**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- Bachelor of Science in Embedded Systems Engineering, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten dreifach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science in Embedded Systems Engineering Prüfungsordnungsversion 2011: Die Modulnote wird nach ECTS-Punkten dreifach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science in Informatik, Prüfungsordnungsversion 2012: Die Modulnote für das Modul "Graphentheorie und Optimierung" (Teilmodul Optimierung) wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science in Mikrosystemtechnik, Prüfungsordnungsversion 2005: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
## Modul / Module

**Optimierung von Fertigungsverfahren / Advanced engineering**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5607</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Reinecke</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Process Technology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>english</td>
</tr>
</tbody>
</table>
| Empfohlene Voraussetzungen: Recommended preconditions | • Statistical Basics  
• Fundamentals of Manufacturing Technology  
• Processes of microsystem technology (clean room fabrication and conventional environment) |

| Empfohlenes Fachsemester: Recommended term of study | 2 |
| ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture |
| Angebotsfrequenz: Regular cycle | Only in the summer term |
| Arbeitsaufwand: Workload | 90 hours  
(28 Hours Full-time attendance course of study + 62 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering  
  - Personal Profile  
- Master of Science in Mikrosystemtechnik  
  - MEMS Processing  
  - Personal Profile  
- Master of Science in Microsystems Engineering  
  - MEMS Processing  
  - Personal Profile

### Lernziele / Learning target

- Learn how to make complex processes controllable with minimum experimental effort a maximum on process significance.
- How to optimize technical results towards no rejects, towards zero failure production.
- Extension of the mathematical methods to organizational structures and management.
<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Design of Experiments</td>
</tr>
<tr>
<td>• Tolerancing and tolerance stacking</td>
</tr>
<tr>
<td>• Failure Mode and Effects Analysis</td>
</tr>
<tr>
<td>• Continuous Improvement Process</td>
</tr>
<tr>
<td>• General business and management methods for this purpose</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• George E. P. Box, Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building (Wiley Series in Probability and Statistics)</td>
</tr>
<tr>
<td>• Effective FMEAs: Achieving Safe, Reliable, and Economical Products and Processes using Failure Mode and Effects Analysis Hardcover – May 15, 2012 by Carl Carlson</td>
</tr>
<tr>
<td>• The Process Improvement Handbook: A Blueprint for Managing Change and Increasing Organizational Performance Hardcover – October 15, 2013 by Tristan Boutros</td>
</tr>
</tbody>
</table>
Modul / Module

Optische Eigenschaften von Mikro- und Nanostrukturen / Optical Properties of Micro and Nano Structures

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE50MO-5211</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>PD Dr. A. Gombert</td>
</tr>
<tr>
<td>Module Type:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Module duration:</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Lecture</td>
</tr>
<tr>
<td>Language:</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-points:</td>
<td>3</td>
</tr>
<tr>
<td>Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Workload</td>
<td>90 hours</td>
</tr>
<tr>
<td>(32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile

Lernziele / Learning target

The objective of this module is learning the fundamentals of technics and physics with respect to the interaction of electro-magnetic waves with predominantly periodically structured matter. The students will be enabled to predict the qualitative optical properties of micro and nano structured materials with the taught methods. The superior learning target is
to master the fundamental capabilities to design diffractive optical elements and optical elements based on subwavelength structures as well as to know their respective technical applications. The students will obtain the engineering know-how for micro and nano optical elements as used in micro systems technology.

**Inhalte Vorlesung / Content of the lecture**

Micro and nano structures have optical properties that differ from macroscopic bodies. The interaction between incident light or more generally incident electromagnetic radiation may lead to a modification of the propagation direction, the polarisation, and the spectral signature of absorption, reflection or transmission. In micro systems or similar technologies these phenomena can be used on purpose or need to be considered when manufacturing micro and nano structures. In this lecture we will work on the theoretical fundamentals as well as on selected applications.

Topics:
- Calculating with complex amplitudes
- Energy transfer at boundaries
- Two beam interference
- Huygens’ principle
- Fresnel’s zone construction
- Introduction into Fourier optics
- Kirchhoff-Fresnel diffraction integral
- Fresnel diffraction
- Fraunhofer diffraction
- Introduction into diffraction gratings
- Spectroscopic gratings
- Theory and applications of subwavelength gratings
- Photonic crystals
- Resonant structures in metals
- Production technologies for micro structures with optical functions

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- E. Hecht: Optics, Addison-Wesley, 1989
Modul / Module

Optische Fallen und Partikel Tracking / Optical Trapping and Particle Tracking

Nummer: Number 11LE50MO-5219

Modulverantwortlicher: Responsible person Prof. Dr. A. Rohrbach

Einrichtung: Organisational unit Chair Bio- and Nanophotonik

Modultyp: Module Type Elective Module

Modulauer Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises

Sprache: Language English

Empfohlenes Fachsemester:: Recommended term of study 4

ECTS-Punkte: ECTS-points 6

SWS: Semester week hours 3 Lecture + 2 Exercises

Angebotsfrequenz: Regular cycle Only in the summer term

Arbeitsaufwand: Workload 180 hours (70 Full-time attendance course of study + 110 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Physik
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Sensors and Actuators
  - Personal Profile

Lernziele / Learning target

Optical traps and optical micro-manipulation techniques do have the potential to play a key role in future micro- and nanosystems in conjunction with the life sciences. In this lecture the students should learn what is doable with optical forces, where physical limits are and what is limited by nowadays technology. Besides fascinating fundamental research various
applications related to biology or fluctuation based systems are presented. The lecture is manifold and teaches basics in optics, statistical physics and biology/biophysics.

<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction</td>
</tr>
<tr>
<td>2. Light - Information carrier and actor</td>
</tr>
<tr>
<td>3. About microscopy</td>
</tr>
<tr>
<td>4. Light scattering</td>
</tr>
<tr>
<td>5. Optical forces</td>
</tr>
<tr>
<td>6. Tracking beyond the uncertainty</td>
</tr>
<tr>
<td>7. Brownian motion and calibration techniques</td>
</tr>
<tr>
<td>8. Photonic force microscopy</td>
</tr>
<tr>
<td>9. Applications in cell biophysics</td>
</tr>
<tr>
<td>10. Time- multiplexing and holographics optical traps</td>
</tr>
<tr>
<td>11. Applications in microsystems technology</td>
</tr>
<tr>
<td>12. Applications in nanotechnology</td>
</tr>
<tr>
<td>75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inhalte Übung / Content of the exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>The tutorials help the students to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this, the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors. 75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)</td>
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</tr>
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<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Studienleistung / Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the lecture and the exercises and at the beginning of each class.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
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<tbody>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• Master of Science in Embedded Systems Engineering, Academic regulations of</td>
</tr>
</tbody>
</table>
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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.
Optische Materialien / Optical Materials

Nummer: 11LE50MO-5113-2

Modulverantwortlicher: Prof. Dr. K. Buse
Einrichtung: Chair Optische Systeme

Modultyp: Elective Module
Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture and exercises
Sprache: English

Empfohlene Voraussetzungen: Knowledge in Micro-optics

Empfohlenes Fachsemester: 3
ECTS-Punkte: 5

SWS: 2 lecture + 2 exercises
Angebotsfrequenz: Only in the winter term

Arbeitsaufwand: 150 hours (64 hours Full-time attendance course of study + 86 hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - MEMS Processing
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - MEMS Processing
  - Photonics
  - Personal Profile

Lernziele / Learning target

Optical devices rely on optical materials that control the propagation (lenses, fibers), the polarization (half-wave plates, Faraday rotators), or the frequency (nonlinear-optical materials) of light. In this course, we will classify optical materials and cover the fundamentals of light-matter interaction as well as effects that are widely used in many...
Our goal is to enable the participants to understand important optical devices from the material point-of-view and to qualify the attendees to select the right material for a particular application.

### Inhalte Vorlesung / Content of the lecture

1. Classification of optical materials
2. Fabrication
3. Interaction of light and matter
4. Pulse propagation in dispersive materials
5. Birefringence
6. Faraday effect
7. Nonlinear-optical effects
8. Pockels effect
9. Kerr effect
10. Photorefractivity
11. Frequency conversion
12. Optical parametric oscillators
13. Optical whispering galleries

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Literatur / Literature

- B. E. A. Saleh, M. C. Teich, „Grundlagen der Photonik“
- A. Yariv, "Photonics: Optical Electronics in Modern Communications"
### Optische MEMS / Optical MEMS

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5240</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Zappe</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Physical Optics</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester:: Recommended term of study | 3 |
| ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 2 Lecture |
| Angebotsfrequenz: Regular cycle | Only in the winter term |
| Arbeitsaufwand: Workload | 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Photonics
  - Personal Profile

### Lernziele / Learning target

- Theoretical understanding of fundamental optical phenomena exploited by the MOEMS technology
- Acquisition of the essential skills necessary for the design, microfabrication, modeling, and characterization of MEMS/MOEMS components
- A comprehensive knowledge of MOEMS based commercial systems and a basic understanding of the particular applications enabled by MOEMS
Inhalte Vorlesung / Content of the lecture

Module 1: MOEMS Fundamentals
- Optics Review
- MEMS Manufacturing Techniques
- Actuators and Position Sensing
- Design and Modeling
- Test and Characterization

Module 2: MOEMS Devices
- Micromirrors
- Tunable Gratings
- Active Microlenses
- Tunable Optical Resonators

Module 3: MOEMS Systems
- Display and Imaging Systems
- MOEMS in Telecommunication Networks
- Scientific Instrumentation

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
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- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

MEMS and MOEMS Related Books
- An Introduction to Microelectromechanical Systems Engineering by N. Maluf
- Microsystem Design by Stephen Senturia
- Micromachined Transducers Sourcebook by G. Kovacs
- Fundamentals of Microfabrication by Marc Madou
- Micro Electro Mechanical System Design by J. Allen
- Analysis and Design Principles of MEMS Devices by Minhang Bao
• The MEMS Handbook by Mohamed Gad-el-Hak
• MOEMS: Micro-Opto-Electro-Mechanical Systems by Manouchehr E. Motamed
• Foundations of MEMS by Chang Liu
• MEMS & Microsystems by Tai-Ran Hsu

Scientific Journals
• Journal of Microelectromechanical Systems / IEEE
• Journal of Micromechanics and Microengineering / IOP
• Journal of Micro/Nanolithography, MEMS, and MOEMS / SPIE
• Microsystem Technologies / SPRINGER
• Sensors and Actuators A-Physical / ELSEVIER
• Applied Optics / OSA
• Optics Letters / OSA
• Optics Express / OSA
• Applied Physics Letters / AIP
• Journal of Biomedical Optics / SPIE

Modul / Module

Optische Messverfahren: Grundlagen und Anwendungen in der Praxis / Optical measurement techniques

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5710</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. K. Buse</td>
</tr>
<tr>
<td>Organisational unit:</td>
<td>Chair Optische Systeme</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Seminar</td>
</tr>
<tr>
<td>Connected events</td>
<td>Sprache: English</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester:          | 2 |
| Recommended term of study          | ECTS-Punkte: ECTS-points |
|                                    | 3 |
| SWS: Semester week hours           | 2 Seminar |
| Workload                           | Angebotsfrequenz: Regular cycle |
|                                    | Only in the summer term |
| Arbeitsaufwand:                    | 90 hours |
| (28 Hours Full-time attendance course of study + 62 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Photonics
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Photonics
  - Sensors and Actuators
  - Personal Profile

Lernziele / Learning target

The students gain knowledge about different optical measurement techniques for shape determination of objects or for material characterization. They achieve a deeper understanding of the physical background. Consequently, the participants are able to estimate the fundamental and technological limitations of the methods presented. This enables the students to select an appropriate optical measurement technique for a given task. Furthermore, the participants get trained in preparing and presenting excellent talks.
### Inhalte Seminar / Content of the seminar

During the first meeting the organizers will present a list of topics from which each active participant of the seminar can select one. For each topic literature will be provided. Starting with this material the active participants of the seminar will familiarize themselves with the content. This will be done by discussions as well as by further literature search. Based on the accumulated knowledge, an outline for talks will be made and finally the viewgraphs will be prepared. Then the talk will be presented in the seminar. Typical duration of the talk is 30 minutes. After the talk there will be a discussion about the content. And as a second part of the discussion technical issues of the talk will be analyzed. Finally, a short written summary of the talk will be prepared. Talks can be given in German or English.

This semester, the following topics are available:

- 3d-shape determination
- Optical microresonators for sensing
- Terahertz waves for material characterization
- Photoacoustic spectroscopy
- Laser spectroscopy
- Fluorescence spectroscopy
- and more

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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### Literatur / Literature

The advisor will provide literature as a starting package.
Modul / Module

Optische Mikrosensoren / Optical Micro-Sensors

<table>
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<tr>
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<th>11LE50MO-5711</th>
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<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. A. Brandenburg</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Institut für Mikrosystemtechnik</td>
</tr>
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<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Vorlesung</td>
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**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and Actuators
  - Personal Profile

**Lernziele / Learning target**

Kenntnis der Prinzipien miniaturisierter optischer Sensoren, Vertiefung bei den Gebieten Wegsensorik, Drehratensensoren sowie chemische und biochemische Sensoren.

**Inhalte Vorlesung / Content of the lecture**

- Vorbereitende Inhalte: Grundlagen der Optik (kurze Wiederholung), Lichtwellenleiter.
- Optische Grundlagen für die Sensorik: Interferometrie, Sagnac-Effekt, Spektroskopie, Fluoreszenz.
- Detaillierte Darstellung der Funktion und der technologischen Realisierung von Wegsensoren, Drehratensensoren, Miniaturspektrometern und fluoreszenzoptischen Sensoren sowie Microarray-Technologien.
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<table>
<thead>
<tr>
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</tr>
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<tbody>
<tr>
<td>• G. Schröder: Technische Optik, Vogel-Verlag, Würzburg 1980</td>
</tr>
<tr>
<td>• T. Tamir (Hrsg.): Guided wave optoelectronics, Springer-Verlag 1988</td>
</tr>
<tr>
<td>• W. Schmidt: Optische Spektroskopie, VCH Verlagsgesellschaft Weinheim 1994</td>
</tr>
</tbody>
</table>
Modul / Module

Partikelsimulationsmethoden / Particle Simulation Methods

Nummer: Number 11LE50MO-5505

Modulverantwortlicher: Responsible person N.N.

Einrichtung: Organisational unit Chair Simulation

Modultyp: Module Type Elective Module

Moduldauer: Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises

Sprache: Language English

Empfohlenes Fachsemester: Recommended term of study 3

ECTS-Punkte: ECTS-points 6

SWS: Semester week hours 2 lecture + 2 exercises

Angebotsfrequenz: Regular cycle Only in the winter term

Arbeitsaufwand: Workload 180 hours (64 hours Full-time attendance course of study + 116 hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and Simulation
  - Personal Profile

Lernziele / Learning target

Lecture:
The students will learn about alternative approaches to the simulation of hydrodynamic phenomena relevant for microsystems engineering. They will have a basic understanding of Molecular Dynamics, Dissipative Particle Dynamics and Smoothed Particle Hydrodynamics. They will understand the relation to continuum methods for fluid dynamics. The students will acquire the knowledge on how to apply particle methods to specific problems in microfluidics simulation.

Practical exercises:
The will be able to compile an adequate model for the description of the phenomenon under investigation. They will be able to decide which of the the respective particle methods detailed in the lecture to apply for the solution. The students will understand the meaning of
particle simulation methods as an experimental tool to investigate materials behaviour through the usage of a particle simulation program and the solution of modeling and simulation assignment.

### Inhalte Vorlesung / Content of the lecture

The lecture will cover the following topics:
- From classical mechanics to statistical mechanics
- Concepts of thermodynamics
- Molecular Dynamics (MD): Basics
- MD: Numerical Techniques
- Dissipative Particle Dynamics (DPD)
- Smoothed Particle Hydrodynamics
- Energy conserving DPD
- Degrees of freedom internal to dissipative particles

### Inhalte Übung / Content of the exercises

These exercises will accompany the topics given in the course on Advanced Topics in Simulation: Particle Methods. The exercises will focus on problems to be solved with the software tool MOLDYN, developed at IMTEK Simulation. Moldyn uses XML input language and provides a wide range of tools for the analysis of results. Direct graphical output can be followed on the computer screen. An interface to Paraview is included to observe different states of the simulation and to produce videos from the results. The students will be assigned with a project to be solved by MOLDYN. To this end a detailed introduction on the usage of MOLDYN will be given.

To pass the exercises, students have to pass minimum 50 % of the exercises sheets.

### Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Andrew R. Leach, Molecular modelling: principles and applications, Prentice Hall (2001)
**Modul / Module**

**Photonische Mikroskopie / Photonic Microscopy**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5901</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. A. Rohrbach</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Bio- und Nanophotonik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester: Recommended term of study**
5

**ECTS-Punkte: ECTS-points**
6

**SWS: Semester week hours**
3 Lecture + 2 Übung

**Angebotsfrequenz: Regular cycle**
Only in the winter term

**Arbeitsaufwand: Workload**
180 hours (80 Hours Full-time attendance course of study + 100 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science inPhysik
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Photonics
  - Personal Profile

**Lernziele / Learning target**

The student should learn how to guide light through optical systems, how optical information can be described very advantageously by three-dimensional transfer functions in Fourier space, how phase information can be transformed to amplitude information to generate image contrast. Furthermore one should experience that wave diffraction is not reducing the information and how to circumvent the optical resolution limit. The student should learn to distinguish between coherent and incoherent imaging, learn about modern techniques using self-reconstructing laser beams, two photon excitation, fluorophores depletion through stimulated emission (STED) or multi-wave mixing by coherent anti-Stokes Raman scattering (CARS). The module has an ongoing emphasis on applications, but nevertheless presents a mixture of fundamental physics, compact mathematical descriptions and many examples and illustrations. The lecture aims to encompass the current state of a scientific field, which
will influence the fields of nanotechnology and biology/medicine quite significantly.

<table>
<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Microscopy: History, Presence and Future</td>
</tr>
<tr>
<td>2. Wave- and Fourier-Optics</td>
</tr>
<tr>
<td>3. Three-dimensional optical imaging and information transfer</td>
</tr>
<tr>
<td>4. Contrast enhancement by Fourier-filtering</td>
</tr>
<tr>
<td>5. Fluorescence – Basics and techniques</td>
</tr>
<tr>
<td>6. Point scanning and confocal microscopy</td>
</tr>
<tr>
<td>7. Microscopy with self-reconstructing beams</td>
</tr>
<tr>
<td>8. Optical tomography</td>
</tr>
<tr>
<td>9. Nearfield and Evanescent Field Microscopy</td>
</tr>
<tr>
<td>10. Super-resolution using structured illumination</td>
</tr>
<tr>
<td>11. Multi-Photon-Microscopy</td>
</tr>
<tr>
<td>12. Super resolution imaging by switching single molecules</td>
</tr>
</tbody>
</table>

75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

<table>
<thead>
<tr>
<th>Inhalte Übung / Content of the exercises</th>
</tr>
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<tbody>
<tr>
<td>The tutorials help the student to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors. 75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zu erbringende Studienleistung / Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the lecture and the exercises and at the beginning of each class.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 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.</td>
</tr>
<tr>
<td>- 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.</td>
</tr>
</tbody>
</table>
- 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.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.
### Modulhandbuch M.Sc. Informatik – Photovoltaische Energiekonversion für Ingenieure / Photovoltaic Energy Conversion for engineers

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Photovoltaische Energiekonversion für Ingenieure / Photovoltaic Energy Conversion for engineers</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5712</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. S. Glunz</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Institut für Mikrosystemtechnik</td>
</tr>
<tr>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>german</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlene Recommended preconditions</th>
<th>Basic knowledge of semiconductor physics and technology.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Recommended term of study</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
<td>Angebotsfrequenz: Regular cycle</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)</td>
<td>Only in the summer term</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and Actuators
  - Personal Profile

**Lernziele / Learning target**

This module gives a general overview of the components of photovoltaic energy systems and the chances of this renewable energy.
### Inhalte Vorlesung / Content of the lecture

Um zur Abschlussprüfung zugelassen zu werden, muss die Vorlesung zu jedem Vorlesungstermin besucht werden. Unentschuldigtes Fehlen führt zu einer Nichtzulassung zur Abschlussprüfung.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to attend the lecture regularly in order to be admitted to the final module exam.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
**Piezoelektrische und dielektrische Wandler / Piezoelectric and dielectric transducers**

**Nummer:** 11LE50MO-5713

**Modulverantwortlicher:** Prof. Dr. P. Woias

**Einrichtung:** Chair Konstruktion von Mikrosystemen

**Modultyp:** Elective Module

**Modulauer:** 1 term

**Zugehörige Lehrveranstaltungen:** Lecture and exercises

**Sprache:** English

**Empfohlene Voraussetzungen:** Mechanics and electronics should be known from bachelor studies

**Empfohlenes Fachsemester:** 2

**ECTS-Punkte:** 3

**SWS:** 2 lecture + 1 exercises

**Angebotsfrequenz:** Only in the summer term

**Arbeitsaufwand:** 90 hours (42 Hours Full-time attendance course of study + 48 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and Actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and Actuators
  - Personal Profile

**Lernziele / Learning target**

You will...
- be able to explain the physical effects that lead to electro-mechanical coupling
- be able to use the linear coupled theory to model dielectric and piezoelectric transducers
- be able to describe nonlinear effects and some ways to model them
- know several applications of dielectric and piezoelectric transducers and their
Inhalte Vorlesung / Content of the lecture

- Introduction to Piezoelectrics (material science)
- Linear theory of Piezoelectrics
- Nonlinear Effects, high field effects, hysteresis
- Other transduction mechanisms (Electrets, Electrostriction)
- Applications

Inhalte Übung / Content of the exercises

To qualify for the exam at least one of the exercise tasks must be solved on the chalk board during an exercise session.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
</table>
# Modul / Module

## Polymere in der Membrantechnik / Polymers in Membrane Technology

**Nummer: Number**

| 11LE50MO-5114 |

**Modulverantwortlicher: Responsible person**

| Prof. Dr. J. Rühe |

**Modultyp: Module Type**

| Elective Module |

**Zugehörige Lehrveranstaltungen: Connected events**

| Lecture |

**Einrichtung: Organisational unit**

| Chair Chemie und Physik von Grenzflächen |

**Moduldauer: Module duration**

| 1 term |

**Sprache: Language**

| English |

**Empfohlenes Fachsemester:: Recommended term of study**

| 2 |

**ECTS-Punkte: ECTS-points**

| 3 |

**SWS: Semester week hours**

| 2 Lecture |

**Angebotsfrequenz: Regular cycle**

| Only in the summer term |

**Arbeitsaufwand: Workload**

| 90 hours (28 hours Full-time attendance course of study + 62 hours Self-study) |

---

### Usability of the module

**Verwendbarkeit der Veranstaltung**

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

---

### Learning target

**Lernziele**

- Gain awareness for separation needs and sustainability impact
- Understand principles of separation
- Understand membrane fabrication and (polymeric) membrane material properties
- Apply polymeric surface modifications to mitigate material limitations and enable new processes
The lecture will focus on polymeric materials for membrane separation technologies. The scope of applications that will be discussed ranges from water to oil & gas, biotech, dialysis to food with a focus on water filtration technologies. Creating awareness for major societal challenges like clean water supply, health care / quality of life and minimization of energy consumption and for contributions that membrane technologies can offer to sustainable solutions for these challenges will be key learning objectives. Focus will be on materials and membrane fabrication / post-modification processes as well as on the underlying principles of separation. Process engineering will be of minor importance. The lecture will concentrate on cognitive levels ‘understanding’ and ‘application’ (Bloom’s taxonomy), case studies will touch upon higher levels.

written or oral examination

The module grade is calculated from the result of the final examination.

- 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.
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- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Various materials are available on the website
Homepage: http://www.imtek.de/cpi
Modul / Module

Projektmanagement für Ingenieure / Project management for engineers

Nummer: Number 11LE50MO-5803

<table>
<thead>
<tr>
<th>Modulverantwortlicher: Responsible person</th>
<th>Prof. Dr. U. Wallrabe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Microactuators</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English and German</td>
</tr>
</tbody>
</table>

Empfohlenes Fachsemester:: Recommended term of study 2 ECTS-Punkte: ECTS-points 3

SWS: Semester week hours 2 Seminar Angebotsfrequenz: Regular cycle Each term

Arbeitsaufwand: Workload 90 hours (28 or 32 hours Full-time attendance course of study + 58 or 62 hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Personal Profile

Lernziele / Learning target

Students shall learn the basic ideas and techniques of project management and apply them to representative examples. They shall realize that planning tasks isn’t always as clear-cut as in engineer courses. A project can be structured in different ways. One plan isn’t necessarily better than the other. Instead, one approach might be more practical or provide a better overview than another. Additionally, the students shall gain insight into the soft skills of project management, i.e. how to deal with operating persons, namely the project team as a social system.
### Inhalte Seminar / Content of the seminar

The course comprises a mixture of lecture and group work with short presentations of the obtained project plans. The different phases of a project and its respective project management, i.e. project assignment, planning, execution and completion of a project, is presented as an introduction into the field. The different roles of people coping with the project, i.e. initiator or customer, project manager and staff, and their duties are presented, and their responsibilities analysed.

Various planning techniques and plans will be introduced: project environment analysis, risk analysis, work breakdown structure, Gantt chart and SWOT analysis.

The financial budgeting of a project will be shown: existing cost factors, their estimation and what exactly has to be considered.

In addition, the more technical aspect of project planning will be supplemented with soft skills, like how to lead a discussion, mediation, etc.

MS Project will be used to make the project management simpler. With its help project plans for fictitious projects will be developed.

The presented lecture content will be visualized with two fictitious projects. The students will have to implement the learning matter in individual and team work. The projects are a journey round the world with fellow students after graduation and a virtual Master thesis.

### Zu erbringende Prüfungsleistung / Examination result

written examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

Regularly updated lecture notes are available.
**Quantenmechanik für Ingenieure / Quantum mechanics for engineers**

**Modul / Module**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5107</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Paul</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Materialien</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Semiconductor Physics or Physical Electronics</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester: Recommended term of study**

<table>
<thead>
<tr>
<th>2</th>
</tr>
</thead>
</table>

**ECTS-Punkte: ECTS-points**

| 6 |

**SWS: Semester week hours**

| 2 lecture + 2 exercises |

**Angebotsfrequenz: Regular cycle**

| Only in the summer term |

**Arbeitsaufwand: Workload**

| 180 hours (56 hours Full-time attendance course of study + 124 hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Sensors and actuators
  - Personal Profile

**Lernziele / Learning target**

The goal is to introduce the students to the main effects of quantum mechanics relevant in technical micro and nano devices. Current semiconductor components in which quantum mechanics plays a role are discussed in depth. The course successively develops the basic mathematical methods required to solve one, two and three-dimensional problems. The
understanding is deepened by practical exercises.

Inhalte Vorlesung / Content of the lecture

- Introduction: Historical overview, unsolved problems at the beginning of the 20th century, probability amplitudes, uncertainty relation
- Wave mechanics: Schrödinger equation, separation of variables, free particle, reflection at wall, potential step, transfer matrix method, wave packets,
- Tunneling: Principle, semiconductor tunneling devices, potential barriers, WKB approximation, triangular potential wall
- Bound states, resonances, and band structure: Potential well, tunneling between wells, infinite series of potential wells
- Single electron transistors: Double-junction SETs, Coulomb barrier, Coulomb staircase, gate-biased SETs, single-electron turnstile, single-electron pumps

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Script
Modul / Module

Reinraumlaborkurs für Ingenieure / Clean Room Laboratory for Engineers

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5804</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Reinecke</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Prozesstechnologie</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>3 Laboratory</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (42 hours Full-time attendance course of study + 48 hours Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Personal Profile

Lernziele / Learning target

Hands-on experience and deepening of obtained knowledge of the module “MST - Technologies and Process”

Inhalte Praktikum / Content of the laboratory

Cleanroom behavior and processing:
- Wafer handling
- Lithography sequence
- Cleaning
- Metal deposition (physical vapour deposition)
- Profilometry
- Lift-Off
- Wafer backside processing
- Electroplating
- Characterization
- Acquisition of relevant processing data and recording
### Zu erbringende Prüfungsleistung / Examination result

5 short tests and lab report are required.

### Benotung / Grading

The module grade is calculated from the average of the grades of the required tests.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- H. Reinecke, MST Technologies and Processes, lecture
- W. Menz, J. Mohr, O. Paul Microsystems Technology, Wiley VCH
- M. Madou, Fundamentals of Microfabrication, CRC Press
- S. M. Sze, Physics of Semiconductor Devices, Wiley VCH
- J.W. Dini, Electrodeposition, Noyes Publications
## Rennautoregelung – Laboratory / Race Car Control Laboratory

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE50MO-5224</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Systemtheorie</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

The lab course includes topics as part of the Race Car project (Simulation, Optimization and Control of small race cars). The project offers a large variety of project topics, students may be assigned topics meeting their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.

**Empfohlenes Fachsemester: Recommended term of study**

| 3 | 6 |
| 4 Laboratory | Angebotsfrequenz: Regular cycle |
| Arbeitsschichten: Workload | 180 hours (56 oder 64 hours Full-time attendance course of study + 124 oder 116 hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Sensors and actuators
  - Personal Profile

**Lernziele / Learning target**
Aim of this module is to use the theoretical background for real applications in a scientific project. Finding creative solutions to problems as well as hands-on testing/verification of soft- and hardware will be part of the projects. The module will also offer experience of working in an international team.

### Inhalte Vorlesung / Content of the lecture

Focus of the lab course is setting up a race track and control system for autonomous driving cars. The set up consists of a track, cars, a color camera, which is tracking the cars and a computer, controlling the cars. The communication between the race cars and the computer will be carried out by hacking the remote control. The color camera can be seen as the sensor of the car, communicating its actual position to the computer.

The course will be accompanied by weekly meetings with one or more team members working on complementary projects addressing the same real world control problem. In the last two to three weeks of the lab course, when the main project aims are achieved, the participants will start to work on a short report for documentation and give a final oral presentation to share their findings with all team members.

### Zu erbringende Prüfungsleistung / Examination result

**Project work:**
- A working project result
- Project documentation and oral presentation

### Benotung / Grading

The final module grade is determined from an average of the grades of the project work.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
RF- and Microwave Design Course

**Module Number:** 11LE50MO-5244

**Module Responsible Person:** PD Dr. R. Quay

**Organisational Unit:** Institut für Mikrosystemtechnik

**Module Type:** Elective Module

**Module Duration:** 1 term

**Connected Events:** Laboratory

**Language:** English

**Mandatory Preconditions:** The prior or parallel participation in either module "RF- and microwave devices and circuits" or "RF- and microwave circuits and systems" is required. No prior knowledge of the software is required.

**Recommended Term of Study:** 2

**ECTS Points:** 3

**Semester Week Hours:** 2 Laboratory

**Regular Cycle:** Only in the summer term

**Workload:** 90 hours (28 Hours Full-time attendance course of study + 62 Hours Self-study)

**Usability of the Module:** Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Personal Profile

**Learning Target:** The students will be enabled to understand, design and layout modern RF- and microwave components and systems by means of the electronic design environment Agilent Advanced Design System including the two- and three dimensional electromagnetic simulators Momentum and EMPro 3D. The detailed use of a complex RF-software environment is a dedicated target of this course. This includes the numerical analysis of complex passive and active devices, the design and layout of hybrid and integrated circuits, and their packaging.
and signal flow. The students will be competent to design and layout passive and active RF-structures including packages and interconnects and circuits of relevance to everyday communication and sensing. The competence includes in-depth understanding and treatment of complex microwave systems and of general system design including the treatment of complex modulated signal flows.

### Inhalte Praktikum / Content of the laboratory

The Design Course: RF- and Microwave Systems deals with the analysis and creation of RF-devices, circuits and systems. It comprises three aspects: the detailed electromagnetic design of high-frequency/RF passive and active structures, the modelling and layout and verification of active electronic RF-devices in circuit environments based on various semiconductor technologies, and the high-level combination of more complex microwave systems. This includes the simulation of printed circuit boards, of integrated circuits and of devices in package including RF-interconnects, and of behavioural system simulation. Advanced analysis of RF-problems, characterisation, modelling and linear and nonlinear simulation techniques are introduced in order to combine knowledge from modern electronics (from various technologies such as silicon complementary MOS and GaAs), from component analysis, RF-circuit design principles, and system engineering. The examples include simple printed circuits boards, integrated circuits, advanced communication transceivers in mobile communication based on UMTS and LTE and modern radar.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skript: Design Course: RF- and Microwave Systems, R. Quay, 2014 (will be provided at the beginning of the lecture)</td>
</tr>
</tbody>
</table>
Modul / Module

RF- und Mikrowellen Bauelemente und Schaltungen / RF- and Microwave Devices and Circuits

Nummer: Number
11LE50MO-5215

Modulverantwortlicher: Responsible person
PD Dr. R. Quay

Einrichtung: Organisational unit
Institut für Mikrosystemtechnik

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 term

Zugehörige Lehrveranstaltungen: Connected events
Lecture

Sprache: Language
English

Empfohlenes Fachsemester: Recommended term of study
5

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
2 Lecture

Angebotsfrequenz: Regular cycle
Only in the winter term

Arbeitsaufwand: Workload
90 hours
(28 Hours Full-time attendance course of study + 62 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module
Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  o Circuits and systems
  o Personal Profile
- Master of Science in Informatik
  o Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  o Circuits and systems
  o Personal Profile
- Master of Science in Microsystems Engineering
  o Circuits and systems
  o Personal Profile

Lernziele / Learning target
The students will be enabled to understand concepts, devices, design, and functioning of modern RF- and microwave transceiver subsystems. This includes the understanding of basic RF-concepts, passive and active devices, circuits, functionalities, their critical figures-of-merrit, and the inclusion into modules. The students will be competent to analyse passive and active RF-structures and circuits, which are relevant for any system with an RF-functionality. The competence includes the full understanding of a transmit/receive module needed for today’s communication and sensing.
Inhalte Vorlesung / Content of the lecture

The lecture RF- and Microwave Devices and Circuits deals with the fundamentals of RF-devices and circuits. It comprises three parts: high-frequency/RF concepts and passive structures, active electronic RF-devices, and RF-circuits and modules. At the interface of modern electronics, dielectric wave propagation, circuit design, and advanced communication and sensing, advanced analysis and characterisation techniques are introduced in order to bridge the gap from modern electronics and modern passive RF-technology to the understanding of RF-communication and sensing systems. The methodologies of RF-analysis, design of devices and circuits, and their basic figures-of-merit, their modelling and characterisation are introduced along with the demonstration of their relevance to modern RF-components and microsystems. This also includes a discussion of the underlying technology and many examples supported by RF-design tools from the microwave oven to today’s RF-applications in mobile communication in the iPod.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

RF- and Microwave passives
- Zinke/Brunswig, Hochfrequenztechnik, Band 1, Springer, 1999
RF-Devices
**Modul / Module**

**RF- und Mikrowellen Schaltungen und Systeme / RF- and Microwave Circuits and Systems**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5232</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>PD Dr. R. Quay</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Institut für Mikrosystemtechnik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester:: Recommended term of study** 5

**ECTS-Punkte: ECTS-points** 3

**SWS: Semester week hours**

- Lecture 2

**Angebotsfrequenz: Regular cycle** Only in the winter term

**Arbeitsaufwand: Workload**

- 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Personal Profile

**Lernziele / Learning target**

The students will be enabled to understand concepts, functioning, and design of modern complex RF-and microwave circuits and systems. This includes the understanding of basic RF-concepts, of more complex passive and active circuits, of modern antennas, of combined functionalities, data acquisition, and aspects of systems and communication theory. The students will be competent to analyse passive and active RF-structures and circuits, full RF-functions, analyze complex signal and data flows, and full system concepts and data acquisition. System concepts for communication, such as for a full transmit-receive system, for remote sensing including imaging and radar, are presented and several examples discussed in detail.
Inhalte Vorlesung / Content of the lecture

The lecture RF- and Microwave Devices and Circuits deals with the analysis and creation of RF-devices, circuits and systems. It comprises three aspects: the detailed electromagnetic design of high-frequency/RF passive and active structures, the modelling and layout and verification of active electronic RF-devices in circuit environments based on various semiconductor technologies, and the high – level combination of more complex microwave systems. This includes the simulation of printed circuit boards, of integrated circuits and of devices in package including RF-interconnects, and of behavioural system simulation.

Advanced analysis of RF-problems, characterization, modelling and linear and nonlinear simulation techniques are introduced in order to combine knowledge from modern electronics (from various technologies such as silicon complementary MOS and GaAs), from component analysis, RF-circuit design principles, and system engineering. The examples include simple printed circuits boards, integrated circuits, advanced communication transceivers in mobile communication based on UMTS and LTE and modern radar.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- RF- and Microwave passives
- Zinke/Brunswig, Hochfrequenztechnik, Band 1, Springer, 1999
- Further literature for systems are presented during the lecture.
## Modul / Module

**Sensor-Aktorschaltungstechnik / Electronic signal processing for sensors and actuators**

<table>
<thead>
<tr>
<th>Nummer</th>
<th>Number</th>
<th>11LE50MO-5714</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher</td>
<td>Responsible person</td>
<td>Prof. Dr. P. Woias</td>
</tr>
<tr>
<td>Einrichtung</td>
<td>Organisational unit</td>
<td>Chair Konstruktion von Mikrosystemen</td>
</tr>
<tr>
<td>Modultyp</td>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer</td>
<td>Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen</td>
<td>Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache</td>
<td>Language</td>
<td>German</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester</th>
<th>Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte</td>
<td>ECTS-points</td>
<td>5</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 lecture + 2 exercises</td>
<td></td>
</tr>
<tr>
<td>Angebotsfrequenz</td>
<td>Regular cycle</td>
<td>Only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand</td>
<td>Workload</td>
<td>150 hours (56 hours Full-time attendance course of study + 94 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Sensors and actuators
  - Personal Profile

### Lernziele / Learning target

### Inhalte Vorlesung / Content of the lecture

Die Lecture ist in folgende Kapitel gegliedert:
- Einführung in elektronische Bauelemente und Funktionsblöcke (Diode, Bipolartransistor, Stromquellen, Stromspiegel, Bandgap-Referenz, Operationsverstärker)
- Stromliefernde Sensoren (Photodiode, amperometrische Elektrode
- Spannungslierehende Sensoren (Ionen sensitiver Feldeffekttransistor)
- Resistive Sensoren nach dem Wheatstone-Brückenprinzip (Druck, Beschleunigung)
- Kapazitive Sensoren (Druck, Beschleunigung, Feuchte)
- Kapazitive Aktoren (elektrostatisch, piezo)

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Modulhandbuch M.Sc. Informatik – Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals

Modul / Module

Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5312</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Stieglitz</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Biomedical Microtechnology</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>english</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester: Recommended term of study | 2 |
| ECTS-Punkte: ECTS-points | 6 |
| SWS: Semester week hours | 2 Lecture |
| Angebotsfrequenz: Regular cycle | Only in the summer term |
| Arbeitsaufwand: Workload | 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

Lernziele / Learning target

The objective of the module is to show, how signal processing and analysis methods can add additional information to the classical ways of interpreting brain signals measured by electroencephalography (EEG) or magnetoencephalography (MEG). This goes beyond the basic signal processing methods to separate the signal from background noise. General techniques for pattern recognition will be presented and how they are tailored for the daily use in clinical practice or neuroscience research. As a result students will have knowledge of general tools in pattern recognition in recordings of brain signals and how to adapt them to the requirements of the specifics needs in clinical use or for research projects.

The second part of the module will add modelling to the signal analysis to perform the localization of generators of brain activity. Different approaches of modelling of the head and the generators of the brain activity will be introduced. The objective is to provide the
students with knowledge about different modelling levels and strategies about the selection of generator models, which are appropriate for a given source localization task.

**Inhalte Vorlesung / Content of the lecture**

The course starts with an introduction to the basic principles of the measurement of neurophysiological signals mainly EEG and MEG. Despite a basic technical introduction of the measurement systems an overview about physiological and pathological patterns and rhythms in brain signal is given. Pattern recognition in the diagnostics of patients suffering from epilepsy is one core topic of the module. Long term recordings of EEG in epilepsy diagnostic create a high demand for automatic EEG analysis procedures. Three different types of events are at the moment in the focus for automatic detection strategies.

a) Epileptic seizures, which are the core syndrome of the disease. Automatic detection may facilitate the review of long term recordings tremendously.

b) Short high amplitude peaks in EEG and MEG called spikes contribute to the diagnoses of epilepsy and give information related to the localization of the seizure onset region in focal epilepsy.

c) Oscillatory activity in the frequency range between 80 Hz and 600 Hz gives according to recent result probably more specific information about the seizure origin area than spikes. Signal processing and pattern recognition strategies are presented and how they can be applied to the patterns of interest in epilepsy diagnostic. In detail following strategies will be presented:

a) Heuristics

b) Template matching

c) Wavelet transformation

d) Hilbert transformation

e) Background and target modelling

f) Artificial neural networks

A second focus of the module is related to the localization of generators of neuronal activity based on EEG and MEG measurements. The introduction starts with the presentation of the Maxwell equations and the common simplifications as they are applied in EEG and MEG source localization. Localization includes two basic components, the forward simulation and an inverse parameter estimation procedure. Concepts of the following forward models representing the physical properties of the head are presented:

a) Spherical model

b) Boundary element model

c) Finite element model

Main types of focal and distributed inverse models will form the contents of the inverse part of the source localization procedure. Exemplary application examples will show the complete processing chain from measurements and image acquisition to localization results.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**
The module grade is calculated from the result of the final examination.

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• Master of Science in Microsystems Engineering, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
<tr>
<td>• Master of Science in Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.</td>
</tr>
</tbody>
</table>
**Modul / Module**

### Siliziumbasierte Neurosonden / Silicon-based Neural Technology

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5116</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Paul</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Materials</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
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<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>3</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Nur im Wintersemester</td>
</tr>
</tbody>
</table>

| Arbeitsaufwand: Workload | 90 hours (32 hours Full-time attendance course of study + 58 hours Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - MEMS Processing
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - MEMS Processing
  - Personal Profile

### Lernziele / Learning target

Students are offered a detailed overview of silicon-based probe arrays applied in fundamental neuroscientific research. They learn how these probes can be combined with specific materials to cover a broad range of needed functionalities. The students get familiarized with the basic requirements in view of system layout and function. They learn the fabrication technologies used to realize probes and systems.

### Inhalte Vorlesung / Content of the lecture

- Introduction – Basic requirements of the field of neuroscience
- Electrical probes
• Fluidic probes
• Optical probes
• Chemotrodes
• IC technologies for signal amplification and data processing
• Assembly technologies

In order to be admitted to the final module exam regular attendance in the lecture is required. The presence in the lecture is monitored by an attendance list.

**Zu erbringende Prüfungsleistung / Examination result**

Written or oral examination

**Zu erbringende Studienleistung / Course achievement**

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

recent conference and journal contributions
**Modul / Module**

**Spektroskopische Methoden / Spectroscopic Methods**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5717</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Wöllenstein</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Dünnschicht-Gassensorik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachsemester:: Recommended term of study**

<table>
<thead>
<tr>
<th>2</th>
</tr>
</thead>
</table>

**ECTS-Punkte: ECTS-points**

<table>
<thead>
<tr>
<th>3</th>
</tr>
</thead>
</table>

**SWS: Semester week hours**

| 2 Lecture |

**Angebotsfrequenz: Regular cycle**

| Only in the summer term |

**Arbeitsaufwand: Workload**

| 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile

- Master of Science in Informatik
  - Application area Mikrosystemtechnik

- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile

- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile

**Lernziele / Learning target**


**Inhalte Vorlesung / Content of the lecture**

Spektroskopische Anwendungen finden sich einer Vielzahl von Industrien, der Anwendungsorientierten- und Grundlagenforschung. In der Lecture wird ein Verständnis der physikalischen Grundlagen der verschiedenen Spektroskopietechniken und häufig
Verwendeten Komponenten vermittelt. Der Stand der Technik der verschiedenen Systeme wird vorgestellt.

**Zu erbringende Prüfungsleistung** / *Examination result*

- written or oral examination

**Bewertung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung** / *Weight of examination result*

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Begleitend zur Vorlesung werden die verwendeten Folien zur Verfügung gestellt.
Modul / Module

Systemtheorie und Regelungstechnik II / Systems theory and automatic control II

Modulnummer: 11LE50MO-5234

Modulverantwortlicher: Prof. Dr. M. Diehl

Organisation: Chair Systemtheorie

Modultyp: Elective Module

Modul dauert: 1 term

Zugehörige Lehrveranstaltungen: Lecture and exercises

Sprache: English

Empfohlenes Fachsemester: 3

ECTS-Punkte: 5

SWS: 2 lecture + 1 exercises

Angebotsfrequenz: Only in the winter term

Arbeitsaufwand: 150 hours (48 Hours Full-time attendance course of study + 102 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Design and simulation
  - Personal Profile

Lernziele / Learning target

Students understand important structures used in practice and can independently apply the acquired knowledge. In addition, they master fundamental methods to describe, analyse and control discrete-time systems and multivariable systems. Furthermore, students can design model-based controllers and understand important concepts of nonlinear control.

Inhalte Vorlesung / Content of the lecture
Based on the Bachelor module "Systemtheorie und Regelungstechnik", advanced methods are discussed to describe, analyze, and control dynamic systems. The course consists of four parts:

The first part focuses on linear single-input single-output (SISO) systems. The methods derived in "systems theory and automatic control I" for continuous-time systems are transferred to discrete-time systems. In particular, the structure of a digital control systems using a analog-to-digital and digital-to-analog converter are discussed. Furthermore, methods to characterize discrete-time systems are introduced such as difference equations, z-transformation, and z-transfer function. The bilinear transformation is introduced in context of controller design.

In the second part, different control structures and design methods for linear SISO systems are discussed which go beyond the standard control loop presented in the course "systems theory and automatic control I". Concepts for feedforward control and disturbance rejection are presented and the basic structure of a cascade controller is discussed. In addition, the internal model controller, the compensation controller and the Smith predictor are treated.

In the third part of the lecture, linear multi-input multi-output (MIMO) systems are treated. The Kalman decomposition is introduced in state space as an important principle to describe the observability and controllability of a MIMO system. Controller design for directly observable systems using pole placement and LQR (Linear Quadratic Regulator) are discussed. Addressing not directly observable systems, the Luenberger observer and the Kalman filter are introduced for state estimation.

The fourth part of the lecture provides an introduction to the control of nonlinear systems. In particular, the concept of Lyapunov stability is treated and used to characterize non-linear systems.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benoitung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
Literatur / Literature

- Lunze, J.: Regelungstechnik 1 - Systemtheoretische Grundlagen, Analyse und Entwurf einschleifiger Regelungen, Springer
- Unbehauen, H.: Regelungstechnik I - Klassische Verfahren zur Analyse und Synthese linearer kontinuierlicher Regelsysteme, Fuzzy-Regelsysteme, Vieweg + Teubner Verlag
- Unbehauen, H.: Regelungstechnik II - Zustandsregelungen, digitale und nichtlineare Regelsysteme, Vieweg + Teubner Verlag
- Föllinger, O.: Regelungstechnik: Einführung in die Methoden und ihre Anwendung, Hüthig Verlag
Modul / Module

Technologien der Implantatfertigung / Implant Manufacturing Technologies

Nummer: Number 11LE50MO-5313

Modulverantwortlicher: Responsible person Prof. Dr. T. Stieglitz

Einrichtung: Organisational unit Chair Biomedical Microtechnology

Modultyp: Module Type Elective Module

Moduldauer: Module duration 1 term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises

Sprache: Language english

Empfohlenes Fachsemester:: Recommended term of study 3

ECTS-Punkte: ECTS-points 3

SWS: Semester week hours 2 lecture + 1 exercises

Angebotsfrequenz: Regular cycle Only in the winter term

Arbeitsaufwand: Workload 90 hours (42 Hours Full-time attendance course of study + 48 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  o Personal Profile
- Master of Science in Informatik
  o Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  o Life Sciences; Biomedical Engineering
  o Personal Profile
- Master of Science in Microsystems Engineering
  o Life Sciences; Biomedical Engineering
  o Personal Profile

Lernziele / Learning target

Learning target and scientific objective of the module is to impart the physical and technological basics to design, develop and manufacture active implantable medical devices including basic structures and elements as well as methods and processes. The lecture lays the theoretical engineering basis to understand function and failure modes in active implantable medical devices. It teaches the students the different fundamental processes with which complex implants can be realised. The accompanying exercise complements the theoretical knowledge and adds practical aspects and guides the students to independently apply the acquired knowledge

Inhalte Vorlesung / Content of the lecture
The lecture "implant manufacturing technologies" teaches knowledge and methods to develop electrically active medical devices, e.g. cardiac pacemakers and cochlea implants. Materials, components, systems, legal requirements are covered in the lecture. Clinically established neural implants as well as latest research applications will be presented and discussed. The following topics will be covered within this course:

- Overview of active implants and neural prostheses in clinical application and research
- Definition and classification of electrical active implants
- Biocompatibility (definition and tests) and Biostability (corrosion and degradation)
- Electrodes
- Concepts of active implants (components, interfaces)
- Silicone rubber as material for encapsulation
- Materials for hermetic packages
- Assembling and packaging technologies
- Legal Requirements (risk management, FMEA, clean rooms, documentation)
- Thin-film technology and implant manufacturing
- Manufacturing of an implant on the example of a BION

The learning targets will be summarized and discussed with the students at the end of every lecture and at the end of the course to facilitate preparation of the exams.

**Inhalte Übung / Content of the exercises**

The exercises are considered passed if 50% of maximum points will be achieved from the tests that are written in the exercises with prior notice.

**Zu erbringende Prüfungsleistung / Examination result**

- Written or oral examination
- Graded exercises/practical exercises

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

**Benotung / Grading**

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the
calculation of the overall grade.
### Modul / Module

#### Technologien der Implantatfertigung – Laboratory / Implant Manufacturing Technologies - Laboratory

<table>
<thead>
<tr>
<th>Number</th>
<th>11LE50MO-5314</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. T. Stieglitz</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer</td>
<td>1 term</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Chair Biomedical Microtechnology</td>
</tr>
<tr>
<td>Sprache:</td>
<td>english</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen:</td>
<td>Laboratory</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen:</td>
<td>Mandatory preconditions</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen:</td>
<td>High school education in mathematics and natural sciences</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:</td>
<td>2</td>
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<tr>
<td>ECTS-Punkte:</td>
<td>3</td>
</tr>
<tr>
<td>SWS:</td>
<td>4 Laboratory</td>
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<tr>
<td>Arbeitsaufwand:</td>
<td>90 hours (56 hours Full-time attendance course of study + 34 Hours Self-study)</td>
</tr>
</tbody>
</table>

#### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Life Sciences: Biomedical Engineering
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Life Sciences: Biomedical Engineering
  - Personal Profile

#### Lernziele / Learning target

Objective of the module is the consolidation of the knowledge and the acquisition of skills to manufacture implants on the background of the theoretical knowledge gathered in the preceding lecture.

The module teaches the students the application and combination of different technological
processes to manufacture electrical active implantable devices under clean room conditions.

**Inhalte Praktikum / Content of the laboratory**

In the course of the practical exercises, the students re-build the first generation of a neuroprosthetic device, a cochlear implant. Groups with a maximum of three persons manufacture the implant in structured learning units on their own under supervision at different manufacturing setups. The learning units include:

- Laser marking and cutting
- Screen printing
- Hybrid implant assembly
- Design of printed circuit boards
- Development and etching of printed circuit boards
- Cleansing and cleaning of substrates
- Silicone encapsulation or electronic circuits
- Packaging and sterilization
- Technical implant function test

**Zu erbringende Prüfungsleistung / Examination result**

Written examination prior to every experiment

**Bewertung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Teststrukturen und Methoden für ICs and MEMS / Test Structures and Methods for ICs and MEMS

<table>
<thead>
<tr>
<th>Nummer / Number</th>
<th>11LE50MO-5110</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher / Responsible person</td>
<td>Prof. Dr. O. Paul</td>
</tr>
<tr>
<td>Einrichtung / Organisational unit</td>
<td>Chair Materialien</td>
</tr>
<tr>
<td>Modultyp / Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulüauer / Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen / Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache / Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen / Recommended preconditions</td>
<td>MEMS and IC Processing, Semiconductor Physics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester / Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte / ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS / Semester week hours</td>
<td>2 lecture + 1 exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz / Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand / Workload</td>
<td>180 hours (48 Hours Full-time attendance course of study + 132 Hours Self-study)</td>
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</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

### Lernziele / Learning target

The aim of this module is to introduce the most relevant material properties, i.e., electrical, mechanical, thermal and magnetic, for materials used in MEMS to realize sensors and actuators and the respective characterization methods to extract these material properties. This theoretical part of the lecture is accomplished with a lab class where the students have to extract material properties by themselves and a seminar section, where actual publications in the field of test structures are presented by the students in 20-minute-talks.
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Content</th>
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<td>1.</td>
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<td>Purpose of lecture</td>
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<td>1.2</td>
<td>Examples and background</td>
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<td>1.3</td>
<td>Organization</td>
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<tr>
<td>1.4</td>
<td>References</td>
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<td>2.</td>
<td>Geometry</td>
</tr>
<tr>
<td>2.1</td>
<td>Film thickness</td>
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<td>2.2</td>
<td>Lateral dimensions</td>
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<td>3.</td>
<td>Mechanical properties</td>
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<tr>
<td>3.1</td>
<td>Fundamentals</td>
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<tr>
<td>3.2</td>
<td>Test methods</td>
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<tr>
<td>4.</td>
<td>Magnetic properties</td>
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<tr>
<td>4.1</td>
<td>Fundamentals</td>
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<tr>
<td>4.2</td>
<td>Test methods</td>
</tr>
<tr>
<td>5.</td>
<td>Electrical properties</td>
</tr>
<tr>
<td>5.1</td>
<td>Fundamentals</td>
</tr>
<tr>
<td>5.2</td>
<td>Test methods</td>
</tr>
<tr>
<td>6.</td>
<td>Thermal properties</td>
</tr>
<tr>
<td>6.1</td>
<td>Fundamentals</td>
</tr>
<tr>
<td>6.2</td>
<td>Test methods</td>
</tr>
<tr>
<td>7.</td>
<td>Coupled domains properties</td>
</tr>
<tr>
<td>7.1</td>
<td>Magnetic-, mechanical-, thermal-, chemical- and radiative-magnetic</td>
</tr>
<tr>
<td>7.2</td>
<td>Electrical-, mechanical-, thermal-, chemical- and radiative-mechanical</td>
</tr>
<tr>
<td>7.3</td>
<td>Electrical-, magnetic-, thermal-, chemical- and radiative-thermal</td>
</tr>
<tr>
<td>7.4</td>
<td>Electrical-, magnetic-, mechanical-, thermal- and radiative-chemical</td>
</tr>
<tr>
<td>7.5</td>
<td>Electrical-, magnetic-, mechanical-, thermal- and chemical-electrical</td>
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<td>8.</td>
<td>Laboratory courses</td>
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<tr>
<td>8.1</td>
<td>Electrical properties</td>
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<td>Mechanical properties</td>
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<td>8.3</td>
<td>Thermal properties</td>
</tr>
<tr>
<td>9.</td>
<td>Seminar presentations</td>
</tr>
</tbody>
</table>
### Inhalte Übung / Content of the exercises

The successful completion of the exercise part of the course necessitates the preparation and delivery of a 20-minute seminar talk. Success is achieved when the talk is rated with a grade of 4 or better. The preparation of the talks by the students allows them to deal in depth with novel scientific findings in the area of the lecture. These findings have to be cast into a form that is both concise and understandable for the other participants. The person responsible for the lecture will assign topics in line with the content of the lecture.

### Zu erbringende Prüfungsleistung / Examination result

- Written or oral examination
- Graded exercises/practical exercises

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Benotung / Grading

The final module grade is calculated from the exercise grade (1/3) plus the grade from the written or oral final exam (2/3).

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

# Modul / Module

## Thermoelektrik / Thermoelectric

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5715</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Wöllenstein</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Dünnschicht-Gassensorik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge physics, electrical engineering, microsystem technology and sensor technology</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Sensors and actuators
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Sensors and actuators
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Sensors and actuators
  - Personal Profile

## Lernziele / Learning target

Inhalte Vorlesung / Content of the lecture


Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- Master of Science in Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

Begleitend zur Lecture werden die verwendeten Folien zur Verfügung gestellt.
Modul / Module

Verbindungshalbleiter / Compound semiconductor devices

Nummer: Number
11LE50MO-5111

Modulverantwortlicher: Responsible person
Prof. Dr. O. Ambacher

Einrichtung: Organisational unit
Chair Verbindungshalbleiter Mikrosysteme

Modultyp: Module Type
Elective Module

Modulverantwortlicher: Responsible person
Prof. Dr. O. Ambacher

Einrichtung: Organisational unit
Chair Verbindungshalbleiter Mikrosysteme

Modultyp: Module Type
Elective Module

Modulverantwortlicher: Responsible person
Prof. Dr. O. Ambacher

Einrichtung: Organisational unit
Chair Verbindungshalbleiter Mikrosysteme

Zugehörige Lehrveranstaltungen: Connected events
Lecture

Sprache: Language
German

Empfohlenes Fachsemester:: Recommended term of study
3

ECTS-Punkte: ECTS-points
3

SWS: Semester week hours
2 Lecture

Angebotsfrequenz: Regular cycle
Only in the winter term

Arbeitsaufwand: Workload
90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

Lernziele / Learning target

### Inhalte Vorlesung / Content of the lecture

Spannende und neue physikalische Eigenschaften ergeben sich aus den immer kleiner werdenden Abmessungen von mechanischen, elektrischen und optischen Bauelementen aus Verbindungshalbleitern (GaN, GaAs, InP). In einer Einführung in die Welt der Verbindungshalbleiter-Mikrosysteme wird die Physik sowie die Technologie zur Herstellung von kleinsten Leuchtdioden und Lasern, mikromechanischen Filtern und Resonatoren sowie kleinsten Sensoren zur Analyse biologischer Prozesse vorgestellt. Neuartige Bauelemente aus Verbindungshalbleitern werden in ihrer Funktionsweise erläutert und ihre Relevanz für unser tägliches Leben dargestellt.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikroystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Rainer Waser (Ed.) Nanoelectronics and Information Technology, Wiley-VCH Verlag GmbH & Co, 2003
## Modul / Module

### Von Mikrosystemen zur Nanowelt / From Microsystems to the Nanoworld

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5101</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. J. Rühe</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Chemie und Physik von Grenzflächen</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauper Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Lecture</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

- Elective Module for students of the study program
  - Bachelor of Science in Embedded Systems Engineering
  - Master of Science in Embedded Systems Engineering
    - Personal Profile
  - Master of Science in Informatik
    - Application area Mikrosystemtechnik
  - Master of Science in Mikrosystemtechnik
    - Materials
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Materials
    - Personal Profile

### Lernziele / Learning target

This module describes the issues encountered at the transition from the world of Microsystems to the nanoworld. It aims at an understanding of the principle concepts for both worlds and describes current trends and problems in the field. It is also attempted to give an outlook for future research within the boundaries of physics.
Inhalte Vorlesung / Content of the lecture

<table>
<thead>
<tr>
<th>1. INTRODUCTION</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>2. FOUNDATIONS</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3. PROBLEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>From Micro to Nano: what’s different. Physical and societal limits of nano engineering.</td>
</tr>
</tbody>
</table>

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
# Wellenoptik / Wave optics

<table>
<thead>
<tr>
<th>Modul / Module</th>
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<td>Wellenoptik / Wave optics</td>
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<tr>
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<td>Prof. Dr. A. Rohrbach</td>
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<td>Einrichtung: Organisational unit</td>
<td>Chair Bio- und Nano-Photonik</td>
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<td>Moduldauer Module duration</td>
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</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
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</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester:: Recommended term of study</th>
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<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
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<tr>
<td>SWS: Semester week hours</td>
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<td>Angebotsfrequenz: Regular cycle</td>
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<td>Arbeitsaufwand: Workload</td>
<td>180 hours (70 Hours Full-time attendance course of study + 110 Hours Self-study)</td>
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## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Physik
- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Photonics
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Photonics
  - Personal Profile
- Master of Science in Physik

## Lernziele / Learning target

Goal of this module is to teach the student how light interacts with small structures and how optical systems guide light. The students will start at Maxwell's equations and move on to the description of light as photon or wave, depending on the given problem. Furthermore, the close connection between spatial and temporal coherence, interference and holography is demonstrated. The last chapter teaches concepts of linear and non-linear light scattering, as well as the most important plasmonic effects. In total, the students learn how to shape light in three dimensions and how optical problems that arise in research and development are solved.
We do not really know what light is, although the concepts to describe light as waves or as particles usually work well. It is a nontrivial task to explain the colorful intensity distributions we see every day, i.e. the interactions of light with matter. Controlling light on the macroscale and the nanoscale is the key for generating impact in research, development and industry. However, this requires a thorough understanding of wave optics and its powerful theoretical instrument, the description by Fourier transforms.

This english lecture is accompanied by many live experiments and by weekly tutorials, where exercises are discussed that students have to calculate from one week to the next. The new lecture is a fusion of the two former lectures “Moderne Optik I & II” and is now organized in 6 chapters.

1. Introduction
   Some motivation, literature and a bit of history

2. From Electromagnetic Theory to Optics
   What is light? Which illustrative pictures do the Maxwell equations provide? If matter, dielectric and metallic, consists of coupled, damped springs (harmonic oscillators), how does matter depend on the frequency of light? What do the wave equation and the Helmholtz equation express and how can one handle waves in position space and frequency space.

3. Fourier-Optics
   How does a wave transforms position information into directional information? Why can this be well described by Fourier transformations in 1D, 2D and 3D? What has this to do with linear optical system theory including spatial frequency filters and the sampling theorem?

4. Wave-optical Light Propagation and Diffraction
   Different methods are introduced of how to describe the propagation of ways in position space and frequency space. We do the direct transfer from propagation to diffraction of light and momentum space. We treat evanescent waves, thin diffracted objects, the propagation of light in inhomogeneous media and the diffraction at gratings. This allows to discuss important active elements such as acousto-optic and spatial light modulators. We end with adaptive optics and phase conjugation.

5. Interference, Coherence and Holography
   We learn how a composition of k-vectors define the phases of interfering waves and the resulting stripe patterns. The relative phases of each partial wave in space and time change the interference significantly and define the coherence of light - these concepts will be discussed in detail. We learn how to write and read phase information in holography.

6. Light Scattering and Plasmonics
   The interaction of light with matter is based on particle scattering: we discuss the theoretical concepts of light scattering on the background of Fourier theory. We expend these approaches to photon diffusion, nonlinear optics, fluorescence and Raman scattering or scattering at semiconductor quantum dots - which are all hot topics in modern Photonics. A big emphasis is put on the description of surface plasmons and particle plasmons, where light can be extremely confined.

1. Introduction
   1.1. Motivation
   1.2. Literatur
   1.3. A bit of history
2. From Electromagnetic Theory to Optics
2.1. What is Light?
2.2. The Maxwell-equations
2.3. The change of Light in Matter
2.4. Wave equation and Helmholtz equation
2.5. Waves in position space and frequency space
3. Fourier-Optics
3.1. Introduction
3.2. The Fourier-Transformation
3.3. Linear Optical Systems
3.4. Spatial frequency filters
3.5. The Sampling Theorem
4. Wave-optical Light Propagation and Diffraction
4.1. Paraxial light propagation by Gaussian beams
4.2. Wave Propagation and Diffraction
4.3. Evanescent waves
4.4. Diffraction at thin Phase and Amplitude Objects
4.5. Light Propagation in inhomogeneous Media
4.6. Diffraction at gratings
4.7. Acousto Optics
4.8. Spatial Light Modulators
4.9. Adaptive Optics and Phase Conjugation
5. Interference, coherence and holography
5.1. Some Basics
5.2. Interferometry
5.3. Foundations of Coherence Theory
5.4. Principles of Holography
6. Light Scattering and Plasmonics
6.1. Scattering of light at particles
6.2. Photon Diffusion
6.3. Basics of Nonlinear Optics
6.4. Fluorescence und Raman-scattering
6.5. Fluorescing quantum dots
6.6. Surface Plasmons and Particle Plasmons
75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

Inhalte Übung / Content of the exercises

The tutorials help the students to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors. 75% attendance in the lecture and tutorials (Note: The attendance is checked before every event)

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written
exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the lecture and the exercises and at the beginning of each class.

**Bemutung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.
# Werkstoffdynamik / Dynamics of Materials

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<tr>
<th>Nummer: Number</th>
<th>11LE50MO-5118</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. S Hiermaier</td>
</tr>
<tr>
<td>Modul Typ: Module Type</td>
<td>Elective module</td>
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<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. S Hiermaier</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
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<td>Zugehörige Lehrveranstaltungen: Connected events</td>
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<td>Englisch</td>
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<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
<th>3</th>
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<tr>
<td>ECTS-Punkte: ECTS-points</td>
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<td>SWS: Semester week hours</td>
<td>2 Lecture + 2 Lecture</td>
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<td>Angebotsfrequenz: Regular cycle</td>
<td>Only in winter term</td>
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<td>Arbeitsaufwand: Workload</td>
<td>150 hours (64 hours Full-time attendance course of study + 86 hours Self-study)</td>
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**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Informatik
  - Application Field Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Materials
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Materials
  - Personal Profile

**Lernziele / Learning target**

Aim of the module is the knowledge of experimental and numerical basics on the mechanical behavior of materials under dynamic loading conditions. It enables the students in deriving strain-rate dependent stress-strain relations and in implementing the resulting constitutive models into numerical codes. General aim is the basic ability for experimental characterization and numerical modeling of dynamic material behavior.
### Inhalte Vorlesung / Content of the lecture

**Material Characterization:**
- Static versus dynamic material testing
- Strain-rate as measure for dynamics in materials
- Wave propagation as means of material testing
- Strain-rate-dependent elasticity, plasticity and failure
- Constitutive strain-rate dependent models
- Mathematical models for code implementation
- Shock-waves in solids
- Equations of State as component of the stress tensor
- Nonlinear Equations of State

**Numerics of Dynamic Deformation Processes:**
- Spatial and Time Discretization of dynamic deformation on solids
- Finite differences for space and time
- Finit Element Basics
- Implicit and explicit time integration
- Mesh-free Discretization

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
### Literatur / Literature

- Zusätzlich wird ein Skript zur Verfügung gestellt.
Zuverlässigkeitslehre / Reliability Engineering

Nummer: 11LE50MO-5214

Modulverantwortlicher: Prof. Dr. J. Wilde
Einrichtung: Chair Aufbau- und Verbindungstechnik

Modultyp: Elective Module
Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture and exercises

Sprache: English

Empfohlene Voraussetzungen: Basic understanding in mathematics (statistics) as well as materials sciences

Empfohlenes Fachsemester: 5
ECTS-Punkte: 3

SWS: 1 Lecture + 1 Übung
Angebotsfrequenz: Only in the winter term

Arbeitsaufwand: 90 hours (32 Hours Full-time attendance course of study + 58 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Master of Science in Embedded Systems Engineering
  - Circuits and systems
  - Personal Profile
- Master of Science in Informatik
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and systems
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and systems
  - Personal Profile

Lernziele / Learning target

It is the aim, that after this module, the student will know:
- The student will have elementary capabilities to solve praxis-relevant.
- He/she will know how experiments can be replaced by simulation and what the necessary input data are.
- He/she will be able to evaluate Microsystems and more complex electronic and mechatronic systems including software.
- Furthermore it is expected that the student will have improved capabilities in the risk
analysis of hazardous applications. 
- Also the students be able to report the corresponding results.

Inhalte Vorlesung / Content of the lecture

1. Definitions
   - 1.1 Quality, dependability, reliability and safety
   - 1.2 Benchmarks for dependability, availability und lifetime
   - 1.3 Statistical description of reliability
2. Dependability of mechanical systems
   - 2.1 Example 1: The ICE-crash at Eschede
   - 2.2 Loads on mechanical components
   - 2.3 Risk factors: notches and cracks
   - 2.4 Fatigue - Woehler’s S-N-curve concept
   - 2.5 Computation of operational strength
3. Reliability of electronic hardware
   - 3.1 Automotive electronics: architecture, requirements and quality level
   - 3.2 Reliability of electronic devices, data
4. Reliability data-bases
5. Reliability of systems
   - 5.1 Reliability block-diagram (failure-rate analysis)
   - 5.2 Overview of failure mode analyses
   - 5.3 Fault tree analysis (FTA)
   - 5.4 State-Space: A general method to compute Rs(t) and Fs(t)
6. Reliability of repairable systems
   - 6.1 Definitions
   - 6.2 Repair rate
   - 6.3 Availability
   - 6.4 Markov-Chains and Markov-Processes
7. Software reliability
   - 7.1 Examples of software-induced accidents
   - 7.2 Probability of software faults
   - 7.3 Reliability models for software
   - 7.4 Misjudgements concerning software use
8. Human factors
9. Pre-requisites for development processes
10. Standards and legislation for medical devices

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benzung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

Short lecture notes and data files with existing ANSYS macros.
Application Area Physics
In the Application Area "Physics" students have to complete modules with a volume of 18 ECTS.

<table>
<thead>
<tr>
<th>Module / Part Module</th>
<th>Course Achievement</th>
<th>ECTS</th>
</tr>
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<tbody>
<tr>
<td>Theoretische Physik II (Mechanik und Spezielle Relativitätstheorie)</td>
<td>PL</td>
<td>9</td>
</tr>
<tr>
<td>Theoretische Physik III (Elektrodynamik und Spezielle Relativitätstheorie)</td>
<td>PL</td>
<td>9</td>
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</tbody>
</table>

The current module descriptions are not yet available.
Application Area Psychology

In the Application Area "Psychology" students have to complete modules with a volume of 18 ECTS.

<table>
<thead>
<tr>
<th>Module / Part Module</th>
<th>Course Achievement</th>
<th>ECTS</th>
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</thead>
<tbody>
<tr>
<td>Sozialpsychologie</td>
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<td>Pädagogische Psychologie</td>
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<tr>
<td>- Vorlesung</td>
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<td>- Seminar</td>
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<tr>
<td>Arbeits- und Organisationspsychologie</td>
<td>PL</td>
<td>5</td>
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</tbody>
</table>

The current module descriptions are not yet available.
Application Area Economics – Business Management

In the Application Area "Economics – Business Management" students have to complete modules with a volume of 18 ECTS. The students have to select Modules with a total amount of 18 ECTS-points out of a huge variety of modules from the Department of Economics.

The current module descriptions are not yet available.
Application Area Economics – Political Economy
In the Application Area "Economics – Political Economy" students have to complete modules with a volume of 18 ECTS. The students have to select Modules with a total amount of 18 ECTS-points out of a huge variety of modules from the Department of Economics.

The current module descriptions are not yet available.
Interdisciplinary Project

Students in the Master's program of Computer Science need to complete 18 credit points in an elective module. Alternatively, students can do an ‘interdisciplinary project’ in order to complete the area of the elective module. As part of the interdisciplinary project students need to visit a lecture and complete an exam in the area of the project.
Specialization Area

The elective part is divided in the Application Area and the Specialization Area.

In Specialization in Computer Science (Specialization modules) students have to complete Specialization Modules and Seminars with a total volume of 32 ECTS. The Specialization Modules and Seminars are offered in 3 different specialization areas:

- Cyber-Physical Systems
- Informationssysteme / Information Systems
- Kognitive technische Systeme / Kognitive Technical Systems

Students have to select 1 area.

Students have to complete 2 Seminars. Minimum 1 Seminar must be part of the selected specialization area.

Specialization Area – Cyber-Physical Systems

In the specialization area "Cyber-Physical Systems" 3 different specialization modules are offered:

- Cyber-Physical Systems - Specialization in Computer Science I
- Cyber-Physical Systems - Specialization in Computer Science II
- Cyber-Physical Systems - Specialization in Computer Science III

Students have to complete 2 modules with a volume of 24 ECTS.

In addition, the students have to complete 2 Seminars. Minimum 1 Seminar must be part of the specialization area "Cyber-Physical Systems".

<table>
<thead>
<tr>
<th>Modul / Module</th>
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<tr>
<td>Cyber-PhysicalSystems - Seminar</td>
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<table>
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<th>11LE13MO-1201</th>
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<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Becker, Prof. Dr. A. Podelski</td>
</tr>
<tr>
<td></td>
<td>Prof. Dr. C. Scholl, Prof. Dr. T. Thiemann</td>
</tr>
<tr>
<td></td>
<td>Prof. Dr. K. van Laerhoven</td>
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<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Rechnerarchitektur,</td>
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<td>Chair Softwaretechnik,</td>
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<td>Chair Betriebssysteme,</td>
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<td>Chair Programmiersprachen,</td>
</tr>
<tr>
<td></td>
<td>Chair Embedded Systems Engineering</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldaauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German or English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Programming skills, knowledge in algorithms and data structures and operations systems</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>4</td>
</tr>
</tbody>
</table>
### Study

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
<th>2 Seminar</th>
<th>Angebotsfrequenz: Regular cycle</th>
<th>Each term</th>
</tr>
</thead>
</table>

### Workload

<table>
<thead>
<tr>
<th>Arbeitsaufwand: Workload</th>
<th>120 hours (28 or 32 hours Full-time attendance course of study + 92 oder 88 hours self-study)</th>
</tr>
</thead>
</table>

### Usability of the Module

Elective Module for students of the study program
- Master of Science in Informatik
<table>
<thead>
<tr>
<th>Lernziele / Learning target</th>
</tr>
</thead>
<tbody>
<tr>
<td>A seminar gives students the opportunity to get acquainted with a specific topic in Cyber-Physical Systems. They shall learn to independently search for scientific literature and to structure the same. Furthermore they will learn to write short scientific texts and present the results to a group. Concerning scientific writing they will learn the rules for good scientific practice.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inhalte Seminar / Content of the seminar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special topics from the selected workspace</td>
</tr>
<tr>
<td>Overall Topics: proper citation, references, documentation of results, avoids misconduct (plagiarism, misrepresentation, etc.)</td>
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</table>

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>The coursework consists of a seminar paper and an oral presentation. In general, the active and regular participation in the course is requested.</td>
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<table>
<thead>
<tr>
<th>Benotung / Grading</th>
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</thead>
<tbody>
<tr>
<td>Academic performance, which can be graded but usually is evaluated with pass or fail.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Master of Science in Computer Science, Academic regulations of 2012: Academic performance which can be graded but is not taken into account in the final grade.</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
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<tbody>
<tr>
<td>Will be announced at the beginning of the course.</td>
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## Information Systems - Seminar

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>Number</th>
<th>11LE13MO-1301</th>
<th>11LE13MO-1302</th>
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</table>

<table>
<thead>
<tr>
<th>Modulverantwortlicher:</th>
<th>Responsible person</th>
<th>Prof. Dr. M. Müller, Prof. Dr. H. Bast, Prof. Dr. F. Kuhn, Prof. Dr. R. Backofen, Prof. Dr. G. Lausen, Prof. Dr. G. Schneider, Prof. Dr. C. Schindelhauer, Prof. Dr. P. Fischer</th>
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<table>
<thead>
<tr>
<th>Einrichtung:</th>
<th>Organisational unit</th>
<th>Institut für Informatik und Gesellschaft, Chair Algorithmen und Datenstrukturen, Chair Algorithmen und Komplexität, Chair Bioinformatik, Chair Datenbanken, Chair Kommunikationssysteme, Chair Rechnernetze und Telematik, Chair Web Science</th>
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<table>
<thead>
<tr>
<th>Modultyp:</th>
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<th>Elective Module</th>
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<table>
<thead>
<tr>
<th>Moduldauer</th>
<th>Module duration</th>
<th>1 Term</th>
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</table>

<table>
<thead>
<tr>
<th>Zugehörige Lehrveranstaltungen:</th>
<th>Connected events</th>
<th>Seminar</th>
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<table>
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<tr>
<th>Sprache:</th>
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<table>
<thead>
<tr>
<th>Empfohlene Voraussetzungen:</th>
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</table>

<table>
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<th>Programming skills, knowledge in algorithms and data structures and operations systems</th>
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<tr>
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<table>
<thead>
<tr>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
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<tr>
<th>SWS:</th>
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<thead>
<tr>
<th>2</th>
<th>Angebotsfrequenz: Regular cycle</th>
<th>Each term</th>
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<table>
<thead>
<tr>
<th>Arbeitsaufwand:</th>
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### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Informatik

### Lernziele / Learning target

A seminar gives students the opportunity to get acquainted with a specific topic in Cyber-Physical Systems. They shall learn to independently search for scientific literature and to structure the same. Furthermore they will learn to write short scientific texts and present the results to a group. Concerning scientific writing they will learn the rules for good scientific practice.
### Inhalte Seminar / Content of the seminar

Special topics from the selected workspace  
Overall Topics: proper citation, references, documentation of results, avoids misconduct (plagiarism, misrepresentation, etc.)

### Zu erbringende Studienleistung / Course Achievement

The coursework consists of a seminar paper and an oral presentation. In general, the active and regular participation in the course is requested.

### Benotung / Grading

Academic performance, which can be graded but usually is evaluated with pass or fail.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Computer Science, Academic regulations of 2012: Academic performance which can be graded but is not taken into account in the final grade.

### Literatur / Literature

Will be announced at the beginning of the course.
### Kognitive Technical Systems - Seminar

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1101 11LE13MO-1102</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. W. Burgard, Prof. Dr. M. Teschner, N.N., Prof. Dr. T. Brox, PD Dr. Hutter</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Autonome Intelligente Systeme, Lehrstuhl Graphische Datenverarbeitung, Chair Maschinelles Lernen, Chair Mustererkennung und Bildverarbeitung, Arbeitsgruppe Automatisches Algorithmdesign</td>
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### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Informatik

### Lernziele / Learning target

A seminar gives students the opportunity to get acquainted with a specific topic in Cyber-Physical Systems. They shall learn to independently search for scientific literature and to structure the same. Furthermore they will learn to write short scientific texts and present the results to a group. Concerning scientific writing they will learn the rules for good scientific practice.
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<td>Will be announced at the beginning of the course.</td>
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</tbody>
</table>
Compilerbau / Compiler Construction

**Nummer:** 11LE13MO-1208

**Modulverantwortlicher:** Prof. Dr. P. Thiemann  
**Einrichtung:** Chair  
**Modultyp:** Elective Module  
**Zugehörige Lehrveranstaltungen:** Lecture and exercises  
**Sprache:** English

**Empfohlene Voraussetzungen:** Knowledge in  
- Algorithms and Data Structures  
- Theoretical Computer Science and Programming Skills in Java

**Empfohlenes Fachterm:** 2  
**ECTS-Punkte:** 6

**SWS:** 3 Lecture + 1 Exercises  
**Angebotsfrequenz:** only in the summer term

**Arbeitsaufwand:** 180 Hours (56 Full-time attendance course of study + 124 Self-study)

**Verwendbarkeit der Veranstaltung**

Elective Module for students of the study program  
- Bachelor of Science in Embedded Systems Engineering  
- Master of Science in Embedded Systems Engineering  
  - Zuverlässige Eingebettete Systeme  
  - Personal Profile  
- Master of Science in Informatik  
  - Cyber-Physical Systems

**Lernziele**

Students recognize fundamental methods of compiler construction and are able to apply them. They can use tools to implement scanners and parsers; they can implement a compiler for a simple language with some optimizations. They understand abstract representations of intermediate code as well as the idea of staging different processing phases in a compiler and are able to apply this understanding in practical examples.

**Inhalte Vorlesung**

- Syntactic analysis  
- semantic analysis  
- intermediate code  
- code transformation  
- optimization  
- generation of machine code: instruction selection, scheduling, register allocation.
### Zu erbringende Prüfungsleistung / Examination result

- written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

### Literatur / Literature

- Appel: Compiling with Continuations. Cambridge University Press, 1992
- Appel: Modern Compiler Implementation in ML. Cambridge University Press, 1998
- Fraser, Hanson: A Retargetable C Compiler: Design and Implementation. Benjamin/Cummings, 1995
Modulhandbuch M.Sc. Informatik – Computerunterstützte Modellierung / Computer Supported Modeling and Reasoning

**Modul / Module**

**Computerunterstützte Modellierung / Computer Supported Modeling and Reasoning**

<table>
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<tr>
<th>Nummer: Number</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. A. Podelski</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Softwaretechnik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachterm: Recommended term of study</th>
<th>3</th>
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<td>SWS: Term week hours</td>
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<td>Arbeitsaufwand: Workload</td>
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</tr>
<tr>
<td></td>
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</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

**Lernziele / Learning target**

The aim of this module is to show how to use logic as a practical tool. Participants will learn how to use a theorem prover to build mathematical theories and carry out machine-checked proofs. The theories can be about artifacts in computer science like system models and requirements, programs, circuits, and the like.

**Inhalte Vorlesung / Content of the lecture**

This lecture is about using logic for program development and program analysis. Programming languages and desired program properties can both be formalised using logic, for the purpose of verifying the properties using computer support. The lecture is roughly structured in four parts. In part 1, we shall introduce various logic systems including propositional logic, first-order logic, and (naive) set theory. We shall see how proofs in these systems can be conducted both using paper and pencil and using the interactive theorem
prover Isabelle. In part 2, we shall attempt to understand what happens behind the scenes: we shall study meta-logic, which is the general theory allowing us to implement all kinds of logic systems using a single tool. In part 3, we shall see how an important part of mathematics and programming languages can be modeled in this framework, including concepts such as arithmetic, data-types, and recursion. Part 4 will be a case study coming from functional or imperative programming or from the area of specification languages.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

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- 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.

**Literatur / Literature**

D. van Dalen: Logic and Structure. Springer-Verlag, 1980. An introductory textbook on logic
Modul / Module

Concurrency – Theory and Practice

Nummer: Number 11LE13MO-1220

Modulverantwortlicher: Responsible person Prof. Dr. P. Thiemann
Einrichtung: Chair Programmiersprachen

Modultyp: Module Type Elective Module
Moduldauer: Module duration 1 Term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises
Sprache: Language English

Empfohlene Voraussetzungen: Recommended preconditions Knowledge in algorithms and data structures and computer science theory; key course in software engineering

Empfohlenes Fachterm: Recommended term of study 3 ECTS-Punkte: ECTS-points 6

SWS: Term week hours 3 Lecture + 1 Exercises Angebotsfrequenz: Regular cycle only in the winter term
Arbeitsaufwand: Workload 180 Hours (64 Full-time attendance course of study + 116 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  o Zuverlässige Eingebettete Systeme
  o Personal Profile
- Master of Science in Informatik
  o Cyber-Physical Systems

Lernziele / Learning target

- Understanding the problems with programming multiple threads accessing shared memory.
- Understanding today's hardware support for concurrent programming.
- Understanding the key elements of the design of most mainstream concurrent data structures.
- Knowledge of traditional and modern synchronization techniques.
- Ability to apply the above points in practical Java programs.
- Knowledge of declarative approaches to concurrent programming.
Inhalte Vorlesung / Content of the lecture

The lecture provides an extensive introduction into the domain of constraint satisfaction problems. For this purpose both theoretic and algorithmic questions will be examined.

In particular, the following topics are planned:

- Foundations and introduction: sets, relations, graphs, constraint networks and satisfiability, binary constraint networks
- Inference-based methods: arc and path consistency, n-consistency and global consistency
- Search: backtracking, backjumping, comparison of methods, stochastic local search
- Selected advanced topics: expressiveness and complexity of constraint languages, qualitative constraint networks

Inhalte Übung / Content of the exercises

To be admitted to the exam, it is mandatory to submit something for each sheet.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.
Literatur / Literature

**Modul / Module**

**Constraint-Satisfaction-Probleme / Constraint-Satisfaction-Problems**

<table>
<thead>
<tr>
<th><strong>Nummer:</strong> Number</th>
<th>11LE13MO-1119</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
<td>Prof. Dr. B. Nebel</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
<td>Chair Grundlagen der Künstlichen Intelligenz</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
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<td><strong>Sprache:</strong> Language</td>
<td>English</td>
</tr>
<tr>
<td><strong>Empfohlene Voraussetzungen:</strong> Recommended preconditions</td>
<td>Knowledge in Artificial Intelligence</td>
</tr>
</tbody>
</table>

| **Empfohlenes Fachterm:** Recommended term of study | 3 |
| **ECTS-Punkte:** ECTS-points | 6 |
| **SWS:** Term week hours | 3 Lecture + 1 Exercises |
| **Angebotsfrequenz:** Regular cycle | only in the winter term |
| **Arbeitsaufwand:** Workload | 180 Hours (64 Full-time attendance course of study + 116 Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
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- Master of Science in Embedded Systems Engineering
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme
  - Kognitive technische Systeme

**Lernziele / Learning target**

The aim of this module is to deepen the understanding of a broad variety of standard techniques used for solving constraint satisfaction problems. After the course students should be able to implement and evaluate such techniques. Moreover students should then be able to understand current research papers and to start qualifying projects or theses on topics related to the lecture.
### Inhalte Vorlesung / Content of the lecture

The lecture provides an in-depth introduction into the field of constraint satisfaction problems (CSP), one of the major fields in current AI research. In particular, we study the following topics:

- Foundations
- Constraint propagation (arc consistency, path consistency, global consistency)
- Search methods (backtracking, backjumping, local search)
- Constraint optimization problems (COP)
- Expressiveness and computational complexity of constraint languages
- CSP on infinite domains

### Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Dechter, Constraint Processing, Morgan Kaufmann, 2003</td>
</tr>
<tr>
<td>• Rossi, van Beek, Walsh, Handbook of Constraint Programming, Elsevier, 2006</td>
</tr>
</tbody>
</table>

Modul / Module

Cyber-Physikalische Systeme – Diskrete Modelle / Cyber-Physical Systems – Discrete Models

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-2070</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Becker, Prof. Dr. A. Podelski, Prof. Dr. P. Thiemann, Prof. Dr. C. Scholl,</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Rechnerarchitektur, Chair Softwaretechnik, Chair Programmiersprachen, Chair Betriebssysteme</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Rechnerarchitektur / Computer Architecture and Softwaretechnik / Software Engineering</td>
</tr>
<tr>
<td>Empfohlenes Fachterm: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours</td>
</tr>
<tr>
<td>(64 Full-time attendance course of study + 116 Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- 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
- Master of Science in Informatik
  - Cyber-Physical Systems

Lernziele / Learning target

Students understand how cyber-physical systems, in the wide range of their heterogeneous aspects (large-scale systems, system of systems, embedded systems, concurrent systems, hardware systems, software systems) can be modeled using the basic notion of transition systems. They know relevant formalisms for modeling correctness properties of cyber-physical systems, and they understand how the models can be analyzed using algorithmic methods in order to prove correctness or find errors.
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.
- Moreover, the students learn how to express properties about such systems. The course covers different mechanisms to specify temporal properties including linear time properties and branching time properties such as LTL, CTL, and CTL* properties.
- Finally, the course demonstrates how to develop algorithms for checking whether these properties hold. After presenting algorithms for explicit state systems we introduce symbolic BDD-based algorithms which are able to tackle the well-known “state explosion problem”. In addition, the course covers basic “Bounded Model Checking” (BMC) techniques which restrict the analysis to computation paths up to a certain length and reduce the verification problem to a Boolean Satisfiability problem.
- All necessary foundations for these algorithms such as fixed point theory, data structures like Binary Decision Diagrams (BDDs), and Satisfiability (SAT) solvers are introduced in the course as well.

**Written or oral examination**

The module grade is calculated from the result of the final examination.

- 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.

**Literature**

<table>
<thead>
<tr>
<th><strong>Modul / Module</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cyber-Physikalische Systeme – Hybrid-Modelle / Cyber-Physical Systems – Hybrid Models</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Nummer: Number</strong></th>
<th>11LE13MO-1207</th>
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<tr>
<td><strong>Modulverantwortlicher: Responsible person</strong></td>
<td>Prof. Dr. B. Becker, Prof. Dr. A. Podelski, Prof. Dr. P. Thiemann, Prof. Dr. C. Scholl,</td>
</tr>
<tr>
<td><strong>Einrichtung: Organisational unit</strong></td>
<td>Chair Rechnerarchitektur, Chair Softwaretechnik, Chair Programmiersprachen, Chair Betriebssysteme</td>
</tr>
<tr>
<td><strong>Modultyp: Module Type</strong></td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer Module duration</strong></td>
<td>1 Term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen: Connected events</strong></td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td><strong>Sprache: Language</strong></td>
<td>English</td>
</tr>
<tr>
<td><strong>Empfohlene Voraussetzungen: Recommended preconditions</strong></td>
<td>Knowledge in Rechnerarchitektur / Computer Architecture and Softwaretechnik / Software Engineering</td>
</tr>
<tr>
<td><strong>Empfohlenes Fachterm:: Recommended term of study</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>ECTS-Punkte: ECTS-points</strong></td>
<td>6</td>
</tr>
<tr>
<td><strong>SWS: Term week hours</strong></td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td><strong>Angebotsfrequenz: Regular cycle</strong></td>
<td>only in the summer term</td>
</tr>
<tr>
<td><strong>Arbeitsaufwand: Workload</strong></td>
<td>180 Hours (56 Full-time attendance course of study + 124 Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

**Lernziele / Learning target**

Students understand how cyber-physical systems handling continuous data (e.g. receiving sensor values and controlling actuators) can be modeled based on transition systems. They know relevant formalisms for modeling systems with continuous parameters including time and probabilities, and they understand how the models can be analyzed using algorithmic methods in order to prove correctness or find errors.
### Inhalte Vorlesung / Content of the lecture

The course provides an introduction to the modeling and analysis of hybrid systems, i.e. systems with discrete-continuous behavior, from the viewpoint of computer science.

- Hybrid automata are introduced as a syntactic model for hybrid systems. Corresponding labeled transition systems are used to define their semantics.
- Timed automata, as an important subclass of hybrid automata that extend discrete systems with a notion of time are considered. The branching time temporal logic TCTL is introduced to specify properties of timed automata and corresponding model checking algorithms are developed.
- As a further important subclass – more general than timed automata – we define linear hybrid automata. We show that the reachability problem for linear hybrid automata is in general undecidable, whereas bounded reachability, i.e., reachability within a fixed number of steps, is still decidable and can be efficiently computed. We also consider bounded reachability for general hybrid automata and discuss corresponding solution approaches.
- Finally, the course provides basic knowledge on stochastic systems and corresponding model checking algorithms. To do so, we introduce discrete-time Markov chains (DTMMs) and probabilistic computation tree logic (PCTL).

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.

### Literatur / Literature

# Echtzeitbetriebssysteme und Zuverlässigkeit / Real-time Systems and Reliability

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE13MO-1201</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Becker, Prof. Dr. A. Podelski, Prof. Dr. P. Thiemann, Prof. Dr. C. Scholl,</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Rechnerarchitektur, Chair Softwaretechnik, Chair Programmiersprachen, Chair Betriebssysteme</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Rechnerarchitektur / Computer Architecture and Softwaretechnik / Software Engineering</td>
</tr>
<tr>
<td>Empfohlenes Fachterm:: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours (56 Full-time attendance course of study + 124 Self-study)</td>
</tr>
</tbody>
</table>

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

## Lernziele / Learning target

The students are familiar with basic methods of real-time operating systems. In particular, they know the essential differences between standard operating systems and real-time operating systems for embedded systems both concerning requirements and concerning concepts of realization (especially in the area of scheduling). The students know basic functions of real-time operating systems and have experience with programming of real-time
systems.

**Inhalte Vorlesung / Content of the lecture**

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.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
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- 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.

**Literatur / Literature**

Will be announced at the beginning of the course.
Modul / Module

Echtzeitsysteme / Real-Time Systems

Nummer: Number 11LE13MO-1212

Modulverantwortlicher: Responsible person Prof. Dr. A. Podelski
Einrichtung: Organisational unit Chair Softwaretechnik

Modultyp: Module Type Elective Module
Moduldauer Module duration 1 Term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises
Sprache: Language English

Empfohlene Voraussetzungen: Recommended preconditions Knowledge in Logik für Informatiker

Empfohlenes Fachterm: Recommended term of study 2
ECTS-Punkte: ECTS-points 6

SWS: Term week hours 3 Lecture + 1 Exercises
Angebotsfrequenz: Regular cycle only in the summer term

Arbeitsaufwand: Workload 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

Lernziele / Learning target

- Basic knowledge in the use of formal methods in the development of safety-critical systems with real-time requirements, from requirements gathering, through the description of designs and implementations for (automatic) verification of correctness
- Ability to formalize properties in logic form using the Duration Calculus or in the form of Timed Automata and understand formalization
- Overview of decidability results for real-time models.
### Inhalte Vorlesung / Content of the lecture

The course largely follows the book "Real-Time Systems" by Olderog and Dierks. For the topics Timed Automata and Live Sequence Charts we use the original literature.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.

### Literatur / Literature

Einführung in Embedded Systems / Introduction to Embedded Systems

Module

Nummer: Number
11LE13MO-910

Modulverantwortlicher: Responsible person
Prof. Dr. B. Becker, Prof. Dr. C. Scholl

Einrichtung: Organisational unit
Chair Rechnerarchitektur, Chair Betriebssysteme

Modultyp: Module Type
Elective Module

Moduldauer Module duration
1 Term

Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

Sprache: Language
German

Empfohlene Voraussetzungen: Recommended prerequisites
Knowledge in Technische Informatik

Empfohlenes Fachterm: Recommended term of study
3

ECTS-Punkte: ECTS-points
4 oder 6

SWS: Term week hours
3 Lecture + 1 Exercises

Angebotsfrequenz: Regular cycle
only in the winter term

Arbeitsaufwand: Workload
180 Hours
(64 Full-time attendance course of study + 116 Self-study)
Or
120 Hours
(64 Full-time attendance course of study + 56 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Mandatory Module for students of the study program
• Bachelor of Science in Embedded Systems Engineering

Elective Module for students of the study program
• Lehramt an Gymnasien in Informatik, Hauptfach
• Lehramt an Gymnasien in Informatik, Erweiterungshauptfach
• Lehramt an Gymnasien in Informatik, Hauptfach in Verbindung mit Bildende Kunst und Musik
• Master of Science in Embedded Systems Engineering - Personal Profile
• Master of Science in Informatik - Cyber-Physical Systems

The 4 ECTS Module is only available in the section “Specialization Module III”.

Lernziele / Educational objectives

The students have a basic understanding of the specific properties of embedded systems. They know the elementary design concepts for these systems as well as criteria for the partitioning in hardware or software. They know the component properties of an embedded
system and understand the resulting demands for interfaces as well as for the entire system. They are able to assess the specific restrictions resulting from the physical laws of the surrounding system and can systematically integrate these into the design process. Finally, they are aware how the specific software technology on the one hand and hardware design methods on the other hand can be combined to create a powerful design methodology respecting requirements for dimensions, reaction times, costs and energy consumption of the resulting system.

Inhalte Vorlesung / Content of the lecture

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.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.

Literatur / Literature

# Entscheidungsprozeduren / Decision Procedures

**Number:** 11LE13MO-1209  
**Modulverantwortlicher:** Prof. Dr. A. Podelski  
**Einrichtung:** Chair Softwaretechnik  
**Modultyp:** Elective Module  
**Moduldauer:** 1 Term  
**Zugehörige Lehrveranstaltungen:** Lecture and exercises  
**Sprache:** English  
**Empfohlene Voraussetzungen:** Knowledge in logics  
**Empfohlenes Fachterm:** 2  
**ECTS-Punkte:** 6  
**SWS:** 3 Lecture + 1 Exercises  
**Angebotsfrequenz:** only in the summer term  
**Arbeitsaufwand:** 180 Hours (56 Full-time attendance course of study + 124 Self-study)

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program  
- Bachelor of Science in Embedded Systems Engineering  
- 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  
  - Zuverlässige Eingebettete Systeme  
  - Personal Profile  
- Master of Science in Informatik  
  - Cyber-Physical Systems

## Lernziele / Learning target

The students should know, for which theory fragments satisfiability is decidable. They should learn the most important algorithms that decide satisfiability. They should also be able to use existing tools to prove their formulas or the correctness of their programs.

## Inhalte Vorlesung / Content of the lecture

Decision Procedures are the basis for program verification: The task of program verification is to give a formal proof that a program meets its specification. This amounts to determining the truth value of a logical formula. A decision procedure is an algorithm that can for a certain type of formulas decide whether the formula is true or false. We will investigate
decision procedures for different logics. Starting with propositional logic we will investigate
decision procedures for logics with integers, reals, recursive structures (lists and trees),
arrays, etc.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benoitung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.

Literatur / Literature

Wird zu Beginn der Lehrveranstaltung bekannt gegeben.
### Modul / Module

**Formale Methoden für Java / Formal Methods for Java**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1210</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. A. Podelski</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Softwaretechnik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Programming, Algorithms and Datenstructures, Logics and Softwaretechnik / Software Engineering</td>
</tr>
<tr>
<td>Empfohlenes Fachterm:: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
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<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours (64 Full-time attendance course of study + 116 Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

### Lernziele / Learning target

Die Studierenden sollen einen Überblick über die verschiedenen Arten der Verifikationswerkzeuge besitzen. Sie sollen abschätzen können, was diese Werkzeuge leisten und sie verwenden können, um Programme zu verifizieren. Sie sollen auch in der Lage sein interaktive Theorembeweiser zu verwenden.

### Inhalte Vorlesung / Content of the lecture

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

** Zu erbringende Prüfungsleistung / Examination result **

written or oral examination

** Benotung / Grading **

The module grade is calculated from the result of the final examination.

** Gewichtung der Prüfungsleistung / Weight of examination result **

- 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.
**Modul / Module**

**Funktionale Programmierung / Functional Programming**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1216</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. P. Thiemann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Programmiersprachen</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

Fun and interest in programming and learning and applying new programming concepts and languages. Further recommended:
- Courses "computer science I" and "Mathematics for Computer Scientists II" successfully completed
- own laptop

Prior knowledge of Haskell is not necessary.

| Empfohlenes Fachterm: Recommended term of study | 3 |
| ECTS-Punkte: ECTS-points | 6 |
| SWS: Term week hours | 3 Lecture + 1 Exercises |
| Angebotsfrequenz: Regular cycle | only in the winter term |
| Arbeitsaufwand: Workload | 180 Hours (67 Full-time attendance course of study + 113 Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

**Lernziele / Learning target**

- Develop an alternative, non-procedural view of algorithms and data structures
- Familiarity with the functions and data of higher order
- Knowledge of basic and advanced functional programming techniques
- Independent development of medium-sized functional programs
Inhalte Vorlesung / Content of the lecture

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

Inhalte Übung / Content of the exercises

Participants must edit each task on each sheet to be admitted to the examination. If the useful processing of a task fails, an appropriate justification must be placed.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
The basis for the first third of the course textbook *Programming in Haskell* by Graham Hutton, which is also in the TF library.
## Grundlagen von Programmiersprachen / Essentials of Programming Languages

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
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<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
<td>Prof. Dr. P. Thiemann</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
<td>Chair Programmiersprachen</td>
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<td>Elective Module</td>
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<tr>
<td><strong>Moduldauer:</strong> Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
<td>English</td>
</tr>
</tbody>
</table>

| **Empfohlenes Fachterm:** Recommended term of study | 2 |
| **ECTS-Punkte:** ECTS-points | 6 |
| **SWS:** Term week hours | 3 Lecture + 1 Exercises |
| **Angebotsfrequenz:** Regular cycle | only in the summer term |
| **Arbeitsaufwand:** Workload | 180 Hours (56 Full-time attendance course of study + 124 Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

- Elective Module for students of the study program
  - Bachelor of Science in Embedded Systems Engineering
  - 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
    - Zuverlässige Eingebettete Systeme
    - Personal Profile
  - Master of Science in Informatik
    - Cyber-Physical Systems

### Lernziele / Learning target

Students have developed an understanding for the abstraction facilities that a programming language can provide.
They have mastered methods for modeling syntax and semantics of programming languages.
Students are aware of tools that support such modeling and they are able to apply them to selected problems.

### Inhalte Vorlesung / Content of the lecture

- Abstract and concrete syntax
- Lambda calculus and functional programming
- imperative programming and objects
• Operational semantics
• Types and logic
• Reasoning with contextual equivalence

Inhalte Übung / Content of the exercises

Participants must edit each task on each sheet to be admitted to the examination. If the useful processing of a task fails, an appropriate justification must be placed.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

• 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.

Literatur / Literature

• B.C. Pierce. Types and Programming Languages. MIT Press, 2002
• S. Krishnamurthi. Programming Languages: Application
## Komplexitätstheorie / Computational Complexity

<table>
<thead>
<tr>
<th>Modul / Module</th>
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</thead>
<tbody>
<tr>
<td>Komplexitätstheorie / Computational Complexity</td>
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<td>Prof. Dr. C. Schindelhauer</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Rechnernetze and Telematik</td>
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<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
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<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**
- Teaching contents of the modules:
  - Introduction to Programming
  - Computer Science II: Algorithms and Datastructures
  - Computer Science III: Theoretical Computer Science
  - Algorithm Theory
  - Graph Theory

**Empfohlenes Fachterm: Recommended term of study**
- 2

**ECTS-Punkte: ECTS-points**
- 6

**SWS: Term week hours**
- 3 Lecture + 1 Exercises

**Angebotsfrequenz: Regular cycle**
- only in the summer term

**Arbeitsaufwand: Workload**
- 180 Hours (56 Full-time attendance course of study + 124 Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteile Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme
- Master of Science in Mathematik

**Lernziele / Learning target**

The students should be able to learn and apply know the basic methodology of complexity theory. You will be introduced to current research topics and be able to classify them. Students will be able to prove basic theorems of complexity theory themselves.
Inhalte Vorlesung / Content of the lecture

First, basics of complexity theory are repeated: Countable, enumerability, machine models, formal language classes, Goedelization, P, NP, completeness, computability. Then a selection of advanced topics will be discussed: hierarchies, simulations, oracle classes, alternating Turing machines, circuit complexity. Finally, selected topics are discussed from the following fields: Average complexity theory, quantum computing, Kolmogorov complexity, interactive complexity classes, randomization.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

Literatur / Literature

- Papadimitriou, Christos H. Computational complexity. John Wiley and Sons Ltd., 2003
Modul / Module

Maschinelles Lernen und Optimierung für Algorithmendesign / Machine Learning and Optimization for Algorithm Design

Nummer: Number | 11LE13MO-1122
---|---
Modulverantwortlicher: Responsible person | Dr. F. Hutter
Einrichtung: Organisational unit | Chair Grundlagen der Künstlichen Intelligenz
Modultyp: Module Type | Elective Module
Moduldauer Module duration | 1 Term
Zugehörige Lehrveranstaltungen: Connected events | Lecture and exercises
Sprache: Language | English
Zwingende Voraussetzungen: Mandatorypreconditions | Basic skills in Python
Empfohlene Voraussetzungen: Recommended preconditions | Foundations of artificial intelligence; machine learning

Empfohlenes Fachterm: Recommended term of study | 3
ECTS-Punkte: ECTS-points | 6
SWS: Term week hours | 3 Lecture + 1 Exercises
Angebotsfrequenz: Regular cycle | only in the winter term
Arbeitsaufwand: Workload | 180 Hours (64 Full-time attendance course of study + 116 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

Students learn the foundations of automatic algorithm design based on methods from machine learning and optimization.
They can explain and apply methods from algorithm configuration and algorithm portfolios to new problems, and can statistically analyze the performance of algorithms.
In particular, they can apply these methods to solve hard combinatorial problems (SAT,
TSP, Planning...) more effectively.

### Inhalte Vorlesung / Content of the lecture

The lectures are partitioned in 6 modules:

- Introduction to NP-Hard Problems,
- Methods for solving combinatorial problems,
- Empirical Evaluation of Algorithms,
- Statistical Models of the Empirical Hardness of NP-Hard Problems,
- Algorithm Configuration,
- Algorithm Portfolios

### Inhalte Übung / Content of the exercises

The exercises follow the lectures. There will be at least one exercise for each module, in which the students independently implement the lecture material.

In the end there is a large project (80h), in which the students apply all aspects of the course to a new problem domain.

This project will be presented in the first part of the final exam.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination
In preparation for the written or oral exam, students work on a project, which they present in the first 15 minutes of the exam. In the second 15 minutes they answer questions about further course material.

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.
Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.
## Modul / Module

### Modellbildung und Systemidentifikation

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<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Systemtheorie</td>
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<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Moduldauer Module duration</td>
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<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
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<tr>
<td>Sprache: Language</td>
<td>Englisch</td>
</tr>
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</table>

**Empfohlene Voraussetzungen: Recommended preconditions**
- Knowledge of
  - Mathematik I für Ingenieure und Informatiker / Mathematics I für Engineers and Computer Scientists
  - Mathematik II für Ingenieure / Mathematics II für Engineers
  - Differentialgleichungen / Differential Equations
  - Systemtheorie und Regelungstechnik / Systems Theory and Feedback Control

**Empfohlenes Fachsemester: Recommended term of study**
- 3

**ECTS-Punkte: ECTS-points**
- 6

**SWS: Semester week hours**
- 2 Lecture + 2 Exercises

**Angebotsfrequenz: Regular cycle**
- Only in winter term

**Arbeitsaufwand: Workload**
- 180 Hours
  - (64 Full-time attendance course of study + 116 Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module

- **Mandatory Module for students in the study program**
  - Master of Science in Embedded Systems Engineering

- **Elective Module for students in the study program**
  - Master of Science in Informatik
    - Cyber-Physical Systems
    - Kognitive technische Systeme
  - Master of Science in Mikrosystemtechnik
    - Circuits and Systems
    - Design and Simulation
    - Personal Profile
  - Master of Science in Microsystems Engineering
    - Circuits and Systems
    - Design and Simulation
    - Personal Profile
Lernziele / Learning target

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.

Inhalte Vorlesung / Content of the lecture

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.

Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Literatur / Literature

- Lecture manuscript
- Lecture manuscript "System Identification“ by J
### Modulhandbuch M.Sc. Informatik – Numerik / Numerics

#### Modul / Module

**Numerik / Numerics**

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<td>Department of Mathematics</td>
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<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
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</tr>
<tr>
<td>SWS: Term week hours</td>
<td>2 Lecture + 2 Lecture</td>
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<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Each term</td>
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<td>Arbeitsaufwand: Workload</td>
<td>240 Hours</td>
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<tr>
<td></td>
<td>(60 Full-time attendance course of study + 180 Self-study)</td>
</tr>
</tbody>
</table>

#### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Informatik
  - Cyber-Physical Systems – Specialization Module III
  - Information Systems – Specialization Module III
  - Kognitive Technical Systems – Specialization Module III

#### Lernziele / Learning target

- Erlernen der grundlegenden Methoden der Numerik.
- Vertrautheit mit den klassischen Algorithmen und numerischen Verfahren und deren Implementierung auf Rechnern.

#### Inhalte Vorlesung / Content of the lecture

**Numerics I:**
- Grundlagen: Zahlendarstellung auf digitalen Rechnern, Matrixnormen, Banachser Fixpunktsatz, Fehleranalyse.
- Berechnung von Eigenwerten: Vektor-Iteration, LR- und QR-Verfahren.
- Lineare Optimierung: Austauschansatz und Simplexverfahren, lineare Ungleichungen.

**Numerics II:**
- Numerische Integration
### Zu erbringende Studienleistung / Course achievement

A written exam of both lectures (Numerics I in winter term, Numerics II in summer term)

### Benotung / Grading

Academic performance, which can be graded but usually is evaluated with pass or fail.

### Gewichtung der Prüfungsleistung / Weight of examination result

Master of Science in Computer Science, Academic regulations of 2012: Academic performance which can be graded but is not taken into account in the final grade.
Optimale Steuerung und Estimation / Optimal Control and Estimation

Number: 11LE50MO-5241

Modulverantwortlicher: Prof. Dr. M. Diehl
Einrichtung: Chair Systemtheorie

Modultyp: Elective Module
Moduldauer: 1 term

Zugehörige Lehrveranstaltungen: Lecture and exercises
Sprache: English

Empfohlene Voraussetzungen:
The module is self contained and can be followed by all students with sufficient mathematical background. Thus, it is recommended not only to master and advanced bachelor students of engineering, but also to students of computer science, mathematics, and physics, that want to obtain a basic understanding of optimization and control. Having heard a basic systems and control course (e.g. Systemtheorie und Regelungstechnik) and an optimization course (e.g. „Convex and Nonlinear Optimization“) is an advantage, but not necessary.

Empfohlenes Fachsemester: 3
ECTS-Punkte: 6

SWS: 4 Lecture 2 Übung
Angebotsfrequenz: Only in the winter term

Arbeitsaufwand: 180 hours (84 Hours Full-time attendance course of study + 96 Hours Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Cyber.Physical Systems
  - Kognitive Technische Systeme
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
### Lernziele / Learning target

Aim of this self contained module is to provide the participants with a working knowledge of modern control theory as it is needed for use in engineering applications, with a focus on optimal control and estimation. At the end of the module the students shall have full understanding of how to use the linear quadratic regulator (LQR), the Kalman filter, Lyapunov and Riccati Equations, dynamic programming, constrained optimal control, moving horizon estimation (MHE) and model predictive control (MPC).

### Inhalte Vorlesung / Content of the lecture

Focus of the course is state space control in discrete time. We start by discussing discrete time linear systems, their basic stability properties, time varying systems, linearization of nonlinear systems. We then enter optimal control, covering linear quadratic optimal control, linear quadratic regulation (LQR) control and Kalman filtering, Lyapunov and Riccati Equations, Dynamic Programming, Constrained Optimal Control, Moving Horizon Estimation (MHE) and Model Predictive Control (MPC). The course will be accompanied by weekly exercises with exercise questions and computer exercises using the environment MATLAB. In the last four weeks of the course (July), the participants will start to work, during the exercise sessions, on self chosen optimal control and estimation application projects, whose results will finally be presented to all course participants at the end of the semester.

### Inhalte Übung / Content of the exercises

Students have to complete 50% of the practical exercises to get the admission for the final module exam.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• M. Diehl: Script on “Numerical Optimal Control”.</td>
</tr>
</tbody>
</table>
**Programmverifikation / Programm Verification**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1211</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. A. Podelski</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachterm: Recommended term of study**
3

**ECTS-Punkte: ECTS-points**
6

**SWS: Term week hours**
3 Lecture + 1 Exercises

**Angebotsfrequenz: Regular cycle**
only in the winter term

**Arbeitsaufwand: Workload**
180 Hours
(64 Full-time attendance course of study + 116 Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**
Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

**Lernziele / Learning target**
Often computers are used in embedded, networked, safety critical applications. The cost of failure is high. In this module we introduce the basis of automatic tools for ensuring that a system does not have bad behaviours. We start with a short introduction to propositional logic and first-order reasoning. We then go on to establish a setting for the verification of programs, whose correctness is specified by a kind of program comments. In this setting, the correctness of the program is reduced to the validity of logical formulas. The validity is proven automatically by a new generation of powerful reasoning engines. Finally, we connect verification with static analysis methods that have been developed originally in compiler optimization and which are formalized by Patrick and Radhia Cousot's framework of abstract interpretation.
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<thead>
<tr>
<th>Inhalte Vorlesung / Content of the lecture</th>
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<tbody>
<tr>
<td>In this lecture we introduce the basis of automatic tools for ensuring that a system does not have bad behaviours. In the lecture, we start with a short introduction to propositional logic and first-order reasoning. We then go on to establish a setting for the verification of programs, whose correctness is specified by a kind of program comments. In this setting, the correctness of the program is reduced to the validity of logical formulas. The validity is proven automatically by a new generation of powerful reasoning engines. Finally, we connect verification with static analysis methods that have been developed originally in compiler optimization and which are formalized by Patrick and Radhia Cousot’s framework of abstract interpretation. Example of a verification problem; Technical documentation, for example of device driver programs for Windows and Linux operating systems, contains 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. We can formalize such rules, for example by a finite automaton. Below a small program for which we would like to know whether it obeys the rule 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). The rule can be formalized by the automaton shown below (the red state is the accepting state of the automaton the automaton accepts exactly the words that correspond to a bad behaviour). Is the program correct? Today tools exist that can answer this question automatically.</td>
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<td>written or oral examination</td>
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<tr>
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</table>
Modul / Module

**Reversible Logik and Quantumcomputer / Reversible Logic and Quantum Computing**

- **Nummer:** 11LE13MO-1221
- **Modulverantwortlicher (Responsible person):** Prof. Dr. C. Scholl
- **Einrichtung (Organisational unit):** Chair Betriebssysteme
- **Modultyp (Module Type):** Elective Module
- **Moduldauer (Module duration):** 1 Term
- **Zugehörige Lehrveranstaltungen (Connected events):** Lecture and exercises
- **Sprache (Language):** English
- **Empfohlenes Fachterm (Recommended term of study):** 3
- **ECTS-Punkte (ECTS-points):** 6
- **SWS (Term week hours):** 3 Lecture + 1 Exercises
- **Angebotsfrequenz (Regular cycle):** only in the winter term
- **Arbeitsaufwand (Workload):** 180 Hours
  (64 Full-time attendance course of study + 116 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

Lernziele / Learning target

The students learn how quantum circuits can be used to describe quantum algorithms. They learn in detail how a desired functionality can be realized in terms of a reversible circuit which is part of the quantum circuit. This strengthens their knowledge on the design flow for digital systems. For the description of algorithms for the synthesis of reversible circuits basics from symmetric groups will be taught.

Inhalte Vorlesung / Content of the lecture

- quantum algorithms
- quantum circuits
- reversible functions
- reversible circuits
• design flow for reversible circuits
• synthesis algorithms
• symmetric groups

Zu erbringende Prüfungsleistung / Examination result
written or oral examination

Bewertung / Grading
The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

• 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.
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Literatur / Literature

Not required:
• Matthias Homeister: Quantum Computing verstehen
• Michael A. Nielsen and Isaac L. Chuang: Quantum Computing and Quantum Information
Modul / Module

Test and Zuverlässigkeit / Test and Reliability

 Nummer: Number 11LE13MO-1202
 Modulverantwortlicher: Responsible person Prof. Dr. B. Becker
 Modultyp: Module Type Elective Module
 Moduldauer: Module duration 1 Term
 Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises
 Sprache: Language English
 Empfohlene Voraussetzungen: Recommended preconditions Knowledge in Technische Informatik and Rechnerarchitektur / Computer Architecture

 Empfohlenes Fachterm: Recommended term of study 2 ECTS-Punkte: ECTS-points 6
 SWS: Term week hours 3 Lecture + 1 Exercises Angebotsfrequenz: Regular cycle only in the summer term
 Arbeitsaufwand: Workload 180 Hours (56 Full-time attendance course of study + 124 Self-study)

 Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
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- Lehramt an Gymnasien in Informatik additional major subject
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- Master of Science in Embedded Systems Engineering
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

 Lernziele / Learning target

The students are familiar with basic problems concerning test of digital circuits, understand corresponding algorithmic techniques, and know how to apply and possibly adapt them to new requirements. They are capable to integrate “Design for Testability” into a concrete design and judge advantages/disadvantages of these measures. The challenges of “the new technologies” are aware to them and state-of-the-art approaches to cope with these challenges can be assessed.
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.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

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Literatur / Literature

## Modul / Module

### Verifikation eingebetteter Systeme / Verification of embedded Systems

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1204</th>
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</table>

<table>
<thead>
<tr>
<th>Modulverantwortlicher: Responsible person</th>
<th>Prof. Dr. B. Becker, Prof. Dr. C. Scholl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Rechnerarchitektur, Chair Betriebssysteme</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlene Voraussetzungen: Recommended preconditions</th>
<th>Basic knowledge in technical computer science. Knowledge of the lecture &quot;Verification of embedded systems&quot; is useful for understanding, but not a prerequisite.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachterm: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours</td>
</tr>
<tr>
<td></td>
<td>(64 Full-time attendance course of study + 116 Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
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- 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
  - Zuverlässige Eingebettete Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems

### Lernziele / Learning target

Embedded systems consist of a digital control unit, but interact with continuous quantities like temperature, velocity and time. Beyond the question merely regarding functional correctness, often properties like the expected life-time, the average performance or the reliability are of central interest. For this, effects which are stochastic by nature have to be taken into account (e.g. communication via unreliable channels, the finite life-time of components, etc.). The students know the formalisms which can be used to model such systems. They are able to apply algorithms for the automatic analysis of such systems regarding a number of...
different relevant properties and understand how these algorithms can be implemented efficiently. The students understand the problems that can occur if these techniques are applied to practically relevant systems and know ways to circumvent or solve these problems.

### Inhalte Vorlesung / Content of the lecture

In this lecture we present formalisms for modeling and analysis of probabilistic systems:
- Discrete-time and continuous-time Markov chains
- Markov reward models
- Markov decision processes

For these classes of models we discuss algorithms which can be used to automatically check a variety of properties, e.g.: "The probability to reach, within the usual period of operation, a safety-critical state is at most 0.00001.", "The average energy consumption is on the long run, 5.8 W.", "On average, 10 tries are necessary until a message has been transmitted successfully."

We consider Markov models from the perspective of computer science with a focus on algorithms for their analysis. The necessary foundations which go beyond the contents of introductory lectures on mathematics and technical computer science (as taught in the curriculum of ESE/Computer Science) are introduced in the lecture.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

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### Gewichtung der Prüfungsleistung / Weight of examination result

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### Literatur / Literature

Christel Baier, Joost-Pieter Katoen: Principles of Model Checking The MIT Press 2008
## Verteilte Systeme / Distributed Systems

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1312</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. C. Schindelhauer, Prof. Dr. L. Lausen</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Rechnernetze and Telematik, Chair Datenbanken and Informationssysteme</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<td>Modulduration: Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
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<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended prerequisites</td>
<td>Knowledge in Datenbanken und Informationssysteme / Data Bases and Information Systems</td>
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<tr>
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### Verwendbarkeit der Veranstaltung / Usability of the module

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- Master of Science in Embedded Systems Engineering
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme

### Lernziele / Learning target

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.
Inhalte Vorlesung / Content of the lecture

After an introduction into distributed systems, the following major topics are discussed.

- System models
- Networks and Communications
- Time and global states
- Consistency and coordination
- Distributed Transactions
- Replication
- Modeling of distributed applications

Furthermore, current issues, which may originate from the following areas, are presented.

- Mobile Distributed Systems
- Web-based Distributed Systems
- Distributed multi-threading
- Peer-to-peer networks

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

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Literatur / Literature

- Additional literature will be presented in the lecture
Specialization Area – Informationssysteme / Information Systems

In the specialization area "Information Systems" 3 different specialization modules are offered:

- Information Systems - Specialization in Computer Science I
- Information Systems - Specialization in Computer Science II
- Information Systems - Specialization in Computer Science III

Students have to complete 2 modules with a volume of 24 ECTS.

In addition, the students have to complete 2 Seminars. Minimum 1 Seminar must be part of the specialization area "Information Systems".

<table>
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<td>Prof. Dr. B. Becker, Prof. Dr. A. Podelski</td>
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<tr>
<td>Prof. Dr. C. Scholl, Prof. Dr. T. Thiemann</td>
</tr>
<tr>
<td>Prof. Dr. K. van Laerhoven</td>
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</thead>
<tbody>
<tr>
<td>Programming skills, knowledge in algorithms and data structures and operations systems</td>
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<table>
<thead>
<tr>
<th>Empfohlenes Fachsemester: Recommended term of study</th>
</tr>
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<tbody>
<tr>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ECTS-Punkte: ECTS-points</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>SWS: Semester week hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Seminar</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Angebotsfrequenz: Regular cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each term</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Arbeitsaufwand: Workload</th>
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</thead>
<tbody>
<tr>
<td>120 hours (28 or 32 hours Full-time attendance course of study + 92 oder 88 hours self-study)</td>
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<tr>
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<td>Elective Module for students of the study program</td>
</tr>
<tr>
<td>Master of Science in Informatik</td>
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<tr>
<td><strong>Lernziele / Learning target</strong></td>
</tr>
<tr>
<td>--------------------------------</td>
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<td>A seminar gives students the opportunity to get acquainted with a specific topic in Cyber-Physical Systems. They shall learn to independently search for scientific literature and to structure the same. Furthermore they will learn to write short scientific texts and present the results to a group. Concerning scientific writing they will learn the rules for good scientific practice.</td>
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<tr>
<td>Special topics from the selected workspace</td>
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<table>
<thead>
<tr>
<th><strong>Literatur / Literature</strong></th>
</tr>
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<tbody>
<tr>
<td>Will be announced at the beginning of the course.</td>
</tr>
</tbody>
</table>
### Information Systems - Seminar

**Nummer: Number**

11LE13MO-1301  
11LE13MO-1302

**Modulverantwortlicher: Responsible person**

Prof. Dr. M. Müller, Prof. Dr. H. Bast, Prof. Dr. F. Kuhn, Prof. Dr. R. Backofen, Prof. Dr. G. Lausen, Prof. Dr. G. Schneider, Prof. Dr. C. Schindelhauer, Prof. Dr. P. Fischer

**Einrichtung: Organisational unit**

Institut für Informatik und Gesellschaft, Chair Algorithmen und Datenstrukturen, Chair Algorithmen und Komplexität, Chair Bioinformatik, Chair Datenbanken, Chair Kommunikationssysteme, Chair Rechnernetze und Telematik, Chair Web Science

**Modultyp: Module Type**

Elective Module

**Moduldaurer Module duration**

1 Term

**Zugehörige Lehrveranstaltungen: Connected events**

Seminar

**Sprache: Language**

German or English

**Empfohlene Voraussetzungen: Recommended preconditions**

Programming skills, knowledge in algorithms and data structures and operations systems

**Empfohlenes Fachsemester:: Recommended term of study**

2

**ECTS-Punkte: ECTS-points**

4

**SWS: Semester week hours**

2 Seminar

**Angebotsfrequenz: Regular cycle**

Each term

**Arbeitsaufwand: Workload**

120 hours  
(28 or 32 hours Full-time attendance course of study + 92 oder 88 hours self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program  
- Master of Science in Informatik

**Lernziele / Learning target**

A seminar gives students the opportunity to get acquainted with a specific topic in Cyber-Physical Systems. They shall learn to independently search for scientific literature and to structure the same. Furthermore they will learn to write short scientific texts and present the results to a group. Concerning scientific writing they will learn the rules for good scientific practice.
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<td>• Master of Science in Computer Science, Academic regulations of 2012: Academic performance which can be graded but is not taken into account in the final grade.</td>
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<table>
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<tr>
<th><strong>Literatur / Literature</strong></th>
</tr>
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<tbody>
<tr>
<td>Will be announced at the beginning of the course.</td>
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</table>
## Modul / Module

### Kognitive Technical Systems - Seminar

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1101</th>
<th>11LE13MO-1102</th>
<th>Modulverantwortlicher: Responsible person</th>
<th>Prof. Dr. W. Burgard, Prof. Dr. M. Teschner, N.N., Prof. Dr. T. Brox, PD Dr. Hutter</th>
<th>Einrichtung: Organisational unit</th>
<th>Chair Autonome Intelligente Systeme, Lehrstuhl Graphische Datenverarbeitung, Chair Maschinelles Lernen, Chair Mustererkennung und Bildverarbeitung, Arbeitsgruppe Automatisches Algorithmdesign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
<td>Modulduauer Module duration</td>
<td>1 Term</td>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
<td>Sprache: Language</td>
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<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Programming skills, knowledge in algorithms and data structures and operations systems</td>
<td></td>
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<td></td>
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<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>2</td>
<td>ECTS-Punkte: ECTS-points</td>
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<td>SWS: Semester week hours</td>
<td>2 Seminar</td>
<td>Angebotsfrequenz: Regular cycle</td>
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<tr>
<td>Arbeitsaufwand: Workload</td>
<td>120 hours (28 or 32 hours Full-time attendance course of study + 92 oder 88 horus self-study)</td>
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</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Informatik

### Lernziele / Learning target

A seminar gives students the opportunity to get acquainted with a specific topic in Cyber-Physical Systems. They shall learn to independently search for scientific literature and to structure the same. Furthermore they will learn to write short scientific texts and present the results to a group. Concerning scientific writing they will learn the rules for good scientific practice.
### Inhalte Seminar / Content of the seminar

Special topics from the selected workspace  
Overall Topics: proper citation, references, documentation of results, avoids misconduct (plagiarism, misrepresentation, etc.)

### Zu erbringende Studienleistung / Course Achievement

The coursework consists of a seminar paper and an oral presentation. In general, the active and regular participation in the course is requested.

### Benotung / Grading

Academic performance, which can be graded but usually is evaluated with pass or fail.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Computer Science, Academic regulations of 2012: Academic performance which can be graded but is not taken into account in the final grade.

### Literatur / Literature

Will be announced at the beginning of the course.
<table>
<thead>
<tr>
<th>Literature / Literature</th>
</tr>
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<tbody>
<tr>
<td>Will be announced at the beginning of the course.</td>
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</table>
## Algorithmen für Funknetze / Algorithms for Radio Networks

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<tr>
<th><strong>Modul</strong> / <strong>Module</strong></th>
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<tbody>
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<td><strong>Algorithmen für Funknetze / Algorithms for Radio Networks</strong></td>
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<tr>
<th><strong>Nummer: Number</strong></th>
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<tbody>
<tr>
<td><strong>Modulverantwortlicher:</strong> <strong>Responsible person</strong></td>
<td>Prof. Dr. C. Schindelhauer</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> <strong>Organisational unit</strong></td>
<td>Chair Rechnernetze and Telematik</td>
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<tr>
<td><strong>Modultyp:</strong> <strong>Module Type</strong></td>
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<td><strong>Moduldauer Module duration</strong></td>
<td>1 Term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> <strong>Connected events</strong></td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td><strong>Sprache:</strong> <strong>Language</strong></td>
<td>English</td>
</tr>
<tr>
<td><strong>Empfohlene Voraussetzungen:</strong> <strong>Recommended preconditions</strong></td>
<td>Knowledge in algorithms and data structures and computer networks</td>
</tr>
<tr>
<td><strong>Empfohlenes Fachterm:</strong> <strong>Recommended term of study</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>ECTS-Punkte:</strong> <strong>ECTS-points</strong></td>
<td>6</td>
</tr>
<tr>
<td><strong>SWS:</strong> <strong>Term week hours</strong></td>
<td>2 Lecture + 2 Exercises</td>
</tr>
<tr>
<td><strong>Angebotsfrequenz:</strong> <strong>Regular cycle</strong></td>
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<tr>
<td><strong>Arbeitsaufwand:</strong> <strong>Workload</strong></td>
<td>180 Hours (64 Full-time attendance course of study + 116 Self-study)</td>
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## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme

## Lernziele / Learning target

The knowledge can be used to design wireless network protocols. Participants can create and evaluate wireless sensor network protocols. They understand the problems of mobile networks, know the current technology, and can create complex routing algorithms.
**Inhalte Vorlesung / Content of the lecture**

We classify wireless networks cellular networks, ad-hoc networks, wireless sensor networks and hybrid versions. For each of these types we present and evaluate algorithms. Cellular networks are known from mobile (phone) networks and WLAN. Communication is handled via dedicated hardware routers or base stations, while direct connections between terminals are not provided. We discuss the effects of the partitioning of the network into cells and the geometric properties of these cells. The allocation of radio frequencies is a combinatorially hard problem. For this and other problems like hand-off we present algorithmic solutions.

Ad hoc networks have no infrastructure. Nodes communicate using multi-hop connections with the help of other participants. Routing in such networks is more challenging. We discuss medium-access protocols, routing algorithms and topology control.

Wireless Sensor Networks connect sensors and actuators with a control station. These sensor nodes have only simple hardware for computation and data transfer. Most importantly the energy resources are very restricted. We present energy-efficient medium access and routing algorithms, which follow a data-centric approach.

Special topics may be included addressing current research like anchor-less localization in radio networks, or communication using coordinated antennas, known as MIMO (multiple input multiple output).

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benoitung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
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## Literature

- Schiller, Mobile Communications, Addison-Wesley, 2000.

Further literature will be recommended in the course.
Algorithmische Grundlagen der Bioinformatik / Algorithmic Foundations of Bioinformatics

Nummer: 11LE13MO-1308

Modulverantwortlicher: Prof. Dr. S. Schuierer
Einrichtung: Institut für Informatik
Modultyp: Elective Module
Moduldauer: 1 Term
Zugehörige Lehrveranstaltungen: Lecture
Sprache: German

Empfohlene Voraussetzungen: Knowledge in algorithms and data structures

Empfohlenes Fachterm: 2 ECTS-Punkte: 6 SWS: 2 Lecture Angebotsfrequenz: only in the summer term Arbeitsaufwand: 180 Hours (28 Full-time attendance course of study + 152 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme

Lernziele / Learning target

Die Studierenden haben Verständnis des Entwurfs und der Analyse von Zeichenkettenalgorithmen in der Bioinformatik. Sie können mit den gängigen Ansätzen zur Analyse umgehen.

Inhalte Vorlesung / Content of the lecture

- Suffixbäume
- Editierdistanz
• Multiples Zeichenkettenalignment
• Suchheuristiken
• Hidden Markov Modelle für die Alignierung von Zeichenketten

Zu erbringende Prüfungsleistung / Examination result
written or oral examination

Bnoteung / Grading
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Literatur / Literature

Algorithms on Strings, Trees and Sequences: Computer Science and Computational Biology von Dan Gusfield von Cambridge University Press
Modul / Module

Bioinformatik I / Bioinformatics I

Nummer: 11LE13MO-1309

Modulverantwortlicher: Prof. Dr. R. Backofen

Einrichtung: Chair Bioinformatik

Modultyp: Elective Module

Moduldauer: 1 Term

Zugehörige Lehrveranstaltungen: Lecture and exercises

Sprache: English

Empfohlene Voraussetzungen:
- Basic knowledge in molecular biology
- Basic knowledge in algorithms

Empfohlenes Fachterm: 2

ECTS-Punkte: 6

SWS: 2 Lecture + 2 Exercises

Angebotsfrequenz: only in the summer term

Arbeitsaufwand: 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme
  - Fachfremder Wahlbereich "Bioinformatik"

Lernziele / Learning target

This module is an introduction to major topics in the field of bioinformatics with a special focus on sequence analysis. In the course we revise fundamental principles in biology 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 course, students will become familiar with applications of
Markov models in Bioinformatics and be able to compute phylogenetic trees.

**Inhalte Vorlesung / Content of the lecture**

Sequenzalignement:
- global and lokal, Distanz and Ähnlichkeit
- affine and beliebige Gap-Kostenfunktionen

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

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

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

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- 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.
Bioinformatics II / Bioinformatics II

**Nummer:** Number 11LE13MO-1310

**Modulverantwortlicher:** Responsible person Prof. Dr. R. Backofen

**Einrichtung:** Organisational unit Chair Bioinformatik

**Modultyp:** Module Type Elective Module

**Moduldauer:** Module duration 1 Term

**Zugehörige Lehrveranstaltungen:** Connected events Lecture and exercises

**Sprache:** Language English

**Empfohlenes Fachterm:** Recommended term of study 3

**ECTS-Punkte:** ECTS-points 6

**SWS:** Term week hours 2 Lecture + 2 Exercises

**Angebotsfrequenz:** Regular cycle only in the winter term

**Arbeitsaufwand:** Workload 180 Hours (64 Full-time attendance course of study + 116 Self-study)

**Verwendbarkeit der Veranstaltung:** Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme
  - Fachfremder Wahlbereich "Bioinformatik"

**Lernziele:** Learning target

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.
### Inhalte Vorlesung / Content of the lecture

<table>
<thead>
<tr>
<th>Topic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple sequence alignment</td>
<td>- Scoring schemes</td>
</tr>
<tr>
<td></td>
<td>- Exact and heuristic methods (progressive approaches, t-coffee etc.)</td>
</tr>
<tr>
<td>Hidden markov models</td>
<td>- Profile HMMs for multiple alignment</td>
</tr>
<tr>
<td></td>
<td>- Learning profile HMMs</td>
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<tr>
<td>Protein structure</td>
<td>- Simple protein models</td>
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<td></td>
<td>- Protein threading</td>
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<td>RNA structure prediction</td>
<td>- Nussinov algorithm</td>
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<td>- Zuker algorithm</td>
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<td>Energy Landscapes</td>
<td>- Monte-Carlo sampling</td>
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<td></td>
<td>- Abstractions</td>
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<tr>
<td></td>
<td>- Folding dynamics</td>
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</tbody>
</table>

### Zu erbringende Prüfungsleistung / Examination result

- written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

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<table>
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<tbody>
<tr>
<td>- D.W. Mount: Bioinformatics - Sequence and Genome Analysis Cold Spring Harbor</td>
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</table>
### Modul / Module

**Constraint-Satisfaction-Probleme / Constraint-Satisfaction-Problems**

<table>
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<th>11LE13MO-1119</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Nebel</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Grundlagen der Künstlichen Intelligenz</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Artificial Intelligence</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachterm: Recommended term of study**

<table>
<thead>
<tr>
<th>3</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
</tbody>
</table>

**SWS: Term week hours**

<table>
<thead>
<tr>
<th>180 Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
</tr>
<tr>
<td>180 Hours</td>
</tr>
<tr>
<td>(64 Full-time attendance course of study + 116 Self-study)</td>
</tr>
</tbody>
</table>

**Arbeitsaufwand: Workload**

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme
  - Kognitive technische Systeme

**Lernziele / Learning target**

The aim of this module is to deepen the understanding of a broad variety of standard techniques used for solving constraint satisfaction problems. After the course students should be able to implement and evaluate such techniques. Moreover students should then be able to understand current research papers and to start qualifying projects or theses on topics related to the lecture.
Inhalte Vorlesung / Content of the lecture

The lecture provides an in-depth introduction into the field of constraint satisfaction problems (CSP), one of the major fields in current AI research. In particular, we study the following topics:

- Foundations
- Constraint propagation (arc consistency, path consistency, global consistency)
- Search methods (backtracking, backjumping, local search)
- Constraint optimization problems (COP)
- Expressiveness and computational complexity of constraint languages
- CSP on infinite domains

Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
<table>
<thead>
<tr>
<th>Literature / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Dechter, Constraint Processing, Morgan Kaufmann, 2003</td>
</tr>
<tr>
<td>- Rossi, van Beek, Walsh, Handbook of Constraint Programming, Elsevier, 2006</td>
</tr>
</tbody>
</table>
Modul / Module

Data Analysis and Query Languages

<table>
<thead>
<tr>
<th>Number</th>
<th>11LE13MO-1322</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher</td>
<td>Prof. Dr. G. Lausen</td>
</tr>
<tr>
<td>Modultyp</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen</td>
<td>Knowledge in Datenbanken and Informationssysteme / Data Bases and Information Systems</td>
</tr>
<tr>
<td>Empfohlenes Fachterm</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte</td>
<td>6</td>
</tr>
<tr>
<td>SWS</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz</td>
<td>only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand</td>
<td>180 Hours</td>
</tr>
<tr>
<td>(56 Full-time attendance course of study + 124 Self-study)</td>
<td></td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

Students will learn to use basic techniques for analysis of web-scale massive datasets. Students will be able to apply these techniques on basic examples. Students will be familiar with query languages designed for the web of data. Students will know how to design processing tasks using the MapReduce paradigm.
### Inhalte Vorlesung / Content of the lecture

<table>
<thead>
<tr>
<th>Lecture Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Basics of the Web</td>
</tr>
<tr>
<td>10. Search Engines and Link Analysis</td>
</tr>
<tr>
<td>11. Query language SPARQL</td>
</tr>
<tr>
<td>12. Web-scale Computation</td>
</tr>
<tr>
<td>13. Finding Similar Items</td>
</tr>
<tr>
<td>14. Mining Data Streams</td>
</tr>
<tr>
<td>15. Advertising and Recommendations</td>
</tr>
<tr>
<td>16. Mining Social Network GraphsMatrix Dimensionality Reduction</td>
</tr>
</tbody>
</table>

### Zu erbringende Prüfungsleistung / Examination result

- written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

### Literatur / Literature

Modulhandbuch M.Sc. Informatik – Einführung in die Modallogik / Introduction to Modal Logic

Einführung in die Modallogik / Introduction to Modal Logic

Nummer: Number 11LE13MO-1121

Modulverantwortlicher: Responsible person Prof. Dr. B. Nebel
Einrichtung: Organisational unit Chair Grundlagen der Künstlichen Intelligenz

Modultyp: Module Type Elective Module
Moduldauer: Module duration 1 Term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises
Sprache: Language English

Empfohlene Voraussetzungen: Recommended preconditions Knowledge in Grundlagen der Künstlichen Intelligenz / Foundations in Artificial Intelligence

Empfohlenes Fachterm: Recommended term of study 2
ECTS-Punkte: ECTS-points 6

SWS: Term week hours 3 Lecture + 1 Exercises
Angebotsfrequenz: Regular cycle only in the summer term

Arbeitsaufwand: Workload 180 Hours (56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Mathematik
- 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
  o Robotics and Computer Vision
  o Personal Profile
- Master of Science in Informatik
  o Informationssysteme
  o Kognitive technische Systeme

Lernziele / Learning target

The aim of this module is to give students a basic understanding of key concepts and standard techniques used in modal logics. After the module students should be able to implement and evaluate such techniques. Moreover students should then be able to understand current research papers and to start qualifying projects or theses on topics related to the lecture.
### Inhalte Vorlesung / Content of the lecture

The term “modal logics” comprises a family of logics, which are used in quite different fields in computer science (such as knowledge representation and reasoning, multi-agent systems, and formal verification). The lecture provides an in-depth introduction into standard techniques used in modal logics and provides an overview of closely related logics as well as their application. In particular, we will study the following topics:

- Uni- and multi-modal logics
- Expressiveness and computational complexity
- Tableaux-based decision procedures
- Epistemic logics
- Temporal and dynamic logics
- Description logics

### Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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
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<table>
<thead>
<tr>
<th>Literatur</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Blackburn, van Benthem, Wolter, Handbook of Modal Logic, Elsevier, 2006</td>
<td></td>
</tr>
</tbody>
</table>
Introduction to Multiagent Systems

**Number**: 11LE13MO-1118

**Module Type**: Elective Module

**Module Duration**: 1 Term

**Language**: English

**Recommended Preconditions**: The module has a strong focus on practical solutions to multi-agent systems. Therefore, programming skills in Java or C++ are mandatory. Furthermore, knowledge of concepts from the lecture Foundations of Artificial Intelligence (Grundlagen der Künstlichen Intelligenz), such as search methods, and probabilistic methods, is useful.

**Recommended Term of Study**: 2

**ECTS-Peints**: 6

**Term Week Hours**: 3 Lecture + 1 Exercises

**Workload**: 180 Hours (56 Full-time attendance course of study + 124 Self-study)

**Usability of the Module**: Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Informationssysteme
  - Kognitive technische Systeme

**Learning Target**: This module will address theoretical and practical aspects of multiagent systems. The rationale behind modeling problems in terms of agents in computer science and robotics will be explained. We will see how this approach is different from and relates to other programming paradigms, and which types problems can be solved using agent architectures. More specifically, the following topics will be included:

Inhalte Vorlesung / Content of the lecture

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

Topics of this course are:

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

Inhalte Übung / Content of the exercises

Für die Zulassung zur Klausur müssen 50% der erreichbaren Punkte aus den Exercisesen und Projekten erreicht werden

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

Um zur Abschlussprüfung zugelassen zu werden, muss die zu diesem Modul gehörige Lehrveranstaltung Exercises erfolgreich absolviert werden. Welche Leistung der Studierenden zu erbringen hat, wird in der Inhaltsbeschreibung der Exercises detailliert beschrieben and ebenso zu Beginn der Lehrveranstaltung vom Dozierenden mitgeteilt.

Benotung / Grading

The module grade is calculated from the result of the final examination.
### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.

### Literatur / Literature

### Handlungsplanung / Artificial Intelligence Planning

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1102</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Nebel</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Grundlagen der Künstlichen Intelligenz / Foundations of Artificial Intelligence</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachterm: Recommended term of study | 2 |
| SWS: Term week hours | 3 Lecture + 1 Exercises |
| Arbeitenaufwand: Workload | 180 Hours |

#### Verwendbarkeit der Veranstaltung / Usability of the module

- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

#### Lernziele / Learning target

Students are made familiar with the theory and the basic algorithms of AI planning to an extent that allows them to understand current research literature in the field of AI planning, to put it into context, and to actively participate in AI planning research.
Inhalte Vorlesung / Content of the lecture

The lecture offers a detailed introduction into theoretical and algorithmic foundations of modern AI planning systems. In more detail, the following topics are covered:

- Formalization of AI planning
- Planning as search: progression and regression
- Satisficing heuristic search planning with delete-relaxation heuristics
- Optimal heuristic search planning with abstraction heuristics
- Nondeterministic and probabilistic planning
- Theoretical complexity of AI planning

Moreover, presumably at least one of the following additional topics will be covered:

- Computation and use of invariants
- Optimal planning as model checking with binary decision diagrams (BDDs)
- Planning as satisfiability

Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.

**Literatur / Literature**

- Rintanen: Introduction to Automated Planning. Lecture Notes for the SS 2005 course. Albert-Ludwigs-Universität-Freiburg, 2005
Informationswiedergewinnung / Information Retrieval

Nummer: Number
11LE13MO-1304

Modulverantwortlicher: Responsible person
Prof. Dr. H. Bast

Modultyp: Module Type
Elective Module

Einrichtung: Organisational unit
Chair Algorithmen und Datenstrukturen

Moduldauer Module duration
1 Term

Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

Sprache: Language
English

Empfohlene Voraussetzungen: Recommended preconditions
Basic knowledge in algorithms and data structures, basic programming skills.

Empfohlenes Fachterm: Recommended term of study
3

ECTS-Punkte: ECTS-points
6

SWS: Term week hours
2 Lecture + 2 Exercises

Angebotsfrequenz: Regular cycle
only in the winter term

Arbeitsaufwand: Workload
180 Hours
(64 Full-time attendance course of study + 116 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

Students should understand the foundations of information systems, in particular search engines. They should be able to apply this knowledge in practice. This concerns algorithmic aspects (e.g., index data structures), quality aspects (e.g. ranking of search results) and user interfaces (e.g. AJAX programming).

Inhalte Vorlesung / Content of the lecture

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.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
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- 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.

**Literatur / Literature**

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.
**Komplexitätstheorie / Computational Complexity**

**Nummer:** 11LE13MO-1320

**Modulverantwortlicher:** Prof. Dr. C. Schindelhauer

**Einrichtung:** Chair Rechnernetze and Telematik

**Modultyp:** Elective Module

**Moduldauer:** 1 Term

**Zugehörige Lehrveranstaltungen:**

- Lecture and exercises

**Sprache:** English

**Empfohlene Voraussetzungen:**

- Introduction to Programming
- Computer Science II: Algorithms and Datastructures
- Computer Science III: Theoretical Computer Science
- Algorithm Theory
- Graph Theory

**Empfohlenes Fachterm:** 2

**ECTS-Punkte:** 6

**SWS:**

- 3 Lecture + 1 Exercises

**Angebotsfrequenz:** only in the summer term

**Arbeitsaufwand:** 180 Hours (56 Full-time attendance course of study + 124 Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteile Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme
- Master of Science in Mathematik

**Lernziele / Learning target**

The students should be able to learn and apply know the basic methodology of complexity theory. You will be introduced to current research topics and be able to classify them. Students will be able to prove basic theorems of complexity theory themselves.
**Inhalte Vorlesung / Content of the lecture**

First, basics of complexity theory are repeated: Countable, enumerability, machine models, formal language classes, Goedelization, P, NP, completeness, computability. Then a selection of advanced topics will be discussed: hierarchies, simulations, oracle classes, alternating Turing machines, circuit complexity. Finally, selected topics to are discussed from the following fields: Average complexity theory, quantum computing, Kolmogorov complexity, interactive complexity classes, randomization.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
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- 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.

**Literatur / Literature**

- Papadimitriou, Christos H. *Computational complexity*. John Wiley and Sons Ltd., 2003
Modul / Module

Maschinelles Lernen / Machine Learning

<table>
<thead>
<tr>
<th>Nummer: Number</th>
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<tr>
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</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Maschinelles Lernen andNatürlichsprachliche Systeme</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Grundlagen der Künstlichen Intelligenz / Foundations of Artificial Intelligence</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachterm: Recommended term of study | 2 |
| ECTS-Punkte: ECTS-points | 6 |
| SWS: Term week hours | 3 Lecture + 1 Exercises |
| Angebotsfrequenz: Regular cycle | only in the summer term |
| Arbeitsaufwand: Workload | 180 Hours |
| | (56 Full-time attendance course of study + 124 Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

Understanding of the basic concepts of machine learning, ability to think on different levels of abstraction, knowledge of exemplary implementations of learning algorithms, ability to independently identify connections of the concepts presented.
### Inhalte Vorlesung / Content of the lecture

Characterization of supervised, unsupervised and reinforcement learning, concept learning, decision trees, neural networks, probabilistic methods, committee techniques, reinforcement learning.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.

### Literatur / Literature

- Mitchell: Machine Learning
- Murphy: Machine Learning – A Probabilistic Perspective
Modul / Module

Maschinelles Lernen und Optimierung für Algorithmendesign / Machine Learning and Optimization for Algorithm Design

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1122</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Dr. F. Hutter</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Grundlagen der Künstlichen Intelligenz</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Zwingende Voraussetzungen: Mandatory prerequisites</td>
<td>Basic skills in Python</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended prerequisites</td>
<td>Foundations of artificial intelligence; machine learning</td>
</tr>
<tr>
<td>Empfohlenes Fachterm: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours</td>
</tr>
<tr>
<td></td>
<td>(64 Full-time attendance course of study + 116 Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
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- 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
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

Students learn the foundations of automatic algorithm design based on methods from machine learning and optimization. They can explain and apply methods from algorithm configuration and algorithm portfolios to new problems, and can statistically analyze the performance of algorithms. In particular, they can apply these methods to solve hard combinatorial problems (SAT,
TSP, Planning...) more effectively.

Inhalte Vorlesung / Content of the lecture

The lectures are partitioned in 6 modules:
- Introduction to NP-Hard Problems,
- Methods for solving combinatorial problems,
- Empirical Evaluation of Algorithms,
- Statistical Models of the Empirical Hardness of NP-Hard Problems,
- Algorithm Configuration,
- Algorithm Portfolios

Inhalte Übung / Content of the exercises

The exercises follow the lectures. There will be at least one exercise for each module, in which the students independently implement the lecture material. In the end there is a large project (80h), in which the students apply all aspects of the course to a new problem domain. This project will be presented in the first part of the final exam.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination
In preparation for the written or oral exam, students work on a project, which they present in the first 15 minutes of the exam. In the second 15 minutes they answer questions about further course material.

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.
### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.
Modul / Module

Netzwerkalgorithmen / Network Algorithms

Nummer: Number
11LE13MO-1313

Modulverantwortlicher: Responsible person
Prof. Dr. F. Kuhn

Einrichtung: Organisational unit
Chair Algorithmen und Komplezität

Modultyp: Module Type
Elective Module

Moduldauer Module duration
1 Term

Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

Sprache: Language
English

Empfohlenes Fachterm: Recommended term of study
2

ECTS-Punkte: ECTS-points
6

SWS: Term week hours
3 Lecture + 1 Exercises

Angebotsfrequenz: Regular cycle
only in the summer term

Arbeitsaufwand: Workload
180 Hours
(56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme

Lernziele / Learning target

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.

Inhalte Vorlesung / Content of the lecture

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
### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.
### Modul / Module

**Numerik / Numerics**

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>Number</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Examiners of the Department of Mathematics</td>
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<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
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<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Lecture and exercises</td>
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<td>Modulverantwortlicher:</td>
<td>Department of Mathematics</td>
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<td>Einrichtung:</td>
<td>Organisational unit</td>
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<tr>
<td>Moduldauer</td>
<td>Module duration</td>
<td>2 Terms</td>
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<tr>
<td>Sprache:</td>
<td>Language</td>
<td>German</td>
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</table>

| Empfohlene Fachterm: | Recommended term of study | 2 and 3 |
| SWS: | Term week hours | 2 Lecture + 2 Lecture |
| Angebotsfrequenz: | Regular cycle | Each term |

<table>
<thead>
<tr>
<th>Arbeitsschwerpunkte:</th>
<th>Workload</th>
<th>240 Hours</th>
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</thead>
<tbody>
<tr>
<td>(60 Full-time attendance course of study + 180 Self-study)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

**Elective Module for students of the study program**
- Master of Science in Informatik
  - Cyber-Physical Systems – Specialization Module III
  - Information Systems – Specialization Module III
  - Kognitive Technical Systems – Specialization Module III

### Lernziele / Learning target

- Erlernen der grundlegenden Methoden der Numerik.
- Vertrautheit mit den klassischen Algorithmen und numerischen Verfahren und deren Implementierung auf Rechnern.

### Inhalte Vorlesung / Content of the lecture

#### Numerics I:
- Grundlagen: Zahlendarstellung auf digitalen Rechnern, Matrixnormen, Banachscher Fixpunktsatz, Fehleranalyse.
- Berechnung von Eigenwerten: Vektor-Iteration, LR- und QR-Verfahren.
- Lineare Optimierung: Austauschschrit und Simplexverfahren, lineare Ungleichungen.

#### Numerics II:
- Numerische Integration

<table>
<thead>
<tr>
<th>Zu erbringende Studienleistung</th>
<th>Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>A written exam of both lectures (Numerics I in winter term, Numerics II in summer term)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung</th>
<th>Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic performance, which can be graded but usually is evaluated with pass or fail.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung</th>
<th>Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master of Science in Computer Science, Academic regulations of 2012: Academic performance which can be graded but is not taken into account in the final grade.</td>
<td></td>
</tr>
</tbody>
</table>
Peer-to-Peer Netzwerke / Peer-to-Peer Networks

Number: 11LE13MO-1314

Module Type: Elective Module
Modulverantwortlicher: Prof. Dr. C. Schindelhauer
Organisational unit: Chair Rechnernetze and Telematik

Zugehörige Lehrveranstaltungen: Lecture and exercises
Language: English

Empfohlene Voraussetzungen: Knowledge in Datenbanken und Informationssysteme / Data Bases and Information Systems

Empfohlenes Fachterm: 3
ECTS-Punkte: 6
SWS: 3 Lecture + 1 Exercises
Angebotsfrequenz: only in the winter term
Arbeitsaufwand: 180 Hours (64 Full-time attendance course of study + 116 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program:
- Bachelor of Science in Embedded Systems Engineering
- Lehramt an Gymnasien Informatik major subject
- Lehramt an Gymnasien Informatik additional major subject
- Lehramt an Gymnasien Informatik major subject in combination with Visual Arts or Music
- Master of Science in Embedded Systems Engineering
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme

Lernziele / Learning target

Students understand the advantages of different peer-to-peer network architectures. They can find appropriate network structures. They can classify existing peer-to-peer networks and analyse their communication structures and classify them. Students can apply anonymization techniques and performance enhancement.

Inhalte Vorlesung / Content of the lecture

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 result

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

### Grading

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

### Weight of examination result

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
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- 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.

### Literature

**Literatur / Literature**

- Shen, X.; Yu, H.; Buford, J.; Akon, M. (Eds.): Handbook of Peer-to-Peer Networking, Springer 2010
## Module: Prinzipien der Wissensrepräsentation / Knowledge Representation

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE13MO-1104</th>
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</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Nebel</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Grundlagen der Künstlichen Intelligenz</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Grundlagen der Künstliche Intelligenz / Foundations of Artificial Intelligence</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachterm:: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours</td>
</tr>
<tr>
<td></td>
<td>(64 Full-time attendance course of study + 116 Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
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- 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
  - Informationssysteme
  - Kognitive technische Systeme

### Lernziele / Learning target

The goal of the module is to enable students to understand logic-based knowledge representation formalisms and their associated inference services. Based on that they will learn how to extend existing KR systems and how to develop new ones. In particular, the course provides the skills for understanding current research literature in this field.
Inhalte Vorlesung / Content of the lecture

This course gives an introduction to logic based knowledge representation formalisms. We cover in particular the following topics:
• Foundations: Formal logic and complexity theory
• Modal logic: Systems and proof techniques
• Non-montonic logics
• Description logic and the semantic web
• Qualitative temporal and spatial representations and reasoning

Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

• 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.
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• 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.
R. J. Brachman and Hector J. Levesque, Knowledge Representation and Reasoning, Morgan Kaufman, 2004
Modul / Module

RNA Bioinformatik / RNA Bioinformatics

Nummer: Number 11LE13MO-1318

Modulverantwortlicher: Responsible person Prof. Dr. R. Backofen
Einrichtung: Organisational unit Chair Bioinformatik

Modultyp: Module Type Elective Module
Moduldauer: Module duration 1 Term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises
Sprache: Language English

Empfohlene Voraussetzungen: Recommended preconditions

- Basic knowledge of Bioinformatics and molecular biology
- Fundamental knowledge in algorithms

Empfohlenes Fachterm: Recommended term of study

<table>
<thead>
<tr>
<th>ECTS-Punkte: ECTS-points</th>
<th>6</th>
</tr>
</thead>
</table>

SWS: Term week hours

<table>
<thead>
<tr>
<th>2 Lecture + 2 Exercises</th>
<th>Angebotsfrequenz: Regular cycle only in the summer term</th>
</tr>
</thead>
</table>

Arbeitsaufwand: Workload

| 180 Hours (56 Full-time attendance course of study + 124 Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
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- Lehramt an Gymnasien in Informatik major subject in combination with Visual Arts or Music
- Master of Science in Embedded Systems Engineering
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

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.

### Inhalte Vorlesung / Content of the lecture

**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

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

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- 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.
<table>
<thead>
<tr>
<th>Literature / Literature</th>
</tr>
</thead>
</table>
Modul / Module

Sicherheit im Geschäftsprozessmanagement / Security in Business Process Management

Nummer: Number 11LE13MO-1315

Modulverantwortlicher: Responsible person Prof. Dr. G. Müller

Einrichtung: Organisational unit Institut für Informatik and Gesellschaft – Telematik

Modultyp: Module Type Elective Module

Moduldauer Module duration 1 Term

Zugehörige Lehrveranstaltungen: Connected events Lecture and exercises

Sprache: Language English

Empfohlenes Fachterm: Recommended term of study 3

ECTS-Punkte: ECTS-points 6

SWS: Term week hours 2 Lecture + 2 Exercises

Angebotsfrequenz: Regular cycle only in the winter term

Arbeitsaufwand: Workload 180 Hours (64 Full-time attendance course of study + 116 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
  - 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
    - Personal Profile
  - Master of Science in Informatik
    - Informationssysteme

Lernziele / Learning target

Business process management is of paramount importance in enterprise information systems. This lecture presents the foundations of business process management in the context of information security. Considering processes in their three possible incarnations, namely process models, runtime process instances and process logs, the lecture introduces the corresponding analysis and requirements formalization techniques and tools to automate the analysis.

Inhalte Vorlesung / Content of the lecture

- Business process management.
- Business process modeling.
- Petri nets for process and requirements modeling.
- Security models for access control/authorization.
- Process mining.
- Tools: WoPED, ProM, Disco, Nitro, SecSy, jBPM

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

### Literatur / Literature

Software Design, Modellierung and Analyse in UML / Software Design, Modelling and Analysis in UML

Nummer: 11LE13MO-1215

Modulverantwortlicher: Prod. Dr. A. Podelski

Einrichtung: Chair Softwaretechnik

Modultyp: Elective Module

Modulauer: 1 Term

Zugehörige Lehrveranstaltungen: Lecture and exercises

Sprache: English

Empfohlene Voraussetzungen: Knowledge in computer science theory; key course in software engineering

Empfohlenes Fachterm: 3

ECTS-Punkte: 6

SWS: 3 Lecture + 1 Exercises

Angebotsfrequenz: only in the winter term

Arbeitsaufwand: 180 Hours

(64 Full-time attendance course of study + 116 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme

Lernziele / Learning target

Approaches to the definition of formal semantics for complex visual formalisms, studied on the example of the Unified Modelling Language (UML) and its natural language semantics descriptions; basic knowledge of model-based software development, i.e. In particular the ability to formalise requirements and design aspects in UML and to understand such formalisations.
### Inhalte Vorlesung / Content of the lecture

Notion of models; usage of UML for documentation and modelling; Object Constraint Language; syntax and semantics of class diagrams for the description of structure; syntax and semantics of state machines and sequence diagrams as examples for constructive and reflective descriptions of behaviour (in the context of the OMG standard documents); concepts inheritance and meta-modelling; the exercises use contemporary tools for UML modelling, simulation, and code-generation.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

### Literatur / Literature

Will be announced at the beginning of the course.
Modul / Module

Spieltheorie / Game Theory

Nummer: Number
11LE13MO-1117

Modulverantwortlicher: Responsible person
Prof. Dr. B. Nebel

Einrichtung: Organisational unit
Chair Grundlagen der Künstlichen Intelligenz

Modultyp: Module Type
Elective Module

Moduldauer Module duration
1 Term

Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

Sprache: Language
English

Empfohlenes Fachterm: Recommended term of study
2

ECTS-Punkte: ECTS-points
4 oder 6

SWS: Term week hours
3 Lecture + 1 Exercises

Angebotsfrequenz: Regular cycle
only in the summer term

Arbeitsaufwand: Workload
180 Hours (56 Full-time attendance course of study + 124 Self-study)
Or 120 Hours (56 Full-time attendance course of study + 64 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Informationssysteme
  - Kognitive technische Systeme

The 4 ECTS Module is only available in the section “Specialization Module III”.

Lernziele / Learning target

After attending the module, students should be able to model simple strategic decision situations according to the game theory and to analyze them with regard to solutions (Nash equilibria, subgame perfect equilibria). Moreover, the students should be able to employ simple mechanisms.

Inhalte Vorlesung / Content of the lecture
Game theory is about rational decision making to further one's own objectives. In particular, it is about interactions and conflicts between the objectives of different players, i.e., about the question how the knowledge about other players' objectives influences one's own behavior. In the lecture, we study strategic and extensive games and discuss formalizations and solution concepts as well as algorithms for the computation of such solutions. In addition, the course is concerned with the mechanism design problem, i.e., with the question of how the rules of a social system should be designed in order to incentivize all participants to behave in a way that maximizes social welfare.

### Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
</table>
Modul / Module

Systeminfrastruktur für Data Science / System Infrastructure for Data Science

Nummer: Number
11LE13MO-1316

Modulverantwortlicher: Responsible person
Prof. Dr. P. Fischer

Einrichtung: Organisational unit
Chair Web Science

Modultyp: Module Type
Elective Module

Modulduer Module duration
1 Term

Zugehörrige Lehrveranstaltungen: Connected events
Lecture and exercises

Sprache: Language
English

Empfohlene Voraussetzungen: Recommended preconditions
Knowledge in Datenbanken und Informationssysteme / Databases and Information Systems

Empfohlenes Fachterm: Recommended term of study
3 ECTS-Punkte: ECTS-points
6

SWS: Term week hours
3 Lecture + 1 Exercises
Angebotsfrequenz: Regular cycle
only in the winter term

Arbeitsaufwand: Workload
180 Hours
(64 Full-time attendance course of study + 116 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

Students will develop and understanding of fundamental architectural options for designing and implementing scalable, expressive and responsive infrastructures for data science. This understanding comes from two directions: From a high-level point of view, students will be able to understand what systems exist and how they can be used. From a bottom-up perspective, students will gain an detailed insight and hand-on experience on the techniques used.
The course covers the fundamentals of different data infrastructure systems, among them classical databases, main-memory databases, data stream systems and cloud computing frameworks. To do so, the course provides details on the foundations of information system architecture, among them data storage, indexing, query processing, operator models and optimization. On this basis, it provides further insights how design assumptions change when such systems are used in contexts which require extreme scalability, very short response times or complex analytical operations.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.

**Literatur / Literature**

The classical data management areas are covered well in the following books:

- Kemper and Eickler. Datenbanksysteme. Eine Einführung. Oldenbourg-Verlag. (in German)

Modern techniques are mostly available in research papers, which are provided during the lecture.
### Modul / Module

**Verteilte Sytsteme / Distributed Systems**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1312</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. C. Schindelhauer, Prof. Dr. L. Lausen</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Rechnernetze and Telematik, Chair Datenbanken and Informationssysteme</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Datenbanken und Informationssysteme / Data Bases and Information Systems</td>
</tr>
</tbody>
</table>

#### Empfohlenes Fachterm:: Recommended term of study
- 2

#### ECTS-Punkte: ECTS-points
- 6

#### SWS: Term week hours
- 3 Lecture + 1 Exercises

#### Angebotsfrequenz: Regular cycle
- only in the summer term

#### Arbeitsaufwand: Workload
- 180 Hours
  - (56 Full-time attendance course of study + 124 Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme

### Lernziele / Learning target

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.
### Inhalte Vorlesung / Content of the lecture

After an introduction into distributed systems, the following major topics are discussed.

- System models
- Networks and Communications
- Time and global states
- Consistency and coordination
- Distributed Transactions
- Replication
- Modeling of distributed applications

Furthermore, current issues, which may originate from the following areas, are presented.

- Mobile Distributed Systems
- Web-based Distributed Systems
- Distributed multi-threading
- Peer-to-peer networks

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

### Literatur / Literature

- Additional literature will be presented in the lecture
## Modul / Module

**Zufallsgesteuerte Algorithmen / Randomized Algorithms**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1317</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Bast</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Algorithmen and Datenstrukturen</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in stochastics</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachterm: Recommended term of study**

<table>
<thead>
<tr>
<th>2</th>
</tr>
</thead>
</table>

**ECTS-Punkte: ECTS-points**

| 6 |

**SWS: Term week hours**

| 3 Lecture + 1 Exercises |

**Angebotsfrequenz: Regular cycle**

| nur im Sommerterm |

**Arbeitsaufwand: Workload**

| 180 Hours (56 Full-time attendance course of study + 124 Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme

### Lernziele / Learning target

Students should know basic techniques and applications for randomization and should get an intuition where randomized algorithms are favourable compared to deterministic strategies. They should understand tools for analyzing randomized algorithms in theory and practice.

### Inhalte Vorlesung / Content of the lecture

In the course, fundamental concepts for randomization are taught (Las Vegas, Monte Carlo algorithms). Based on applications in various areas as sorting, searching, testing, computational geometry, AI and graph theory, techniques for applying randomization are
introduced and analyzed. The focus lies on showing how randomized algorithms can improve the problem complexity in theory and practice. Moreover randomized on-line algorithms and the probabilistic method are motivated and applied to several problem classes.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Bewertung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
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- 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.

**Literatur / Literature**

The lecture will not follow a specific book; nevertheless standard text books for randomized algorithms will cover large portions of the content, e.g. Randomized Algorithms [Rajeev Motwani, Prabhakar Raghavan]. Additional literature in the form of papers will be announced during the course.
Specialization Area – Kognitive Technische Systeme / Cognitive Technical Systems

In the specialization area "Cognitive Technical Systems" 3 different specialization modules are offered:

- Cognitive Technical Systems - Specialization in Computer Science I
- Cognitive Technical Systems - Specialization in Computer Science II
- Cognitive Technical Systems - Specialization in Computer Science III

Students have to complete 2 modules with a volume of 24 ECTS.

In addition, the students have to complete 2 Seminars. Minimum 1 Seminar must be part of the specialization area "Cognitive Technical Systems".

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**Modul / Module**

**Cyber-PhysicalSystems - Seminar**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1201 11LE13MO-1202</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Becker,\n Prof. Dr. A. Podelski\n Prof. Dr. C. Scholl,\n Prof. Dr. T. Thiemann\n Prof. Dr. K. van Laerhoven</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair\n Rechnerarchitektur,\n Chair Softwaretechnik,\n Chair Betriebssysteme,\n Chair Programmiersprachen,\n Chair Embedded Systems Engineering</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German or English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Programming skills, knowledge in algorithms and data structures and operations systems</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester:: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>4</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Seminar</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Each term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>120 hours\n (28 or 32 hours Full-time attendance course of study + 92 oder 88 hours self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Master of Science in Informatik
### Lernziele / Learning target

A seminar gives students the opportunity to get acquainted with a specific topic in Cyber-Physical Systems. They shall learn to independently search for scientific literature and to structure the same. Furthermore they will learn to write short scientific texts and present the results to a group. Concerning scientific writing they will learn the rules for good scientific practice.

### Inhalte Seminar / Content of the seminar

Special topics from the selected workspace  
Overall Topics: proper citation, references, documentation of results, avoids misconduct (plagiarism, misrepresentation, etc.)

### Zu erbringende Studienleistung / Course Achievement

The coursework consists of a seminar paper and an oral presentation. In general, the active and regular participation in the course is requested.

### Benotung / Grading

Academic performance, which can be graded but usually is evaluated with pass or fail.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Computer Science, Academic regulations of 2012: Academic performance which can be graded but is not taken into account in the final grade.

### Literatur / Literature

Will be announced at the beginning of the course.
Modulhandbuch M.Sc. Informatik – Information Systems - Seminar

**Information Systems - Seminar**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1301 11LE13MO-1302</th>
</tr>
</thead>
</table>

**Modulverantwortlicher: Responsible person**  
Prof. Dr. M. Müller, Prof. Dr. H. Bast, Prof. Dr. F. Kuhn, Prof. Dr. R. Backofen, Prof. Dr. G. Lausen, Prof. Dr. G. Schneider, Prof. Dr. C. Schindelhauer, Prof. Dr. P. Fischer

**Einrichtung: Organisational unit**  
Institut für Informatik und Gesellschaft, Chair Algorithmen und Datenstrukturen, Chair Algorithmen und Komplexität, Chair Bioinformatik, Chair Datenbanken, Chair Kommunikationssysteme, Chair Rechnernetze und Telematik, Chair Web Science

**Modultyp: Module Type**  
Elective Module

**Modulduer Module duration**  
1 Term

**Zugehörige Lehrveranstaltungen: Connected events**  
Seminar

**Sprache: Language**  
German or English

**Empfohlene Voraussetzungen: Recommended preconditions**  
Programming skills, knowledge in algorithms and data structures and operations systems

**Empfohlenes Fachsemester: Recommended term of study**  
2

**ECTS-Punkte: ECTS-points**  
4

**SWS: Semester week hours**  
2 Seminar

**Angebotsfrequenz: Regular cycle**  
Each term

**Arbeitsaufwand: Workload**  
120 hours  
(28 or 32 hours Full-time attendance course of study + 92 oder 88 hours self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program  
- Master of Science in Informatik

**Lernziele / Learning target**

A seminar gives students the opportunity to get acquainted with a specific topic in Cyber-Physical Systems. They shall learn to independently search for scientific literature and to structure the same. Furthermore they will learn to write short scientific texts and present the results to a group. Concerning scientific writing they will learn the rules for good scientific practice.
### Inhalte Seminar / Content of the seminar

Special topics from the selected workspace  
Overall Topics: proper citation, references, documentation of results, avoids misconduct  
(plagiarism, misrepresentation, etc.)

### Zu erbringende Studienleistung / Course Achievement

The coursework consists of a seminar paper and an oral presentation. In general, the active and regular participation in the course is requested.

### Benotung / Grading

Academic performance, which can be graded but usually is evaluated with pass or fail.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Computer Science, Academic regulations of 2012: Academic performance which can be graded but is not taken into account in the final grade.

### Literatur / Literature

Will be announced at the beginning of the course.
## Kognitive Technical Systems - Seminar

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1101 11LE13MO-1102</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. W. Burgard, Prof. Dr. M. Teschner, N.N., Prof. Dr. T. Brox, PD Dr. Hutter</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Autonome Intelligente Systeme, Lehrstuhl Graphische Datenverarbeitung, Chair Maschinelles Lernen, Chair Mustererkennung und Bildverarbeitung, Arbeitsgruppe Automatisches Algorithmen-</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Seminar</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German or English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Programming skills, knowledge in algorithms and data structures and operations systems</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>4</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>2 Seminar</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Each term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>120 hours (28 or 32 hours Full-time attendance course of study + 92 oder 88 hours self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Informatik

### Lernziele / Learning target

A seminar gives students the opportunity to get acquainted with a specific topic in Cyber-Physical Systems. They shall learn to independently search for scientific literature and to structure the same. Furthermore they will learn to write short scientific texts and present the results to a group. Concerning scientific writing they will learn the rules for good scientific practice.
### Inhalte Seminar / Content of the seminar

Special topics from the selected workspace. Overall Topics: proper citation, references, documentation of results, avoids misconduct (plagiarism, misrepresentation, etc.)

### Zu erbringende Studienleistung / Course Achievement

The coursework consists of a seminar paper and an oral presentation. In general, the active and regular participation in the course is requested.

### Benotung / Grading

Academic performance, which can be graded but usually is evaluated with pass or fail.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Master of Science in Computer Science, Academic regulations of 2012: Academic performance which can be graded but is not taken into account in the final grade.

### Literatur / Literature

Will be announced at the beginning of the course.
### Modul / Module

**3D Bildanalyse / 3D Image Analysis**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1105</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Ronneberger</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Bildanalyse</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modul dauern: Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>english</td>
</tr>
</tbody>
</table>
| Empfohlene Voraussetzungen: Recommended preconditions | Skills in:  
  - Image Processing and Computer Graphics  
  - Programming skills (preferably in C++) |

<table>
<thead>
<tr>
<th>Empfohlenes Fachterm: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the summer term</td>
</tr>
</tbody>
</table>
| Arbeitsaufwand: Workload | 180 Hours  
  (56 Full-time attendance course of study + 124 Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program:
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme
### Lernziele / Learning target

The students understand the basic concepts for analysis of 3D volumetric data sets, with focus on registration and feature extraction. They have an overview over existing state-of-the-art methods. They apply these concepts to solve tasks in biomedical applications.

### Inhalte Vorlesung / Content of the lecture

This course will introduce the basic concepts and techniques that are used in analysis of 3D images (volumetric data sets). The focus will be on data sets that are recorded in the biomedical research. The exercises will focus on practical applications of the concepts, efficient 3D data handling and processing in C++, common libraries and tools in this area. The students are expected to write small programs that solve given 3D image analysis tasks.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
### Bioinformatics I / Bioinformatics I

<table>
<thead>
<tr>
<th><strong>Number</strong></th>
<th>11LE13MO-1309</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher</strong></td>
<td>Prof. Dr. R. Backofen</td>
</tr>
<tr>
<td><strong>Einrichtung</strong></td>
<td>Chair Bioinformatik</td>
</tr>
<tr>
<td><strong>Modultyp</strong></td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer</strong></td>
<td>1 Term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen</strong></td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td><strong>Sprache</strong></td>
<td>English</td>
</tr>
</tbody>
</table>
| **Empfohlene Voraussetzungen** | • Basic knowledge in molecular biology  
• Basic knowledge in algorithms |
| **Empfohlenes Fachterm:** | 2 |
| **ECTS-Punkte:** | 6 |
| **SWS:** | 2 Lecture + 2 Exercises |
| **Angebotsfrequenz:** | only in the summer term |
| **Arbeitsaufwand:** | 180 Hours  
(56 Full-time attendance course of study + 124 Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme
  - Fachfremder Wahlbereich “Bioinformatik”

### Lernziele / Learning target

This module is an introduction to major topics in the field of bioinformatics with a special focus on sequence analysis. In the course we revise fundamental principles in biology 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 course, students will become familiar with applications of Markov models in Bioinformatics and be able to compute phylogenetic trees.
### Inhalte Vorlesung / Content of the lecture

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

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

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

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
Modul / Module

Bioinformatik II / Bioinformatics II

<table>
<thead>
<tr>
<th>Nummer</th>
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</thead>
<tbody>
<tr>
<td>Modulverantwortlicher</td>
<td>Prof. Dr. R. Backofen</td>
</tr>
<tr>
<td>Einrichtung</td>
<td>Chair Bioinformatik</td>
</tr>
<tr>
<td>Modultyp</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache</td>
<td>English</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachterm</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte</td>
<td>6</td>
</tr>
<tr>
<td>SWS</td>
<td>2 Lecture + 2 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand</td>
<td>180 Hours</td>
</tr>
<tr>
<td>Workload</td>
<td>(64 Full-time attendance course of study + 116 Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
- Verteilte Systeme
- Personal Profile
- Master of Science in Informatik
- Informationssysteme
- Kognitive technische Systeme
- Fachfremder Wahlbereich “Bioinformatik”

Lernziele / Learning target

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.
**Inhalte Vorlesung / Content of the lecture**

<table>
<thead>
<tr>
<th>Multiple sequence alignment</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Scoring schemes</td>
<td></td>
</tr>
<tr>
<td>• Exact and heuristic methods (progressive approaches, t-coffee etc.)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hidden markov models</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Profile HMMs for multiple alignment</td>
<td></td>
</tr>
<tr>
<td>• Learning profile HMMs</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Protein structure</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Simple protein models</td>
<td></td>
</tr>
<tr>
<td>• Protein threading</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RNA structure prediction</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Nussinov algorithm</td>
<td></td>
</tr>
<tr>
<td>• Zuker algorithm</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy Landscapes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Monte-Carlo sampling</td>
<td></td>
</tr>
<tr>
<td>• Abstractions</td>
<td></td>
</tr>
<tr>
<td>• Folding dynamics</td>
<td></td>
</tr>
</tbody>
</table>

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
<table>
<thead>
<tr>
<th>Literature / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• D.W. Mount: Bioinformatics - Sequence and Genome Analysis Cold Spring Harbor</td>
</tr>
</tbody>
</table>
## Computer Vision I

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1107</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Brox</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Mustererkennung und Bildverarbeitung</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Image Processing and Computer Graphics</td>
</tr>
</tbody>
</table>

### Empfohlenes Fachterm: Recommended term of study

<table>
<thead>
<tr>
<th>ECTS-Punkte: ECTS-points</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours (64 Full-time attendance course of study + 116 Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
- Kognitive technische Systeme

### Lernziele / Learning target

Students learn about some of the typical problems and methodologies in computer vision. After the course, they should be capable to read the current literature and understand standard concepts used in computer vision research. Moreover, they should be able to implement the techniques discussed in the lectures and to adapt them to their needs, if necessary.

### Inhalte Vorlesung / Content of the lecture

The course presents some of the typical computer vision tasks and current solutions. This includes various image enhancement methods like nonlinear diffusion and deblurring. The
main focus is on various segmentation techniques and motion estimation in video sequences. Further topics will be covered by the successive course Computer Vision II in the summer term. The exercises mainly consist of programming assignments and help to get a deeper insight in the discussed methods. The most relevant techniques will be implemented in C++ and leave the students with a useful toolbox at the end of the course.

### Zu erbringende Prüfungsleistung / Examination result

- written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
## Computer Vision II

<table>
<thead>
<tr>
<th><strong>Nummer:</strong> Number</th>
<th>11LE13MO-1108</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
<td>Prof. Dr. T. Brox</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
<td>Chair Mustererkennung und Bildverarbeitung</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer:</strong> Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
<td>English</td>
</tr>
</tbody>
</table>
| **Empfohlene Voraussetzungen:** Recommended preconditions | • Bildverarbeitung und Computergraphik / Image Processing and Computer Graphics  
• Computer Vision I |
| **Empfohlenes Fachterm:** Recommended term of study | 2 |
| **ECTS-Punkte:** ECTS-points | 4 oder 6 |
| **SWS:** Term week hours | 3 Lecture + 1 Exercises |
| **Angebotsfrequenz:** Regular cycle | only in the winter term |
| **Arbeitsaufwand:** Workload | 180 Hours  
(56 Full-time attendance course of study + 124 Self-study)  
or  
120 Hours  
(56 Full-time attendance course of study + 64 Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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  
  - Personal Profile
- Master of Science in Informatik  
  - Kognitive technische Systeme

The 4 ECTS Module is only available in the section “Specialization Module III”.

### Lernziele / Learning target

Students learn about the typical problems and methodologies in computer vision not covered in the course Computer Vision I. After the course, they should be capable to read the current literature and understand almost all of the standard concepts currently used in computer vision research. They should be able to implement the techniques discussed in the lectures and to adapt them to their needs, if necessary.
### Inhalte Vorlesung / Content of the lecture

The course continues the course Computer Vision I. It presents the typical computer vision tasks not covered in the previous course. This includes point and objects tracking, 3D geometry and reconstruction of 3D scenes from stereo images or videos, as well as object recognition. The exercises mainly consist of programming assignments and help to get a deeper insight in the discussed methods. Some of the most relevant techniques will be implemented in C++ and leave the students with a useful toolbox at the end of the course.

### Inhalte Übung / Content of the exercises

Programming assignments, completion and presentation of a project work

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination (4 ECTS)

### Zu erbringende Studienleistung / Course Achievement

Programming assignments, completion and presentation of a project work (2 ECTS)

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
**Modul / Module**

**Constraint-Satisfaction-Probleme / Constraint-Satisfaction-Problems**

<table>
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<th>Nummer: Number</th>
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<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Nebel</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Grundlagen der Künstlichen Intelligenz</td>
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<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
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<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Artificial Intelligence</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachterm: Recommended term of study</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
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</tr>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours</td>
</tr>
<tr>
<td></td>
<td>(64 Full-time attendance course of study + 116 Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme
  - Kognitive technische Systeme

**Lernziele / Learning target**

The aim of this module is to deepen the understanding of a broad variety of standard techniques used for solving constraint satisfaction problems. After the course students should be able to implement and evaluate such techniques. Moreover students should then be able to understand current research papers and to start qualifying projects or theses on topics related to the lecture.
### Inhalte Vorlesung / Content of the lecture

The lecture provides an in-depth introduction into the field of constraint satisfaction problems (CSP), one of the major fields in current AI research. In particular, we study the following topics:

- Foundations
- Constraint propagation (arc consistency, path consistency, global consistency)
- Search methods (backtracking, backjumping, local search)
- Constraint optimization problems (COP)
- Expressiveness and computational complexity of constraint languages
- CSP on infinite domains

### Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
<table>
<thead>
<tr>
<th>Literature / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Dechter, Constraint Processing, Morgan Kaufmann, 2003</td>
</tr>
<tr>
<td>- Rossi, van Beek, Walsh, Handbook of Constraint Programming, Elsevier, 2006</td>
</tr>
</tbody>
</table>
Datenanalyse and Abfragesprachen / Data Analysis and Query Languages

Nummer: 11LE13MO-1322

Modulverantwortlicher: Prof. Dr. G. Lausen

Einrichtung: Chair Datenbanken and Informationssysteme

Modultyp: Elective Module

Modulverantwortlicher: Prof. Dr. G. Lausen

Modulverantwortlicher: Prof. Dr. G. Lausen

Modulverantwortlicher: Prof. Dr. G. Lausen

Modulverantwortlicher: Prof. Dr. G. Lausen

Zugehörige Lehrveranstaltungen: Lecture and exercises

Sprache: English

Empfohlene Voraussetzungen: Knowledte in Datenbanken and Informationssysteme / Data Bases and Information Systems

Empfohlenes Fachterm:: 2

ECTS-Punkte: 6

SWS: 3 Lecture + 1 Exercises

Angebotsfrequenz: only in the summer term

Arbeitsaufwand: 180 Hours

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

Students will learn to use basic techniques for analysis of web-scale massive datasets. Students will be able to apply these techniques on basic examples. Students will be familiar with query languages designed for the web of data. Students will know how to design processing tasks using the MapReduce paradigm.
### Inhalte Vorlesung / Content of the lecture

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.</td>
<td>Basics of the Web</td>
</tr>
<tr>
<td>18.</td>
<td>Search Engines and Link Analysis</td>
</tr>
<tr>
<td>19.</td>
<td>Query language SPARQL</td>
</tr>
<tr>
<td>20.</td>
<td>Web-scale Computation</td>
</tr>
<tr>
<td>21.</td>
<td>Finding Similar Items</td>
</tr>
<tr>
<td>22.</td>
<td>Mining Data Streams</td>
</tr>
<tr>
<td>23.</td>
<td>Advertising and Recommendations</td>
</tr>
<tr>
<td>24.</td>
<td>Mining Social Network GraphsMatrix</td>
</tr>
<tr>
<td></td>
<td>Dimensionality Reduction</td>
</tr>
</tbody>
</table>

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

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- 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.

### Literatur / Literature

Module / Module

Einführung in die Mobile Robotik / Introduction to Mobile Robotics

**Nummer: Number** 11LE13MO-1115

**Modulverantwortlicher: Responsible person** Prof. Dr. W. Burgard

**Modultyp: Module Type** Elective Module

**Zugehörige Lehrveranstaltungen: Connected events** Lecture and exercises

**Sprache: Language** English

**Getempfohlene Voraussetzungen: Recommended preconditions** Knowledge in Grundlagen der Künstlichen Intelligenz / Foundations in Artificial Intelligence

**Empfohlenes Fachterm: Recommended term of study** 2

**ECTS-Punkte: ECTS-points** 6

**SWS: Term week hours** 3 Lecture + 1 Exercises

**Angebotsfrequenz: Regular cycle** only in the winter term

**Arbeitsaufwand: Workload** 180 Hours (56 Full-time attendance course of study + 124 Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Cognitive technische Systeme

**Lernziele / Learning target**

Throughout this module participants will learn foundations of mobile robotics. They will learn basic principles of drives and sensors. Additionally, they will learn the mathematical foundations of state estimation processes and different implementations of recursive Bayes filters including the discrete filter, the Kalman filter and the particle filter. Furthermore, participants will understand how to apply these filters in the context of different state estimation problems in robotics. Finally, participants will get to know basic approaches to navigation including localization, mapping, path planning, collision avoidance and perception.
**Inhalte Vorlesung / Content of the lecture**

Throughout the course, the following concepts will be presented: Drives and sensors for mobile robotics including their characteristics, recursive Bayes filters, Kalman filter, particle filter, discrete filter, probabilistic localization, mapping, simultaneous localization and mapping, path planning, collision avoidance and sensor interpretation.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
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- 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.

**Literatur / Literature**

# Einführung in die Modallogik / Introduction to Modal Logic

**Number:** 11LE13MO-1121  
**Modulverantwortlicher:** Prof. Dr. B. Nebel  
**Einrichtung:** Chair Grundlagen der Künstlichen Intelligenz  
**Modultyp:** Elective Module  
**Module duration:** 1 Term  
**Zugehörige Lehrveranstaltungen:** Lecture and exercises  
**Sprache:** English  
**Empfohlene Voraussetzungen:** Knowledge in Grundlagen der Künstlichen Intelligenz / Foundations in Artificial Intelligence  
**Empfohlenes Fachterm:** 2  
**ECTS-Punkte:** 6  
**SWS:** 3 Lecture + 1 Exercises  
**Angebotsfrequenz:** only in the summer term  
**Arbeitsaufwand:** 180 Hours (56 Full-time attendance course of study + 124 Self-study)  

## Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program  
- Bachelor of Science in Embedded Systems Engineering  
- Bachelor of Science in Mathematik  
- 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  
  - Personal Profile  
- Master of Science in Informatik  
  - Informationssysteme  
  - Kognitive technische Systeme  

## Lernziele / Learning target

The aim of this module is to give students a basic understanding of key concepts and standard techniques used in modal logics. After the module students should be able to implement and evaluate such techniques. Moreover students should then be able to understand current research papers and to start qualifying projects or theses on topics related to the lecture.

## Inhalte Vorlesung / Content of the lecture
The term “modal logics” comprises a family of logics, which are used in quite different fields in computer science (such as knowledge representation and reasoning, multi-agent systems, and formal verification). The lecture provides an in-depth introduction into standard techniques used in modal logics and provides an overview of closely related logics as well as their application. In particular, we will study the following topics:

- Uni- and multi-modal logics
- Expressiveness and computational complexity
- Tableaux-based decision procedures
- Epistemic logics
- Temporal and dynamic logics
- Description logics

### Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
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- 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.
Literatur / Literature

**Modul / Module**

**Einführung in die Multiagentensysteme / Introduction to Multiagent Systems**

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE13MO-1118</th>
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</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Nebel</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Grundlagen der Künstlichen Intelligenz</td>
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<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

The module has a strong focus on practical solutions to multi-agent systems. Therefore, programming skills in Java or C++ are mandatory. Furthermore, knowledge of concepts from the lecture Foundations of Artificial Intelligence (Grundlagen der Künstlichen Intelligenz), such as search methods, and probabilistic methods, is useful.

**Empfohlenes Fachterm: Recommended term of study**

<table>
<thead>
<tr>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Lecture + 1 Exercises</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the summer term</td>
</tr>
</tbody>
</table>

**Arbeitsaufwand: Workload**

| 180 Hours (56 Full-time attendance course of study + 124 Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program

- Bachelor of Science in Embedded Systems Engineering
- 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
  - Informationssysteme
  - Kognitive technische Systeme

**Lernziele / Learning target**

This module will address theoretical and practical aspects of multiagent systems. The rationale behind modeling problems in terms of agents in computer science and robotics will be explained. We will see how this approach is different from and relates to other programming paradigms, and which types problems can be solved using agent architectures. More specifically, the following topics will be included:
Inhalte Vorlesung / Content of the lecture

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

Topics of this course are:
- Agent architectures
- Agent planning
- Methods of communication
- Game Theory
- Common sensing and world-modeling
- Distributed decision making
- Cooperation and coordination

Inhalte Übung / Content of the exercises

Für die Zulassung zur Klausur müssen 50% der erreichbaren Punkte aus den Exercisesen und Projekten erreicht werden

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

Um zur Abschlussprüfung zugelassen zu werden, muss die zu diesem Modul gehörige Lehrveranstaltung Exercises erfolgreich absolviert werden. Welche Leistung der Studierenden zu erbringen hat, wird in der Inhaltsbeschreibung der Exercises detailliert beschrieben und ebenso zu Beginn der Lehrveranstaltung vom Dozierenden mitgeteilt.

Benotung / Grading

The module grade is calculated from the result of the final examination.
<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
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</thead>
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<tr>
<td>• 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.</td>
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<tr>
<td>• 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.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
</table>
### Modul / Module

**Fortgeschrittene Computergraphik / Advanced Computer Graphics**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1106</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Teschner</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Graphische Datenverarbeitung</td>
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<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>
| Empfohlene Voraussetzungen: Recommended preconditions | • Programming skills  
• Knowledge in Algorithms and Data Structures, Linear Algebra and Analysis  
• Knowledge in Image Processing and Computer Graphics |
| Empfohlenes Fachterm: Recommended term of study | 2 |
| ECTS-Punkte: ECTS-points | 6 |
| SWS: Term week hours | 2 Lecture + 2 Exercises |
| Angebotsfrequenz: Regular cycle | only in the summer term |
| Arbeitsaufwand: Workload | 180 Hours  
(56 Full-time attendance course of study + 124 Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme

### Lernziele / Learning target

The module offers deeper insights into generative computer graphics. Various models, data structures, numerical techniques and algorithms for all components of the raytracing concept for image generation are covered. The students learn a variety of relevant techniques. They also learn how to analyze the characteristics of the approaches and how to compare them.
Inhalte Vorlesung / Content of the lecture

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.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

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- 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.

Literatur / Literature

- Dutre, Bala, Bekaert: Advanced Global Illumination, A K Peters, 2006
- Pharr, Humphreys: Physically Based Rendering, Elsevier, 2010
## Modulhandbuch M.Sc. Informatik – Handlungsplanung / Artificial Intelligence Planning

### Handlungsplanung / Artificial Intelligence Planning

<table>
<thead>
<tr>
<th>Nummer: Number</th>
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<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Nebel</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Grundlagen der Künstlichen Intelligenz</td>
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<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
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<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Grundlagen der Künstlichen Intelligenz / Foundations of Artificial Intelligence</td>
</tr>
<tr>
<td>Empfohlenes Fachterm: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
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<tr>
<td>SWS: Term week hours</td>
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<td>Arbeitsaufwand: Workload</td>
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</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
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- 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
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

### Lernziele / Learning target

Students are made familiar with the theory and the basic algorithms of AI planning to an extent that allows them to understand current research literature in the field of AI planning, to put it into context, and to actively participate in AI planning research.
### Inhalte Vorlesung / Content of the lecture

The lecture offers a detailed introduction into theoretical and algorithmic foundations of modern AI planning systems. In more detail, the following topics are covered:

- Formalization of AI planning
- Planning as search: progression and regression
- Satisficing heuristic search planning with delete-relaxation heuristics
- Optimal heuristic search planning with abstraction heuristics
- Nondeterministic and probabilistic planning
- Theoretical complexity of AI planning

Moreover, presumably at least one of the following additional topics will be covered:

- Computation and use of invariants
- Optimal planning as model checking with binary decision diagrams (BDDs)
- Planning as satisfiability

### Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

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### Gewichtung der Prüfungsleistung / Weight of examination result

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- 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.

**Literatur / Literature**

- Rintanen: Introduction to Automated Planning. Lecture Notes for the SS 2005 course. Albert-Ludwigs-Universität-Freiburg, 2005
Modul / Module

Ingenieurwissenschaft trifft auf Biologie / Engineering meets Biology

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-PM-03</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. O. Ronneberger</td>
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<td>Einrichtung: Organisational unit</td>
<td>Chair Bildverarbeitung</td>
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<td>Moduldauer Module duration</td>
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<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>

Empfohlenes Fachterm:: Recommended term of study | 3 |
| ECTS-Punkte: ECTS-points | 6 |
| SWS: Term week hours | 2 Lecture + 3,4 Exercises |
| Angebotsfrequenz: Regular cycle | only in the winter term |
| Arbeitsaufwand: Workload | 180 Hours (86,5 Full-time attendance course of study + 93,5 Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Interdisciplinary Track
- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme

Lernziele / Learning target

Dieses gemeinsame Modul für Studierende der Biologie und der Ingenieurwissenschaften soll dazu anregen, die Methoden der jeweils anderen Disziplin kennen zu lernen und mit denjenigen der eigenen Disziplin zu kombinieren. Die Studierenden können
- die Prinzipien der Synthetischen Biologie erklären.
- können genetische Netzwerke designen und analysieren.
- den Prozess der Bildaufnahme erklären und einfache Bildanalyseaufgaben durchführen.
- können neuronale Netzwerke beschreiben und neurophysiologische Messverfahren anwenden.
- elementare Prinzipien, Vorgehensweisen, momentane Begrenzungen und Perspektiven der Neurotechnologie beschreiben und erklären.
- ethische and sicherheitsrelevante Aspekte der Synthetischen Biologie and Neurotechnologie benennen and erläutern.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Bewertung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.

**Literatur / Literature**

Lectureshandout and Skript zu den Exercisesen werden in den Veranstaltungen verteilt.
### Informationswiedergewinnung / Information Retrieval

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1304</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Bast</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Algorithmen and Datenstrukturen</td>
</tr>
<tr>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Bast</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Bast</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Bast</td>
</tr>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Bast</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in algorithms and data structures, basic programming skills.</td>
</tr>
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<td>Empfohlenes Fachterm: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Term week hours</td>
<td>2 Lecture + 2 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours (64 Full-time attendance course of study + 116 Self-study)</td>
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</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program:
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

### Lernziele / Learning target

Students should understand the foundations of information systems, in particular search engines. They should be able to apply this knowledge in practice. This concerns algorithmic aspects (e.g., index data structures), quality aspects (e.g. ranking of search results) and user interfaces (e.g. AJAX programming).

### Inhalte Vorlesung / Content of the lecture

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.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Bewertung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

Literatur / Literature

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.
Modul / Module

Maschinelles Lernen / Machine Learning

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<td>Responsible person</td>
<td>N.N.</td>
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<tr>
<td>Einrichtung:</td>
<td>Organisational unit</td>
<td>Chair Maschinelles Lernen and Natürlichsprachliche Systeme</td>
</tr>
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<td>Modultyp:</td>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer:</td>
<td>Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen:</td>
<td>Recommended preconditions</td>
<td>Knowledge in Grundlagen der Künstlichen Intelligenz / Foundations of Artificial Intelligence</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachterm: | Recommended term of study | 2 |
| ECTS-Punkte: | ECTS-points | 6 |
| SWS: | Term week hours | 3 Lecture + 1 Exercises |
| Angebotsfrequenz: | Regular cycle | only in the summer term |
| Arbeitsaufwand: | Workload | 180 Hours (56 Full-time attendance course of study + 124 Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

Understanding of the basic concepts of machine learning, ability to think on different levels of abstraction, knowledge of exemplary implementations of learning algorithms, ability to independently identify connections of the concepts presented.
### Inhalte Vorlesung / Content of the lecture

Characterization of supervised, unsupervised and reinforcement learning, concept learning, decision trees, neural networks, probabilistic methods, committee techniques, reinforcement learning.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

### Literatur / Literature

- Mitchell: Machine Learning
- Murphy: Machine Learning – A Probabilistic Perspective
Maschinelles Lernen in Lebenswissenschaften / Machine Learning in Life Science

**Modulverantwortlicher:**
Prof. Dr. R. Backofen

**Modulverantwortlicher:**
Chair Bioinformatik

**Modultyp:**
Elective Module

**Modulnummer:**
11LE13MO-1112

**Empfohlene Voraussetzungen:**
Knowledge in machine learning and basic knowledge in molecular biology. Specialisation course in Bioinformatics II is helpful.

**Empfohlener Fachbereich:**
Recommended term of study

**SWS:**
2 Lecture + 2 Exercises

**Arbeitsaufwand:**
180 Hours

**Verwendbarkeit der Veranstaltung / Usability of the module**
Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme

**Lernziele / Learning target**
The aim of this module is to introduce the basic techniques and types of machine learning models employed in modern molecular biology research.

**Inhalte Vorlesung / Content of the lecture**
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.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.

**Literatur / Literature**

The course material is based on influential publications both in the Machine Learning and/or Bioinformatics literature:

- P Baldi, S Brunak, Y Chauvin, C.A.F Andersen, H Nielsen, Assessing the accuracy of prediction algorithms for classification: an overview, Bioinformatics 2000
- T Fawcett, An introduction to ROC analysis, Pattern Recognition Letters 2006
- T Dietterich, Approximate statistical tests for comparing supervised classification learning algorithms, Neural Computation 1998
- D Jiang, C Tang, A Zhang, Cluster analysis for gene expression data: A survey, IEEE transactions on knowledge and data engineering 2004
- S.C Madeira, A.L Oliveira, Biclustering algorithms for biological data analysis: a survey, IEEE Transactions on computational Biology and Bioinformatics 2004
- A Krause, J Stoye, Large scale hierarchical clustering of protein sequences, BMC bioinformatics 2005
- X.W. Chen, Prediction of protein-protein interactions using random decision forest framework, Bioinformatics 2005
Modul / Module

Maschinelles Lernen und Optimierung für Algorithmendesign / Machine Learning and Optimization for Algorithm Design

Nummer: Number | 11LE13MO-1122
---|---
Modulverantwortlicher: Responsible person | Dr. F. Hutter
Einrichtung: Organisational unit | Chair Grundlagen der Künstlichen Intelligenz
Modultyp: Module Type | Elective Module
Moduldauer: Module duration | 1 Term
Zugehörige Lehrveranstaltungen: Connected events | Lecture and exercises
Sprache: Language | English
Zwingende Voraussetzungen: Mandatory preconditions | Basic skills in Python
Empfohlene Voraussetzungen: Recommended preconditions | Foundations of artificial intelligence; machine learning

Empfohlenes Fachterm: Recommended term of study | 3
ECTS-Punkte: ECTS-points | 6
SWS: Term week hours | 3 Lecture + 1 Exercises
Angebotsfrequenz: Regular cycle | only in the winter term
Arbeitsaufwand: Workload | 180 Hours
(64 Full-time attendance course of study + 116 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

Students learn the foundations of automatic algorithm design based on methods from machine learning and optimization. They can explain and apply methods from algorithm configuration and algorithm portfolios to new problems, and can statistically analyze the performance of algorithms. In particular, they can apply these methods to solve hard combinatorial problems (SAT,
TSP, Planning...) more effectively.

### Inhalte Vorlesung / Content of the lecture

The lectures are partitioned in 6 modules:
- Introduction to NP-Hard Problems,
- Methods for solving combinatorial problems,
- Empirical Evaluation of Algorithms,
- Statistical Models of the Empirical Hardness of NP-Hard Problems,
- Algorithm Configuration,
- Algorithm Portfolios

### Inhalte Übung / Content of the exercises

The exercises follow the lectures. There will be at least one exercise for each module, in which the students independently implement the lecture material.

In the end there is a large project (80h), in which the students apply all aspects of the course to a new problem domain.

This project will be presented in the first part of the final exam.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

In preparation for the written or oral exam, students work on a project, which they present in the first 15 minutes of the exam. In the second 15 minutes they answer questions about further course material.

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.
<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
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### Modellbildung und Systemidentifikation

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<td>Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Organisational unit</td>
<td>Chair Systemtheorie</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulduauer:</td>
<td>Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>Englisch</td>
</tr>
</tbody>
</table>

#### Empfohlene Voraussetzungen:

Knowledge of:
- Mathematik I für Ingenieure und Informatiker / Mathematics I für Engineers and Computer Scientists
- Mathematik II für Ingenieure / Mathematics II für Engineers
- Differentialgleichungen / Differential Equations
- Systemtheorie und Regelungstechnik / Systems Theory and Feedback Control

#### Empfohlenes Fachsemester:

<table>
<thead>
<tr>
<th>Fachsemester:</th>
<th>Recommended term of study</th>
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</tr>
</thead>
<tbody>
<tr>
<td>ECTS-Punkte:</td>
<td>ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS:</td>
<td>Semester week hours</td>
<td>2 Lecture + 2 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz:</td>
<td>Regular cycle</td>
<td>Only in winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand:</td>
<td>Workload</td>
<td>180 Hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(64 Full-time attendance course of study + 116 Self-study)</td>
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</tbody>
</table>

#### Verwendbarkeit der Veranstaltung / Usability of the module

Mandatory Module for students in the study program
- Master of Science in Embedded Systems Engineering

Elective Module for students in the study program
- Master of Science in Informatik
  - Cyber-Physical Systems
  - Kognitive technische Systeme
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
### Lernziele / Learning target

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.

### Inhalte Vorlesung / Content of the lecture

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.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

### Literatur / Literature

- Lecture manuscript
- Lecture manuscript "System Identification" by J
### Modul / Module

#### Numerik / Numerics

<table>
<thead>
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</tr>
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<tbody>
<tr>
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<td>Examiners of the Department of Mathematics</td>
</tr>
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<td>Einrichtung: Organisational unit</td>
<td>Department of Mathematics</td>
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<td>Moduldauer Module duration</td>
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<td>Lecture and exercises</td>
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<td>Sprache: Language</td>
<td>German</td>
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<td>Empfohlenes Fachterm: Recommended term of study</td>
<td>2 and 3</td>
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<td>8</td>
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<tr>
<td>SWS: Term week hours</td>
<td>2 Lecture + 2 Lecture</td>
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<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>Each term</td>
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<tr>
<td>Arbeitsaufwand: Workload</td>
<td>240 Hours (60 Full-time attendance course of study + 180 Self-study)</td>
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</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Informatik
  - Cyber-Physical Systems – Specialization Module III
  - Information Systems – Specialization Module III
  - Kognitive Technical Systems – Specialization Module III

### Lernziele / Learning target

- Erlernen der grundlegenden Methoden der Numerik.
- Vertrautheit mit den klassischen Algorithmen und numerischen Verfahren und deren Implementierung auf Rechnern.

### Inhalte Vorlesung / Content of the lecture

**Numerics I:**
- Grundlagen: Zahlendarstellung auf digitalen Rechnern, Matrixnormen, Banacherscher Fixpunktsatz, Fehleranalyse.
- Berechnung von Eigenwerten: Vektor-Iteration, LR- und QR-Verfahren.
- Lineare Optimierung: Austauschschritt und Simplexverfahren, lineare Ungleichungen.

**Numerics II:**
• Numerische Integration

<table>
<thead>
<tr>
<th>Zu erbringende Studienleistung / Course achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>A written exam of both lectures (Numerics I in winter term, Numerics II in summer term)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic performance, which can be graded but usually is evaluated with pass or fail.</td>
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</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
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</thead>
<tbody>
<tr>
<td>Master of Science in Computer Science, Academic regulations of 2012: Academic performance which can be graded but is not taken into account in the final grade.</td>
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</table>
Modul / Module

Numerische Optimierung / Numerical Optimization

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</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. M. Diehl</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Systemtheorie</td>
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<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Modulduer: Module duration</td>
<td>1 term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester:: Recommended term of study | 3                             |
| ECTS-Punkte: ECTS-points | 6                             |
| SWS: Semester week hours | 4 Lecture + 2 Exercises |
| Angebotsfrequenz: Regular cycle | Only in Winter term |
| Arbeitsaufwand: Workload | 180 hours (96 hours Full-time attendance course of study + 84 Hours Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Robotics and Computer Vision
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile

Lernziele / Learning target

Students understand important optimization methods used in practice for solution of convex and nonlinear programming problems and can independently apply the acquired knowledge.
### Inhalte Vorlesung / Content of the lecture

The course is divided into four major parts:

10. Unconstrained Optimization and Newton Type Algorithms: Stability of Solutions, Gradient and Conjugate Gradient, Exact Newton, Quasi-Newton, BFGS and Limited Memory BFGS, and Gauss-Newton, Line Search and Trust Region Methods, Algorithmic Differentiation
12. Inequality Constrained Optimization Algorithms: Karush-Kuhn-Tucker Conditions, Linear and Quadratic Programming, Active Set Methods, Interior Point Methods, Sequential Quadratic and Convex Programming, Quadratic and Nonlinear Parametric Optimization

### Inhalte Übung / Content of the exercises

Theoretical and computer exercises accompany the lecture to deepen the understanding. Successful participation/solution of at least 50% of the weekly exercise sheets.

### Zu erbringende Prüfungsleistung / Examination result

Written or oral examination

### Zu erbringende Studienleistung / Course achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Master of Science in Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade
of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

**Literatur / Literature**

- Stephen Boyd and Lieven Vandenberghe, Convex Optimization, Cambridge Univ. Press, 2004
Empfohlene Voraussetzungen: 
**Recommended preconditions**

The module is self contained and can be followed by all students with sufficient mathematical background. Thus, it is recommended not only to master and advanced bachelor students of engineering, but also to students of computer science, mathematics, and physics, that want to obtain a basic understanding of optimization and control. Having heard a basic systems and control course (e.g. Systemtheorie und Regelungstechnik) and an optimization course (e.g. „Convex and Nonlinear Optimization“) is an advantage, but not necessary.

Empfohlenes Fachsemester:: 
**Recommended term of study**

3

ECTS-Punkte: 
**ECTS-points**

6

SWS: 
**Semester week hours**

4 Lecture 2 Übung

Angebotsfrequenz: 
**Regular cycle**

Only in the winter term

Arbeitsaufwand: 
**Workload**

180 hours
(84 Hours Full-time attendance course of study + 96 Hours Self-study)

Verwendbarkeit der Veranstaltung / **Usability of the module**

Elective Module for students of the study program

- Master of Science in Embedded Systems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Informatik
  - Cyber.Physical Systems
  - Kognitive Technische Systeme
  - Application area Mikrosystemtechnik
- Master of Science in Mikrosystemtechnik
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Circuits and Systems
  - Design and Simulation
  - Personal Profile
**Lernziele / Learning target**

Aim of this self contained module is to provide the participants with a working knowledge of modern control theory as it is needed for use in engineering applications, with a focus on optimal control and estimation. At the end of the module the students shall have full understanding of how to use the linear quadratic regulator (LQR), the Kalman filter, Lyapunov and Riccati Equations, dynamic programming, constrained optimal control, moving horizon estimation (MHE) and model predictive control (MPC).

**Inhalte Vorlesung / Content of the lecture**

Focus of the course is state space control in discrete time. We start by discussing discrete time linear systems, their basic stability properties, time varying systems, linearization of nonlinear systems. We then enter optimal control, covering linear quadratic optimal control, linear quadratic regulation (LQR) control and Kalman filtering, Lyapunov and Riccati Equations, Dynamic Programming, Constrained Optimal Control, Moving Horizon Estimation (MHE) and Model Predictive Control (MPC). The course will be accompanied by weekly exercises with exercise questions and computer exercises using the environment MATLAB. In the last four weeks of the course (July), the participants will start to work, during the exercise sessions, on self chosen optimal control and estimation application projects, whose results will finally be presented to all course participants at the end of the semester.

**Inhalte Übung / Content of the exercises**

Students have to complete 50% of the practical exercises to get the admission for the final module exam.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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 2011: 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 Microsystems Engineering, Academic regulations of 2009: 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 Mikrosystemtechnik, Academic regulations of 2009: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.
<table>
<thead>
<tr>
<th>Literature / Literature</th>
</tr>
</thead>
</table>
Optimierendes Lernen / Reinforcement Learning

<table>
<thead>
<tr>
<th>Nummer: Number</th>
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<tbody>
<tr>
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<td>N.N.</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Maschinelles Lernen und Natürlichsprachliche Systeme</td>
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<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Modulsdauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Artificial Intelligence and Machine Learning</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachterm: Recommended term of study | 3 |
| ECTS-Punkte: ECTS-points | 6 |
| SWS: Term week hours | 3 Lecture + 1 Exercises |
| Angebotsfrequenz: Regular cycle | only in the winter term |
| Arbeitsaufwand: Workload | 180 Hours |
| | (64 Full-time attendance course of study + 116 Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme

Lernziele / Learning target

- Comprehension of the fundamental concepts of Reinforcement Learning
- Ability to think on different levels of abstraction
- Knowledge of exemplary implementations of learning algorithms
- Ability to independently identify connections of the concepts presented
- Skills for the practical application
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.

written or oral examination

The module grade is calculated from the result of the final examination.

- 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.

- Sutton, Barton: Reinforcement Learning – An Introduction.
Prinzipien der Wissensrepräsentation / Knowledge Representation

Nummer: 11LE13MO-1104

Modulverantwortlicher: Prof. Dr. B. Nebel
Einrichtung: Chair Grundlagen der Künstlichen Intelligenz

Modultyp: Elective Module
Moduldauer: 1 Term

Zugehörige Lehrveranstaltungen: Lecture and exercises
Sprache: English

Empfohlene Voraussetzungen: Knowledge in Grundlagen der Künstliche Intelligenz / Foundations of Artificial Intelligence

Empfohlenes Fachterm: 3
ECTS-Punkte: 6

SWS: 3 Lecture + 1 Exercises
Angebotsfrequenz: only in the winter term
Arbeitsaufwand: 180 Hours
(64 Full-time attendance course of study + 116 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Informationssysteme
  - Kognitive technische Systeme

Lernziele / Learning target

The goal of the module is to enable students to understand logic-based knowledge representation formalisms and their associated inference services. Based on that they will learn how to extend existing KR systems and how to develop new ones. In particular, the course provides the skills for understanding current research literature in this field.
### Inhalte Vorlesung / Content of the lecture

This course gives an introduction to logic based knowledge representation formalisms. We cover in particular the following topics:

- Foundations: Formal logic and complexity theory
- Modal logic: Systems and proof techniques
- Non-montonic logics
- Description logic and the semantic web
- Qualitative temporal and spatial representations and reasoning

### Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>R. J. Brachman and Hector J. Levesque, Knowledge Representation and Reasoning, Morgan Kaufman, 2004</td>
</tr>
</tbody>
</table>
# Modul-handbuch M.Sc. Informatik – RNA Bioinformatik / RNA Bioinformatics

## RNA Bioinformatik / RNA Bioinformatics

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1318</th>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. R. Backofen</td>
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<td>Einrichtung: Organisational unit</td>
<td>Chair Bioinformatik</td>
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<td>Modultyp: Module Type</td>
<td>Elective Module</td>
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<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
</tbody>
</table>
| Empfohlene Voraussetzungen: Recommended preconditions | • Basic knowledge of Bioinformatics and molecular biology  
• Fundamental knowledge in algorithms |
| Empfohlenes Fachterm: Recommended term of study | 2 |
| ECTS-Punkte: ECTS-points | 6 |
| SWS: Term week hours | 2 Lecture + 2 Exercises |
| Angebotsfrequenz: Regular cycle | only in the summer term |
| Arbeitsaufwand: Workload | 180 Hours  
(56 Full-time attendance course of study + 124 Self-study) |

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program:
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

### Lernziele / Learning target

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.

### Inhalte Vorlesung / Content of the lecture

**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

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
</table>
Roboter-Kartierung / Robot Mapping

Modul / Module

<table>
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<tr>
<th>Nummer: Number</th>
<th>11LE13MO-1116</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Prof. Dr. W. Burgard</td>
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<td>Einrichtung: Organisational unit</td>
<td>Chair Autonome Intelligente Systeme</td>
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<td>Elective Module</td>
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<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
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<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in Einführung in die Mobile Robotik / Introduction to Mobile Robotics</td>
</tr>
</tbody>
</table>

Empfohlenes Fachterm: Recommended term of study | 3 |
ECTS-Punkte: ECTS-points | 6 |
SWS: Term week hours | 3 Lecture + 1 Exercises |
Angebotsfrequenz: Regular cycle | only in the winter term |
Arbeitsaufwand: Workload | 180 Hours (64 Full-time attendance course of study + 116 Self-study) |

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme

Lernziele / Learning target

The students should be able to understand, characterize, and implement different approach to robot mapping and the simultaneous localization and mapping problem. This includes parametric and non-parametric filters, optimization-based approaches as well as techniques for addressing data association problems. The students will get practical experience with mapping systems and implement the basic methods.

Inhalte Vorlesung / Content of the lecture

The lecture will cover different topics and techniques in the context of environment modeling with mobile robots. This includes techniques such as the family of Kalman filters, information
filters, particle filters, graph-based approaches, least-squares error minimization, techniques for place recognition and appearance-based mapping, data association as well as information-driven approaches for observation processing. The exercises and homework assignments will also cover practical hands-on experience with mapping techniques, as basic implementations will be part of the homework assignments.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Benotung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.

**Literatur / Literature**

- Thrun et al., Probabilistic Robotics, MIT Press, 2005
- Springer Handbook on Robotics, Chapter on Simultaneous Localization and Mapping
- Grisetti et al., A Tutorial on Graph-based SLAM, 2009

Further material will be available via the course website

Modul / Module

Simulation in Computergraphik / Simulation in Computer Graphics

Nummer: Number
11LE13MO-1113

Modulverantwortlicher: Responsible person
Prof. Dr. M. Teschner

Einrichtung: Organisational unit
Chair Graphische Datenverarbeitung

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 Term

Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

Sprache: Language
English

Empfohlene Voraussetzungen: Recommended preconditions
- Programming skills
- Knowledge in algorithms and data structures, linear algebra and analysis.

Empfohlenes Fachterm:
Recommended term of study
3

ECTS-Punkte:
ECTS-points
4 or 6

SWS:
Term week hours
2 Lecture + 2 Exercises

Angebotsfrequenz:
Regular cycle
only in the winter term

Arbeitsaufwand:
Workload
180 Hours
(64 Full-time attendance course of study + 116 Self-study)
Or
120 Hours
(64 Full-time attendance course of study + 56 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme
- Master of Science in Mathematik

The 4 ECTS Module is only available in the section “Specialization Module III”.

Lernziele / Learning target

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.

Inhalte Vorlesung / Content of the lecture

The course addresses various aspects of the dynamics of mass-point systems, rigid objects and fluids. In the context of fluids, grid- and particle-based approaches are covered. The course further addresses techniques to detect collisions and to handle contacts. Here, bounding-volume hierarchies, space-subdivision techniques and image-based techniques are discussed.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the result of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science in Embedded Systems Engineering, 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.

Literatur / Literature

- Hanke-Bourgeois: Grundlagen der Numerischen Mathematik and des
**Modul / Module**

**Spieltheorie / Game Theory**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. B. Nebel</td>
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<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Grundlagen der Künstlichen Intelligenz</td>
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<td>Modultyp: Module Type</td>
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<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
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<tr>
<td>Sprache: Language</td>
<td>English</td>
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<tr>
<th>Empfohlenes Fachterm:: Recommended term of study</th>
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<tbody>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>4 oder 6</td>
</tr>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours (56 Full-time attendance course of study + 124 Self-study)</td>
</tr>
<tr>
<td>Or</td>
<td>120 Hours (56 Full-time attendance course of study + 64 Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Informationssysteme
  - Kognitive technische Systeme

The 4 ECTS Module is only available in the section “Specialization Module III”.

**Lernziele / Learning target**

After attending the module, students should be able to model simple strategic decision situations according to the game theory and to analyze them with regard to solutions (Nash equilibria, subgame perfect equilibria). Moreover, the students should be able to employ simple mechanisms.

**Inhalte Vorlesung / Content of the lecture**
Game theory is about rational decision making to further one's own objectives. In particular, it is about interactions and conflicts between the objectives of different players, i.e., about the question how the knowledge about other players' objectives influences one's own behavior. In the lecture, we study strategic and extensive games and discuss formalizations and solution concepts as well as algorithms for the computation of such solutions. In addition, the course is concerned with the mechanism design problem, i.e., with the question of how the rules of a social system should be designed in order to incentivize all participants to behave in a way that maximizes social welfare.

### Inhalte Übung / Content of the exercises

For admission to the exam students must attain 50% of all points reachable in the assignments and projects.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

### Benotung / Grading

The module grade is calculated from the result of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Osborne, Rubinstein, A Course in Game Theory, The MIT Press, Cambridge, MA, 1994</td>
</tr>
<tr>
<td>• Nisan, Roughgarden, Tardos, Vazirani (Hrsg.), Algorithmic Game Theory, Cambridge University Press, 2007</td>
</tr>
</tbody>
</table>
**Modulhandbuch M.Sc. Informatik – Statistische Mustererkennung / Statistical Pattern Recognition**

### Modul / Module

**Statistische Mustererkennung / Statistical Pattern Recognition**

<table>
<thead>
<tr>
<th>Nummer:</th>
<th>Number</th>
<th>11LE13MO-1114</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Responsible person</td>
<td>Prof. Dr. T. Brox</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Organisational unit</td>
<td>Chair Musterkennung and Bildverarbeitung</td>
</tr>
<tr>
<td>Modultyp:</td>
<td>Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer:</td>
<td>Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>English</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachterm: / Recommended term of study**

| 2 | ECTS-Punkte: / ECTS-points | 6 |
| SWS: / Term week hours | 2 Lecture + 2 Exercises | Angebotsfrequenz: / Regular cycle | only in the summer term |
| Arbeitsaufwand: / Workload | 180 Hours (56 Full-time attendance course of study + 124 Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Kognitive technische Systeme

**Lernziele / Learning target**

After taking the module, students should know about the most relevant pattern recognition techniques and the basic concepts of statistical learning. They should be able to read and understand related scientific literature. Moreover, they can apply the learned techniques to solve learning problems in various application domains. They should develop basic skills in working with Matlab.

**Inhalte Vorlesung / Content of the lecture**

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
help deepen the understanding of the material.

**Zu erbringende Prüfungsleistung / Examination result**

written or oral examination

**Bemutung / Grading**

The module grade is calculated from the result of the final examination.

**Gewichtung der Prüfungsleistung / Weight of examination result**

- 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.
### Modul / Module

**Systeminfrastruktur für Data Science / System Infrastructure for Data Science**

<table>
<thead>
<tr>
<th><strong>Nummer:</strong> Number</th>
<th>11LE13MO-1316</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modulverantwortlicher:</strong> Responsible person</td>
<td>Prof. Dr. P. Fischer</td>
</tr>
<tr>
<td><strong>Einrichtung:</strong> Organisational unit</td>
<td>Chair Web Science</td>
</tr>
<tr>
<td><strong>Modultyp:</strong> Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td><strong>Moduldauer:</strong> Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td><strong>Zugehörige Lehrveranstaltungen:</strong> Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td><strong>Sprache:</strong> Language</td>
<td>English</td>
</tr>
<tr>
<td><strong>Empfohlene Voraussetzungen:</strong> Recommended preconditions</td>
<td>Knowledge in Datenbanken und Informationssysteme / Databases and Information Systems</td>
</tr>
<tr>
<td><strong>Empfohlenes Fachterm:</strong> Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td><strong>ECTS-Punkte:</strong> ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td><strong>SWS:</strong> Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td><strong>Angebotsfrequenz:</strong> Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td><strong>Arbeitsaufwand:</strong> Workload</td>
<td>180 Hours (64 Full-time attendance course of study + 116 Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Verteilte Systeme
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme
  - Kognitive technische Systeme

### Lernziele / Learning target

Students will develop and understand of fundamental architectural options for designing and implementing scalable, expressive and responsive infrastructures for data science. This understanding comes from two directions: From a high-level point of view, students will be able to understand what systems exist and how they can be used. From a bottom-up perspective, students will gain an detailed insight and hand-on experience on the techniques used.
## Inhalte Vorlesung / Content of the lecture

The course covers the fundamentals of different data infrastructure systems, among them classical databases, main-memory databases, data stream systems and cloud computing frameworks. To do so, the course provides details on the foundations of information system architecture, among them data storage, indexing, query processing, operator models and optimization. On this basis, it provides further insights how design assumptions change when such systems are used in contexts which require extreme scalability, very short response times or complex analytical operations.

## Zu erbringende Prüfungsleistung / Examination result

written or oral examination

## Benotung / Grading

The module grade is calculated from the result of the final examination.

## Gewichtung der Prüfungsleistung / Weight of examination result

- 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.

## Literatur / Literature

The classical data management areas are covered well in the following books:
- Kemper and Eickler. Datenbanksysteme. Eine Einführung. Oldenbourg-Verlag. (in German)

Modern techniques are mostly available in research papers, which are provided during the lecture.
### Zufallsgesteuerte Algorithmen / Randomized Algorithms

<table>
<thead>
<tr>
<th>Number</th>
<th>11LE13MO-1317</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Bast</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Algorithmen and Datenstrukturen</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in stochastics</td>
</tr>
</tbody>
</table>

**Empfohlenes Fachterm:: Recommended term of study**
- 2

**ECTS-Punkte: ECTS-points**
- 6

**SWS: Term week hours**
- 3 Lecture + 1 Exercises

**Angebotsfrequenz: Regular cycle**
- nur im Sommerterm

**Arbeitsaufwand: Workload**
- 180 Hours (56 hours Full-time attendance course of study + 124 hours Self-study)

### Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- 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
  - Personal Profile
- Master of Science in Informatik
  - Informationssysteme

### Lernziele / Learning target

Students should know basic techniques and applications for randomization and should get an intuition where randomized algorithms are favourable compared to deterministic strategies. They should understand tools for analyzing randomized algorithms in theory and practice.

### Inhalte Vorlesung / Content of the lecture

In the course, fundamental concepts for randomization are taught (Las Vegas, Monte Carlo algorithms). Based on applications in various areas as sorting, searching, testing,
computational geometry, AI and graph theory, techniques for applying randomization are introduced and analyzed. The focus lies on showing how randomized algorithms can improve the problem complexity in theory and practice. Moreover randomized on-line algorithms and the probabilistic method are motivated and applied to several problem classes.

<table>
<thead>
<tr>
<th>Zu erbringende Prüfungsleistung / Examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>written or oral examination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benotung / Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>The module grade is calculated from the result of the final examination.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>The lecture will not follow a specific book; nevertheless standard text books for randomized algorithms will cover large portions of the content, e.g. Randomized Algorithms [Rajeev Motwani, Prabhakar Raghavan]. Additional literature in the form of papers will be announced during the course.</td>
</tr>
</tbody>
</table>
Prerequired modules for permission of study

All of the modules which can be specified by the admission committee as a prerequisite for the admission to study in this Master's program are listed in this part. If the candidate does not meet the necessary requirements for the study program, the committee can pronounce a provisionally admission which includes preconditions. Within the 1st and 2nd semester the student has to fulfill certain modules as a precondition to the study program. The student will be notified in written which modules they have to fulfill additionally.

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algorithmentheorie / Algorithms Theory</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. H. Bast, Prof. Dr. F. Kuhn</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Algorithmen und Datenstrukturen, Chair Algorithmen und Komplexität</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>german or english</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Basic knowledge in algorithms and data structures</td>
</tr>
<tr>
<td>Empfohlenes Fachterm:: Recommended term of study</td>
<td>1</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the winter term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours (64 Full-time attendance course of study + 116 Self-study)</td>
</tr>
</tbody>
</table>

Verwendbarkeit der Veranstaltung / Usability of the module

Mandatory Module for students of the study program
- 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

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Informatik
- Bachelor of Science polyvalent in Informatik
- Bachelor of Science in Mathematik
Lernziele / Learning target

Students should learn fundamental algorithms and data structures, and a variety of fundamental techniques for their design and analysis. They should be able to apply them and also adapt them to slightly changed circumstances. They should learn to understand when the various principles are appropriate and they should be able to mathematically analyze algorithms that were designed according to these principles.

Inhalte Vorlesung / Content of the lecture

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.

Inhalte Übung / Content of the exercises

In order to be admitted to the exam, you need to have 50% of all exercise points. 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.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the results of the final examination.
<table>
<thead>
<tr>
<th>Gewichtung der Prüfungsleistung / Weight of examination result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• Bachelor of Science in Informatik, 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.</td>
</tr>
<tr>
<td>• Bachelor of Science in Informatik, 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• 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.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Jon Kleinberg and Éva Tardos: Algorithm Design, Addison Wesley</td>
</tr>
<tr>
<td>• Thomas Ottmann and Peter Widmayer: Algorithmen und Datenstrukturen, Spektrum Akademischer Verlag</td>
</tr>
</tbody>
</table>
**Modul / Module**

**Bildverarbeitung and Computergraphik / Image Processing and Computer Graphics**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. T. Brox, Prof. Dr. M. Teschner</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Mustererkennung und Bildverarbeitung, Chair Graphische Datenverarbeitung</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>german or english</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in algorithms and data structures as well as in advanced programming and mathematical foundations.</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachterm: Recommended term of study | 1 |
| ECTS-Punkte: ECTS-points | 6 |
| SWS: Term week hours | 3 Lecture + 1 Exercises |
| Angebotsfrequenz: Regular cycle | only in the winter term |
| Arbeitsaufwand: Workload | 180 Hours |
| (64 Full-time attendance course of study + 116 Self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Informatik
- Bachelor of Science polyvalent in Informatik
- Bachelor of Science in Mathematik
- 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
- Master of Science in Informatik

**Lernziele / Learning target**

The students get an introduction to basic approaches in image processing and computer graphics. The students learn how to approach typical problems in image processing and in generative computer graphics. The students get familiar with recent publications in image processing and computer graphics.
### Inhalte Vorlesung / Content of the lecture

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.

### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Benotung / Grading

The module grade is calculated from the results of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Bachelor of Science in Informatik, 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 Informatik, 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 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.

### Literatur / Literature

Will be announced in each lesson.
### Computer Science Theory – Bridging Course

<table>
<thead>
<tr>
<th>Number:</th>
<th>11LE13MO-410</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsible person</td>
<td>Examiners of the Department of Computer Science</td>
</tr>
<tr>
<td>Modultype:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Language</td>
<td>English</td>
</tr>
<tr>
<td>Recommended term of study</td>
<td>1</td>
</tr>
<tr>
<td>ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>Term week hours</td>
<td>2 Lecture + 2 Exercises</td>
</tr>
<tr>
<td>Regular cycle</td>
<td>Each term</td>
</tr>
<tr>
<td>Workload</td>
<td>180 Hours (64 or 56 Full-time attendance course of study + 116 or 124 Self-study)</td>
</tr>
</tbody>
</table>

### Prerequired modules for students of the study program
- Master of Science in Embedded Systems Engineering
- Master of Science in Informatik

### Lernziele / Learning target
- 

### Inhalte Vorlesung / Content of the lecture

### Zu erbringende Studienleistung / Course Achievement
The coursework consists of a seminar paper and an oral presentation. In general, the active and regular participation in the course is requested.

### Benotung / Grading
Academic performance, which can be graded but usually is evaluated with pass or fail.

### Gewichtung der Prüfungsleistung / Weight of examination result
- Master of Science in Computer Science, Academic regulations of 2012: Academic performance which can be graded but is not taken into account in the final grade.

**Literatur / Literature**

Will be announced at the beginning of the course.
# Datenbanken and Informationssysteme / Data Bases and Information Systems

<table>
<thead>
<tr>
<th>Modulverantwortlicher:</th>
<th>Prof. Dr. G. Lausen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modultyp:</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Modulnummer:</td>
<td>11LE13MO-2060</td>
</tr>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. G. Lausen</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Chair Datenbanken und Informationssysteme</td>
</tr>
<tr>
<td>Modulnummer:</td>
<td>11LE13MO-2060</td>
</tr>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. G. Lausen</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Chair Datenbanken und Informationssysteme</td>
</tr>
<tr>
<td>Modulnummer:</td>
<td>11LE13MO-2060</td>
</tr>
<tr>
<td>Modulverantwortlicher:</td>
<td>Prof. Dr. G. Lausen</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Chair Datenbanken und Informationssysteme</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen:**
- Einführung in die Programmierung oder Einführung in die Informatik
- Systeme I: Betriebssysteme
- Informatik II: Algorithmen und Datenstrukturen

**Sprache:** German

**Moduldauer:** 1 Term

**Zugehörige Lehrveranstaltungen:**
- Lecture and exercises

**Empfohlene Fachterm:**

<table>
<thead>
<tr>
<th>Term week hours</th>
<th>Lecture + 1 Exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS:</td>
<td>ECTS-Punkte:</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

**ECTS-Punkte:** 6

**Angebotsfrequenz:**
- only in the winter term

**Arbeitsaufwand:**
- 180 Hours (64 Full-time attendance course of study + 116 Self-study)

**Verwendbarkeit der Veranstaltung / Usability of the module**

**Mandatory Module for students of the study program**
- Bachelor of Science in Informatik
- Bachelor of Science polyvalent 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

**Elective Module for students of the study program**
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Mathematik
- Master of Science in Embedded Systems Engineering
- Master of Science in Informatik
### Lernziele / Learning target

- Verständnis der grundlegenden Konzepte zu Datenbanken.
- Fähigkeit des Denkens auf unterschiedlichen Abstraktionsebenen.
- Methodische Fähigkeiten einen Datenbankentwurf vorzunehmen.
- Kennenlernen wesentlicher Konzepte des SQL-Standards.
- Praktische Erfahrung in der Verwendung einer deklarativen, mengenorientierten Sprache für Datenbanken.
- Fähigkeit den Bearbeitungsaufwand einer Anfrage abschätzen zu können.
- Fähigkeit zum Umgang mit Zugriffsrechten.

### Inhalte Vorlesung / Content of the lecture

Aufgabe von Datenbanken ist die Verwaltung großer, dauerhafter Datenbestände in der Weise, dass eine Menge von Benutzern diese Daten unabhängig voneinander, effizient, bequem and sicher verarbeiten können.

Der Stoff der Lecture wird in Exercisesen and einem parallel laufenden Praktikum anhand verschiedener Datenbanksysteme konkretisiert.

Es werden im einzelnen die folgenden Aspekte behandelt:

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

### Inhalte Übung / Content of the exercises


### Zu erbringende Prüfungsleistung / Examination result

written or oral examination

### Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.
### Benotung / Grading

The module grade is calculated from the results of the final examination.

### Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Bachelor of Science in Informatik, 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 Informatik, 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 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.

### Literatur / Literature

**Modul / Module**

**Graphentheorie**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-130</th>
</tr>
</thead>
</table>
| Modulverantwortlicher: Responsible person | Prof. Dr. Thiemann  
Prof. Dr. Schindelhauer |
| Einrichtung: Organisational unit | Lehrstuhl Programmiersprachen  
Lehrstuhl Rechnernetze und Telematik |
| Modultyp: Module Type | Elective Module |
| Moduldauer Module duration | 1 Term |
| Zugehörige Lehrveranstaltungen: Connected events | Lecture and exercises |
| Sprache: Language | German |
| Empfohlene Voraussetzungen: Recommended preconditions | Kenntnisse aus den Modulen  
- Einführung in die Programmierung  
- Informatik II – Algorithmen und Datenstrukturen |

| Empfohlenes Fachsemester: Recommended term of study | 3 |
| ECTS-Punkte: ECTS-points | 3 |
| SWS: Semester week hours | 1 Lecture + 1 Exercises |
| Angebotsfrequenz: Regular cycle | Only in winter term |
| Arbeitsaufwand: Workload | 90 hours  
(32 hours Full-time attendance course of study + 58 hours self-study) |

**Verwendbarkeit der Veranstaltung / Usability of the module**

Pflichtmodul für Studierende des Studiengangs
- Bachelor of Science im Fach Informatik
- Bachelor of Science polyvalent im Fach Informatik
- Lehramt an Gymnasien im Fach Informatik als Hauptfach (nur wenn als 2. Hauptfach Physik oder Mathematik gewählt wurde)

**Lernziele / Learning target**

Die Studierenden lernen die grundlegenden Begriffe zu Graphen und deren Verwendung in der Informatik. Literatur und andere Vorlesungen, die Konzepte der Graphentheorie verwenden sollen selbständig verstanden werden können.


In den Übungen wird der Stoff durch mathematische Beweise und dem Finden eigener algorithmischer Lösungen vertieft.

Die Modulnote errechnet sich zu 100% aus der schriftlichen oder mündlichen Abschlussprüfung.

- Bachelor of Science im Fach Informatik, Prüfungsordnungsversion 2012: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.

- Graphentheoretische Konzepte und Algorithmen, Sven Oliver Krumke und Hartmut Noltemeier. Springer 2012
- Graph Theory, Reinhard Diestel, Electronic Edition 2010
**Modul / Module**

**Grundlagen der Künstlichen Intelligenz / Foundations of Artificial Intelligence**

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. W. Burgard, Prof. Dr. B. Nebel, NN</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Autonome Intelligente Systeme, Chair Grundlagen der Künstlichen Intelligenz, Chair Maschinelles Lernen and natürlichsprachliche Systeme</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German or english</td>
</tr>
<tr>
<td>Empfohlenes Fachterm: Recommended term of study</td>
<td>2</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>6</td>
</tr>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours (56 Full-time attendance course of study + 124 Self-study)</td>
</tr>
</tbody>
</table>

**Verwendbarkeit der Veranstaltung / Usability of the module**

Elective Module for students of the study program
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Informatik
- Bachelor of Science polyvalent in Informatik
- Bachelor of Science in Mathematik
- 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
- Master of Science in Informatik

**Lernziele / Learning target**

The goal of this module is to give an overview of the various techniques and methods in Artificial Intelligence. The students will learn the basic principles of Artificial Intelligence and will be able to use the scientific terminology and methods of this field. They will be able to interpret problems in terms of search in a formal search space and will be able to apply search algorithms to new situations. They will learn how to apply various Artificial Intelligence techniques and how to assess the application of such techniques in new situations.
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

The module grade is calculated from the results of the final examination.

- 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.
- Bachelor of Science in Informatik, 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 Informatik, 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 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.

Artificial Intelligence: A modern approach, Stuart Russel and Peter Norvig, Prentice Hall, 2003
**Modul / Module**

**Informatik II: Algorithmen und Datenstrukturen**

<table>
<thead>
<tr>
<th>Number: Number</th>
<th>11LE13MO-120</th>
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</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. Bast</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Lehrstuhl Algorithmen und Datenstrukturen</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Pflichtmodul</td>
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<tr>
<td>Moduldauer Module duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Vorlesung und Übung</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>Deutsch</td>
</tr>
</tbody>
</table>

**Empfohlene Voraussetzungen: Recommended preconditions**

Vorausgesetzt werden Kenntnisse aus dem Modul "Einführung in die Programmierung".

**Empfohlenes Fachsemester: Recommended term of study**

<table>
<thead>
<tr>
<th>2</th>
<th>ECTS-Punkte: ECTS-points</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Vorlesung + 2 Übung</td>
<td>Angebotsfrequenz: Regular cycle</td>
<td>nur im Sommersemester</td>
</tr>
</tbody>
</table>

**Arbeitsaufwand: Workload**

240 Stunden (88 Stunden Präsenzstudium + 152 Stunden Selbststudium)

**Verwendbarkeit der Veranstaltung / Usability of the module**

Pflichtmodul für Studierende des Studiengangs
- Bachelor of Science im Fach Informatik
- Bachelor of Science polyvalent im Fach Informatik
- Lehramt an Gymnasien im Fach Informatik als Hauptfach
- Lehramt an Gymnasien im Fach Informatik als Erweiterungshauptfach
- Lehramt an Gymnasien im Fach Informatik als Hauptfach in Verbindung mit dem Fach Bildende Kunst oder Musik

Wahlpflichtmodul für Studierende des Studiengangs
- Bachelor of Science im Fach Interdisciplinary Track
- Bachelor of Science im Fach Mathematik
- Bachelor of Science im Fach Physik

**Lernziele / Learning target**

Inhalte Vorlesung / Content of the lecture

Im Einzelnen werden folgende Themen behandelt:
Formale Eigenschaften von Algorithmen, Korrektheit, Effizienz, Zeit- und Platzbedarf, Groß-O-Notation, Omega-Notation; best, worst, average, amortized-worst-case Analyse von Algorithmen; Divide & Conquer u.a. Entwurfsverfahren; Elementare Datenstrukturen, Liste, Stapel, Schlange; Skiplisten als Beispiel einer randomisierten Struktur; Sortierverfahren: elementare, Heapsort, Quicksort, Radixsort; untere Schranke; Suchverfahren: lineare, exponentielle Suche; Hashverfahren, insbesondere offene Hashverfahren; Bäume, natürliche Suchbäume, Durchlaufreihenfolgen; Balancierte Bäume, AVL-Bäume, B-Bäume; Union-Find-Strukturen u.a. Datenstrukturen; Graphen.

Inhalte Übung / Content of the exercises

Beamervortrag in der Vorlesung, Vortragsfolien und Übungsblätter werden auf der Internetseite der Veranstaltung bereitgestellt.
Um an der Abschlussprüfung teilnehmen zu können, brauchen Sie mindestens 50% der Punkte aus den Übungsblättern.

Zu erbringende Prüfungsleistung / Examination result

schriftliche oder mündliche Abschlussprüfung

Zu erbringende Studienleistung / Course Achievement

Um zur Abschlussprüfung zugelassen zu werden, muss die zu diesem Modul gehörige Lehrveranstaltung Übung erfolgreich absolviert werden. Welche Leistung der Studierenden zu erbringen hat, wird in der Inhaltsbeschreibung der Übung detailliert beschrieben und ebenso zu Beginn der Lehrveranstaltung vom Dozierenden mitgeteilt.

Benoitung / Grading

Die Modulnote errechnet sich zu 100% aus der schriftlichen oder mündlichen Abschlussprüfung.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science im Fach Informatik, Prüfungsordnungsversion 2009: Die Modulnote für das Modul "Praktische Informatik " (Teilmodul Informatik II: Algorithmen und Datenstrukturen) wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science im Fach Informatik, Prüfungsordnungsversion 2012: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science polyvalent im Fach Informatik, Prüfungsordnungsversion 2015: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Endnote für das Fach Informatik eingerechnet.

Literatur / Literature
Modulhandbuch M.Sc. Informatik – Informatik III: Theoretische Informatik

<table>
<thead>
<tr>
<th>Modul / Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informatik III: Theoretische Informatik</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-130</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. Lausen, Prof. Dr. Nebel, Prof. Dr. Podelski</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Lehrstuhl Datenbanken und Informationssysteme, Lehrstuhl Grundlagen der Künstlichen Intelligenz, Lehrstuhl Softwaretechnik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Pflichtmodul</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Vorlesung und Übung</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>Deutsch</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Vorausgesetzt werden Kenntnisse aus den Modulen &quot;Einführung in die Programmierung&quot; und &quot;Informatik II: Algorithmen und Datenstrukturen&quot;.</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>3</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>8</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>4 Vorlesung + 2 Übung</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>nur im Wintersemester</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>240 Stunden (100 Stunden Präsenzstudium + 140 Stunden Selbststudium)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Verwendbarkeit der Veranstaltung / Usability of the module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pflichtmodul für Studierende des Studiengangs</td>
</tr>
<tr>
<td>• Bachelor of Science im Fach Informatik</td>
</tr>
<tr>
<td>• Bachelor of Science polyvalent im Fach Informatik</td>
</tr>
<tr>
<td>• Lehramt an Gymnasien im Fach Informatik als Hauptfach</td>
</tr>
<tr>
<td>• Lehramt an Gymnasien im Fach Informatik als Erweiterungshauptfach</td>
</tr>
<tr>
<td>• Lehramt an Gymnasien im Fach Informatik als Hauptfach in Verbindung mit dem Fach Bildende Kunst oder Musik</td>
</tr>
<tr>
<td>Wahlpflichtmodul für Studierende des Studiengangs</td>
</tr>
<tr>
<td>• Bachelor of Science im Fach Interdisciplinary Track</td>
</tr>
<tr>
<td>• Bachelor of Science im Fach Mathematik</td>
</tr>
<tr>
<td>• Bachelor of Science im Fach Physik</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lernziele / Learning target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studierende sollen lernen, intuitive Konzepte wie Algorithmen, Berechenbarkeit, Komplexität formal und präzise zu fassen und ihre grundsätzliche Bedeutung für die Lösbarkeit von</td>
</tr>
</tbody>
</table>

### Inhalte Vorlesung / Content of the lecture


### Inhalte Übung / Content of the exercises


### Zu erbringende Prüfungsleistung / Examination result

Schriftliche oder mündliche Abschlussprüfung

### Zu erbringende Studienleistung / Course Achievement

Um zur Abschlussprüfung zugelassen zu werden, muss die zu diesem Modul gehörige Lehrveranstaltung Übung erfolgreich absolviert werden. Welche Leistung der Studierenden zu erbringen hat, wird in der Inhaltsbeschreibung der Übung detailliert beschrieben und ebenso zu Beginn der Lehrveranstaltung vom Dozierenden mitgeteilt.

### Benotung / Grading

Die Modulnote errechnet sich zu 100% aus der schriftlichen oder mündlichen Abschlussprüfung.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science im Fach Informatik, Prüfungsordnungsversion 2009: Die
Modulnote wird nach ECTS-Punkten dreifach gewichtet in die Gesamtnote eingerechnet.

- Bachelor of Science im Fach Informatik, Prüfungsordnungsversion 2012: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science polyvalent im Fach Informatik, Prüfungsordnungsversion 2015: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Endnote für das Fach Informatik eingerechnet.

Literatur / Literature

# Modulhandbuch M.Sc. Informatik – Optimierung

## Modul / Module

### Optimierung

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-720</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. F. Kuhn und Prof. Dr. T. Brox</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Lehrstuhl Algorithmen und Komplexität und Bildverarbeitung und Computergraphik</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Wahlpflichtmodul</td>
</tr>
<tr>
<td>Moduldauer: Module duration</td>
<td>1 Semester</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Vorlesung und Übung</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>Deutsch</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Kenntnisse aus den Modulen</td>
</tr>
<tr>
<td></td>
<td>• Einführung in die Programmierung</td>
</tr>
<tr>
<td></td>
<td>• Informatik II – Algorithmen und Datenstrukturen</td>
</tr>
<tr>
<td>Empfohlenes Fachsemester: Recommended term of study</td>
<td>4</td>
</tr>
<tr>
<td>ECTS-Punkte: ECTS-points</td>
<td>3</td>
</tr>
<tr>
<td>SWS: Semester week hours</td>
<td>1 Vorlesung + 1 Übung</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>nur im Sommersemester</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>90 Stunden</td>
</tr>
<tr>
<td></td>
<td>(28 Stunden Präsenzstudium + 62 Stunden Selbststudium)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

Pflichtmodul für Studierende des Studiengangs
- Bachelor of Science im Fach Informatik
- Lehramt an Gymnasien im Fach Informatik als Hauptfach (nur wenn als 2. Hauptfach Physik oder Mathematik gewählt wurde)

Wahlpflichtmodul für Studierende des Studiengangs
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science in Mikrosystemtechnik
- Master of Science in Embedded Systems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Microsystems Engineering
  - Design and simulation
  - Personal Profile
- Master of Science in Mikrosystemtechnik
  - Design and simulation
  - Personal Profile

### Lernziele / Learning target

Die Studierenden lernen, welche Optimierungsprobleme es gibt und wie sie gelöst werden
können. Sie sollen die Schwierigkeit von Optimierungsproblemen analysieren und einschätzen lernen und in die Lage versetzt werden, die besprochenen Optimierungsverfahren in Anwendungsfällen einzusetzen.

### Inhalte Vorlesung / Content of the lecture


### Zu erbringende Prüfungsleistung / Examination result

Schriftliche oder mündliche Abschlussprüfung

### Benotung / Grading

Die Modulnote errechnet sich zu 100% aus der schriftlichen oder mündlichen Abschlussprüfung.

### Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science im Fach Embedded Systems Engineering, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten dreifach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science im Fach Embedded Systems Engineering Prüfungsordnungsversion 2011: Die Modulnote wird nach ECTS-Punkten dreifach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science im Fach Informatik, Prüfungsordnungsversion 2012: Die Modulnote für das Modul "Graphentheorie und Optimierung" (Teilmodul Optimierung) wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science im Fach Mikrosystemtechnik, Prüfungsordnungsversion 2005: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science im Fach Embedded Systems Engineering Prüfungsordnungsversion 2012: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Master of Science im Fach Mikrosystemtechnik, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
Modul / Module

Rechnerarchitektur / Computer Architecture

Nummer: Number
11LE13MO-2020

Modulverantwortlicher: Responsible person
Prof. Dr. B. Becker, Prof. Dr. C. Scholl

Einrichtung: Organisational unit
Chair Rechnerarchitektur, Chair Betriebssysteme

Modultyp: Module Type
Elective Module

Moduldauer: Module duration
1 Term

Zugehörige Lehrveranstaltungen: Connected events
Lecture and exercises

Sprache: Language
German or english

Empfohlene Voraussetzungen: Recommended preconditions
Basic knowledge in operation systems and technical computer science

Empfohlenes Fachterm: Recommended term of study
2

ECTS-Punkte: ECTS-points
6

SWS: Term week hours
3 Lecture + 1 Exercises

Angebotsfrequenz: Regular cycle
only in the summer term

Arbeitsaufwand: Workload
180 Hours
(56 Full-time attendance course of study + 124 Self-study)

Verwendbarkeit der Veranstaltung / Usability of the module

Elective Module for students of the study program
• Bachelor of Science in Embedded Systems Engineering
• Bachelor of Science in Informatik
• Bachelor of Science polyvalent in Informatik
• Bachelor of Science in Mathematik
• 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
• Master of Science in Informatik

Lernziele / Learning target

The students are familiar with the main steps for the design of digital systems on the one hand side. On the other hand side they acquire architectural knowledge about computers. The module aims at a deepened understanding of methods for modeling and validation/verification and corresponding optimization methods. Students are able to judge the specific restrictions arising from the physics of technical systems and gain experience to include them into the design process. Finally they understand how limitations resulting from digital technology and specific computer architectures influence higher levels of abstraction, in particular the software level.
Inhalte Vorlesung / Content of the lecture

An introduction to elementary questions, methods and techniques of computer design and architecture is given. In particular the following areas are of interest: Integrated circuits, design, test, machine languages, computer arithmetic, data path and control, pipelining, memory hierarchy, processes, interrupts, interfaces, parallel computing.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Benotung / Grading

The module grade is calculated from the results of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Bachelor of Science in Informatik, 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 Informatik, 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 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.

Literatur / Literature

# Modul / Module

## SoftwareTechnik / Software Engineering

<table>
<thead>
<tr>
<th>Nummer: Number</th>
<th>11LE13MO-2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulverantwortlicher: Responsible person</td>
<td>Prof. Dr. A. Podelski, Prof. Dr. P. Thiemann</td>
</tr>
<tr>
<td>Einrichtung: Organisational unit</td>
<td>Chair Softwaretechnik, Chair Programmiersprachen</td>
</tr>
<tr>
<td>Modultyp: Module Type</td>
<td>Elective Module</td>
</tr>
<tr>
<td>Moduldauer Module duration</td>
<td>1 Term</td>
</tr>
<tr>
<td>Zugehörige Lehrveranstaltungen: Connected events</td>
<td>Lecture and exercises</td>
</tr>
<tr>
<td>Sprache: Language</td>
<td>German or English</td>
</tr>
<tr>
<td>Empfohlene Voraussetzungen: Recommended preconditions</td>
<td>Knowledge in advanced programming, algorithms and data structures, computer science theory and mathematics.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Empfohlenes Fachterm: Recommended term of study</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS: Term week hours</td>
<td>3 Lecture + 1 Exercises</td>
</tr>
<tr>
<td>Angebotsfrequenz: Regular cycle</td>
<td>only in the summer term</td>
</tr>
<tr>
<td>Arbeitsaufwand: Workload</td>
<td>180 Hours</td>
</tr>
<tr>
<td></td>
<td>(56 Full-time attendance course of study + 124 Self-study)</td>
</tr>
</tbody>
</table>

### Verwendbarkeit der Veranstaltung / Usability of the module

**Mandatory Module for students of the study program**
- 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

**Elective Module for students of the study program**
- Bachelor of Science in Embedded Systems Engineering
- Bachelor of Science polyvalent in Informatik
- Bachelor of Science in Mathematik
- Master of Science in Embedded Systems Engineering
- Master of Science in Informatik
Lernziele / Learning target

The students master basic modeling techniques and principles of design, construction, testing, and verification for software systems. They are able to apply these techniques in the small and to acquire advanced techniques by themselves. The applied formal methods to examples and are able to assess in which situations it is necessary to apply such methods.

Inhalte Vorlesung / Content of the lecture

Basic techniques in software engineering: Revision Control, Process Models, Requirements Analysis, Formal and Semiformal Modeling Techniques, Object Oriented Analysis, Object Oriented Design, Design Patterns, Testing.

Inhalte Übung / Content of the exercises

For admission to the exam at least 50% of the admission points must be achieved from the exercise sheets.

Zu erbringende Prüfungsleistung / Examination result

written or oral examination

Zu erbringende Studienleistung / Course Achievement

The students have to complete assessed coursework in order to be admitted to the final module exam. Coursework can include regular attendance, presentations, quizzes, written exams, exercise sheets and class minutes. The nature of the coursework is defined in the description of the exercises and at the beginning of each class.

Benotung / Grading

The module grade is calculated from the results of the final examination.

Gewichtung der Prüfungsleistung / Weight of examination result

- 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.
- Bachelor of Science in Informatik, 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 Informatik, 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 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.

**Literatur / Literature**

- Balzert, H. Lehrbuch der Softwaretechnik, Bd. 1 + 2 (main source of the lecture)
- Jacobson, I. et al. Object Oriented Software-Engineering - A Use Case Driven Approach
- Davis, A. Software Requirements - Analysis and Specification
Modulhandbuch M.Sc. Informatik – Systeme II: Rechnernetze

Modul / Module

Systeme

Teilmodul / Part-module

Systeme II: Rechnernetze

Nummer: Number
11LE13MO-155

Modulverantwortlicher: Responsible person
Prof. Dr. Schindelhauer

Einrichtung: Organisational unit
Lehrstuhl Rechnernetze und Telematik

Modultyp: Module Type
Pflichtmodul

Moduldauer Module duration
1 Semester

Zugehörige Lehrveranstaltungen: Connected events
Vorlesung und Übung

Sprache: Language
Deutsch

Empfohlenes Fachsemester:: Recommended term of study
2

ECTS-Punkte: ECTS-points
6

SWS: Semester week hours
3 Vorlesung + 1 Übung

Angebotsfrequenz: Regular cycle
nur im Sommersemester

Arbeitsaufwand: Workload
180 Stunden
(58 Stunden Präsenzstudium + 122 Stunden Selbststudium)

Verwendbarkeit der Veranstaltung / Usability of the module

Pflichtmodul für Studierende des Studiengangs
- Bachelor of Science im Fach Informatik
- Bachelor of Science polyvalent im Fach Informatik
- Lehramt an Gymnasien im Fach Informatik als Hauptfach
- Lehramt an Gymnasien im Fach Informatik als Erweiterungshauptfach
- Lehramt an Gymnasien im Fach Informatik als Hauptfach in Verbindung mit dem Fach Bildende Kunst oder Musik

Wahlpflichtmodul für Studierende des Studiengangs
- Bachelor of Science im Fach Interdisciplinary Track
- Bachelor of Science im Fach Mathematik
- Bachelor of Science im Fach Physik

Lernziele / Learning target

Die Studierenden lernen die Grundlagen der Rechnernetze kennen. Sie haben Einblick in diverse Schichten (Bitübertragungsschicht (Physical Layer), Sicherungsschicht (Data Link Layer), Vermittlungsschicht (Routing Layer), Transportschicht (Transport Layer)) und können das theoretische Wissen in die Praxis transferieren, insbesondere am Beispiel des Internets.
Inhalte Vorlesung / Content of the lecture


Inhalte Übung / Content of the exercises

Um zur Abschlussprüfung zugelassen zu werden, müssen mindestens 50% der Übungen korrekt bearbeitet werden.

Zu erbringende Prüfungsleistung / Examination result

schriftliche oder mündliche Abschlussprüfung

Zu erbringende Studienleistung / Course Achievement

Um zur Abschlussprüfung zugelassen zu werden, muss die zu diesem Modul gehörige Lehrveranstaltung Übung erfolgreich absolviert werden. Welche Leistung der Studierenden zu erbringen hat, wird in der Inhaltsbeschreibung der Übung detailliert beschrieben und ebenso zu Beginn der Lehrveranstaltung vom Dozierenden mitgeteilt.

Benotung / Grading

Die Modulnote errechnet sich zu 100% aus der schriftlichen oder mündlichen Abschlussprüfung.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science im Fach Informatik, Prüfungsordnungsversion 2009: Die Modulnote für das Modul "Systeme " (Teilmodul Systeme II: Rechnernetze) wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science im Fach Informatik, Prüfungsordnungsversion 2012: Die Modulnote für das Modul "Systeme " (Teilmodul Systeme II: Rechnernetze) wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science polyvalent im Fach Informatik, Prüfungsordnungsversion 2015: Die Modulnote für das Modul "Systeme" (Teilmodul Systeme II: Rechnernetze) wird nach ECTS-Punkten einfach gewichtet in die Endnote für das Fach Informatik eingerechnet.
<table>
<thead>
<tr>
<th>Literatur / Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Andrew Tanenbaum: Computer Networks, Prentice Hall, 1989</td>
</tr>
<tr>
<td>• James F. Kurose, Keith W. Ross, Computer Networking - A Top-Down Approach Featuring the Internet, Prentice Hall</td>
</tr>
<tr>
<td>• Fred Halsall: Data Communications, Computer Networks and Open Systems. Addison-Wesley, 1992</td>
</tr>
<tr>
<td>• W. Richard Stevens, TCP/IP Illustrated, Volume 1 - The Protocols, Addison-Wesley</td>
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</tbody>
</table>
## Modulhandbuch M.Sc. Informatik – Technische Informatik

### Modul / Module

#### Technische Informatik

<table>
<thead>
<tr>
<th>Nummer:</th>
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<th>11LE13MO-140</th>
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<tbody>
<tr>
<td>Modulverantwortlicher:</td>
<td>Responsible person</td>
<td>Prof. Dr. B. Becker und Prof. Dr. C. Scholl</td>
</tr>
<tr>
<td>Einrichtung:</td>
<td>Organisational unit</td>
<td>Lehrstuhl Rechnerarchitektur und Lehrstuhl Betriebssysteme</td>
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<tr>
<td>Modultyp:</td>
<td>Module Type</td>
<td>Wahlpflichtmodul</td>
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<tr>
<td>Moduldauer</td>
<td>Module duration</td>
<td>1 Semester</td>
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<tr>
<td>Zugehörige Lehrveranstaltungen:</td>
<td>Connected events</td>
<td>Vorlesung und Übung</td>
</tr>
<tr>
<td>Sprache:</td>
<td>Language</td>
<td>Deutsch</td>
</tr>
</tbody>
</table>

| Empfohlenes Fachsemester:: | Recommended term of study | 5 |
| ECTS-Punkte: | ECTS-points | 8 |
| SWS: | Semester week hours | 4 Vorlesung + 2 Übung |
| Angebotsfrequenz: | Regular cycle | nur im Wintersemester |
| Arbeitsaufwand: | Workload | 240 Stunden (66 Stunden Präsenzstudium + 144 Stunden Selbststudium) |

### Verwendbarkeit der Veranstaltung / Usability of the module

- Pflichtmodul für Studierende des Studiengangs
  - Bachelor of Science im Fach Embedded Systems Engineering
  - Bachelor of Science im Fach Informatik
  - Bachelor of Science polyvalent im Fach Informatik
  - Lehramt an Gymnasien im Fach Informatik als Hauptfach
  - Lehramt an Gymnasien im Fach Informatik als Erweiterungshauptfach
  - Lehramt an Gymnasien im Fach Informatik als Hauptfach in Verbindung mit dem Fach Bildende Kunst oder Musik

- Wahlpflichtmodul für Studierende des Studiengangs
  - Bachelor of Science im Fach Biologie
  - Bachelor of Science im Fach Interdisciplinary Track
  - Bachelor of Science im Fach Mathematik
  - Bachelor of Science im Fach Mikrosystemtechnik
  - Bachelor of Science im Fach Physik

Dieses Modul kann für die Zulassung zu einem Masterstudium als Auflage festgelegt werden.
### Lernziele / Learning target


### Inhalte Vorlesung / Content of the lecture


### Inhalte Übung / Content of the exercises


Als Studienleistung muss
- mindestens 50% der erreichbaren Punkte aus den Übungen erreicht werden
- regelmäßig aktiv an den Übungsgruppen teilgenommen werden
- mindestens eine Übung in der Übungsgruppe vorgerechnet werden.

Zur Abschlussklausur zugelassen ist, wer die Studienleistungen für diese Veranstaltung erbracht hat.

### Zu erbringende Prüfungsleistung / Examination result

Schriftliche oder mündliche Abschlussprüfung

### Zu erbringende Studienleistung / Course Achievement

Um zur Abschlussprüfung zugelassen zu werden, muss die zu diesem Modul gehörige
Lehrveranstaltung Übung erfolgreich absolviert werden. Welche Leistung der Studierenden zu erbringen hat, wird in der Inhaltsbeschreibung der Übung detailliert beschrieben und ebenso zu Beginn der Lehrveranstaltung vom Dozierenden mitgeteilt.
Benotung / Grading

Die Modulnote errechnet sich zu 100% aus der schriftlichen oder mündlichen Abschlussprüfung.

Gewichtung der Prüfungsleistung / Weight of examination result

- Bachelor of Science im Fach Embedded Systems Engineering, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science im Fach Embedded Systems Engineering, Prüfungsordnungsversion 2011: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science im Fach Informatik, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science im Fach Informatik, Prüfungsordnungsversion 2012: Die Modulnote für das Modul "Technische Informatik" (Teilmodul Technische Informatik) wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
- Bachelor of Science polyvalent im Fach Informatik, Prüfungsordnungsversion 2015: Die Modulnote für das Modul "Technische Informatik" (Teilmodul Technische Informatik) wird nach ECTS-Punkten einfach gewichtet in die Endnote für das Fach Informatik eingerechnet.
- Bachelor of Science im Fach Mikrosystemtechnik, Prüfungsordnungsversion 2005: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.

Literatur / Literature
