
# Module Handbook
# Master Computer Engineering

Faculty for Computer Science, Electrical Engineering and Mathematics
Paderborn University

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# Contents

# Chapter 1

# Description of Program Master Computer Engineering

This module handbook describes the modules and courses of the master program Computer Engineering with their goals, contents and relationships. For students, the module handbook shall provide useful and binding information to support them in planning their studies. For teachers and the interested reader the handbook provides an in-depth view into the structure and organization of the study program.

The following paragraphs present a list of abbreviations, the curriculum of the Master program Computer Engineering and an exemplary schedule of courses, comment on the training of soft skills and show the schemes for describing modules and courses used in this handbook. Details and regulations regarding examination modalities and grading rules are provided in the document „Prüfungsordnung für den Master-Studiengang Computer Engineering“.

## 1.1 List of Abbreviations

| | |
|---|---|
| LP | Credit points according to ECTS |
| SWS | Weekly presence hours for the course |
| 2V | Lecture with 2 SWS |
| 2Ü | Exercise with 2 SWS |
| 2P | Project with 2 SWS |
| 2S | Seminar with 2 SWS |
| WS | Winter semester |
| SS | Summer semester |

## 1.2 Curriculum & Schedule

Figure 1.1 shows the curriculum and an exemplary schedule of courses for the master program Computer Engineering. The master program comprises four mandatory modules (6 LP each), elective modules (42 LP), a seminar module (6 LP), the module project group (18 LP) and the master theses (30 LP). For the elective modules, the program defines six focus areas for which this handbook lists corresponding module catalogs. Each student selects one out of these focus areas and completes modules totalling 24 LP in this focus area. Another set of modules totalling 18 LP can be selected from any of the focus areas. The seminar module contains a seminar with 4 LP and an elective, ungraded course with 2 LP.

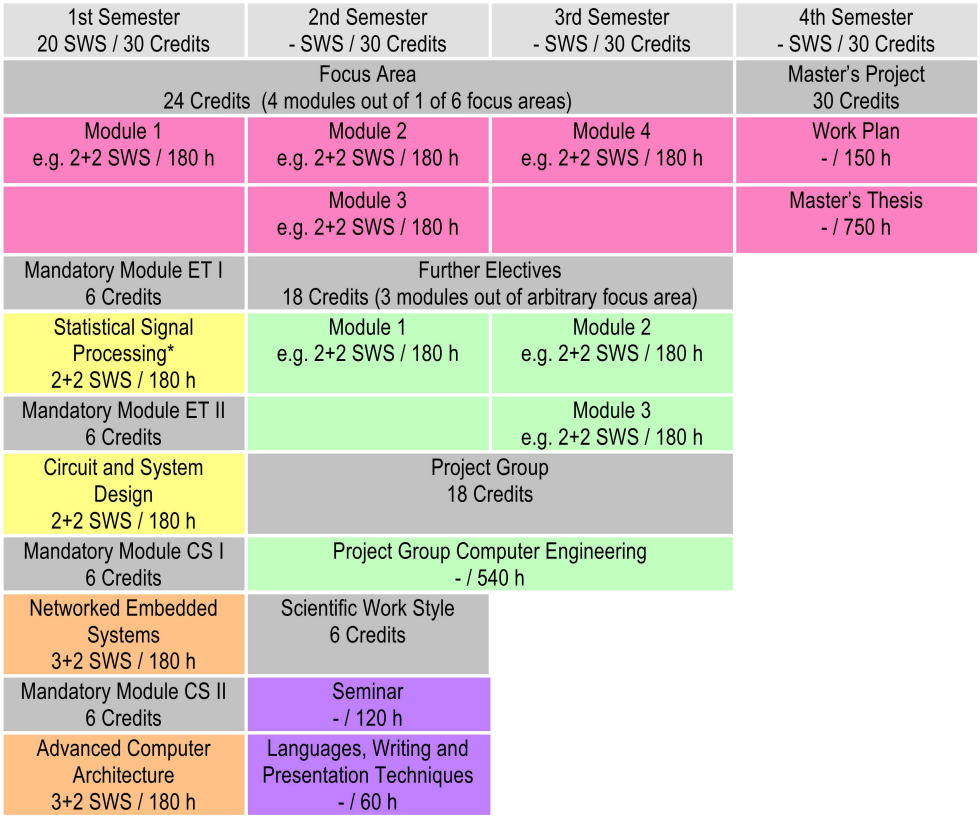


Figure 1.1: Curriculum and Schedule Master Computer Engineering

## 1.3 Training of Soft Skills

The master program Computer Engineering includes a number of courses in which training of soft skills is an integral component:

- project group Computer Engineering (module Project Group)
- seminar (module Seminar)
- an elective course in languages or scientific writing (module Seminar)
- master thesis including the presentation of the theses and the work schedule (module Master Thesis)

Besides providing training in a joined-up scientific-technical way of thinking, these courses greatly strengthen communication, presentation, moderation and self-reflection skills. The amount of credit points devoted to soft skills training totals to 54 LP. Actually, the number of courses including soft skills training is much higher, since exercise sessions often require and train communication skills, the ability to work in a team and competences in using modern information technology. This also applies to many of the lectures when using novel forms of teaching.

## 1.4 Scheme for Module Descriptions

The module descriptions are consistently structured according to the following scheme:

| | |
|---|---|
| Module name | <Module Name> |
| Workload | <Overall Workload in hours> |
| Credits | <Credits in ECTS> |
| Semester | <Summer, winter, or arbitrary> |

| **Courses: Teaching form (Contact hours / Self study / Language / Date / Group size)** |
|---|
| <List of the contained course elements, dividing the workload into contact time and self study time. Language the course is given in, winter semester or summer semester, group size> |

| **Choices in Module** |
|---|
| <List of choices> |

| **Course prerequisites** |
|---|
| <Prerequisites for participation> |

| **Recommended proficiencies** |
|---|
| <Recommendations, not checked as prerequisites> |

| **Content** |
|---|
| <Overview over the module's main content> |

| **Learning objectives** |
|---|
| <Enumeration of the intended knowledge, abilities and professional expertise> |

| **Implementation Method** |
|---|
| <Working forms and teaching methods applied> |

| **Assessment modalities (duration)** |
| --- |
| <Form and duration of the examination> |

| **Partial module exams** |
| --- |
| <Form of partial examinations, if any> |

| **Course achievement / qualifying participation** |
| --- |
| <Form of course achievement or qualifying participation> |

| **Prerequisites for participation in module exam** |
| --- |
| <Formal prerequisites for taking the module exam> |

| **Prerequisites for obtaining credits** |
| --- |
| <Formal Prerequisites for obtaining credits> |

| **Weight for overall grade** |
| --- |
| <Modules weight when computing the overall grade> |

| **Module contained in the following programmes** |
| --- |
| <List of programs that use that module> |

| **Person responsible for the module** |
| --- |
| <Person who is responsible for the module.> |

| **Lerning material, Literature** |
| --- |
| <List of references to literature, teaching material, etc.> |

| **Remarks** |
| --- |
| <Further remarks> |

## 1.5 List of organization forms

The following organization forms are used in this program:

**Final thesis**

**Lecture with exercices and practical work** Combination of a lecture with exercises and a phase of practical work.

**Lecture with practical assignments** A combination constisting of a lecture and exercises. Usually practical problems are solved during the exercises. There may also be homework assignments.

**Project**

**Seminar and elective courses**

## 1.6 List of examination forms

The following examination forms are used in this program:

**Written Exam** In written examinations the candidate has to demonstrate that she or he is capable of recognizing problems of the subject with the help of the tools allowed by the examiner and solve them with the common methods within the given time frame. A list of the allowed aids has to be announced together with the date of the examination.

Every written examination is graded by one examiner. In case of the last repetition, the assessment is conducted by two examiners.

The duration of a sit-down examination depends on the sum of the credit points in a module. It takes 90 to 120 minutes in case of up to 5 credit points and 120 to 180 minutes in case of more than 5 credit points.

**Oral Exam** In oral examinations the candidate has to demonstrate that she or he recognizes the interrelations within the examined area, is able to put specific questions into context and find solutions within the time given.

Oral examinations are performed in front of two examiners or one examiner in presence of one competent observer as group examinations or as single examinations. In any case it must be possible to differentiate and grade the contribution counted as an examination performance of each candidate separately. Before setting a grade the examiner consults the observer in absence of the candidate. In case of the last repetition, two examiners do the grading.

The duration of an oral examination per candidate depends on the sum of the credit points of the underlying courses. It takes 20 to 30 minutes in case of up to 5 credit points and 30 to 45 minutes in case of more than 5 credit points. For group examinations the total duration of the examination extends accordingly. The essential content and results of the examination have to be recorded in the minutes of the examination. The result of the examination has to be announced to the candidate subsequent to the oral examination by the examiner.

Students who want to take the same examination at a later examination date will be admitted as listeners according to the spatial conditions, as long as no candidate disagrees. Admission does not extend to the consultation and announcement of the examination result.

**Presentation** A presentation is a performance of about 30 minutes on the basis of a written composition. Thereby students have to prove that they are able to elaborate a topic scientifically and can present results.

**Written Term Paper** Within the framework of a written term paper with a scope of ten DIN-A4 pages a task is dealt with and solved properly within a thematic area of a course with the help of relevant literature, if necessary. The performance can also be made as a group performance, as long as an individual assessment and evaluation of each group member is possible.

**Colloquium** In a colloquium students have to prove that they can recognize technical interrelations and are able to put specific questions into a context in a conversation of 20 to 30 minutes with the examiner and other participants of the colloquium.

**Project** In a project the students work on a topic given by the lecturer by themselves or in a group. Projects usually include a draft and structure of hardware and software prototypes, as well as an ensuing experimental evaluation. Other parts of a project are usually the technical documentation and the presentation of the work and its results.

**Qualified Participation** A qualified participation is given, if the achieved performances indicate that the subjects underlying a given problem have been dealt with more than just superficially. The evidence of a qualified participation can be requested in a module, if this is necessary for ensuring the acquisition of competences in the module besides the module examination. The evidence of a qualified participation in a module can be a requirement for the allocation of credit points or a requirement for the participation in examinations. The evidence of a qualified participation is provided especially by one or more short written examinations, an expert discussion, the preparation of a protocol, exercises prepared during the course or as homework, short tests ("Testate"), a presentation. Details are provided in the module description. If the module description only sets the framework, then the exact rules must be published by the lecturer in the campus management system or in another suitable way no later than three weeks after the beginning of semester.

**Course Work** As a course work exercises can be requested which usually are put as homework and / or presence tasks on a weekly basis. Further forms of course work can be a written paper or report of 5 - 10 pages, a presentation of 10 - 20 minutes duration or a short written examination of at most 30 minutes duration. Details are provided in the module description. If the module description only sets the framework, then the exact rules must be published by the lecturer in the campus management system or in another suitable way no later than three weeks after the beginning of semester.

**Bonus System** Voluntary bonus work is possible in addition to examinations. Bonus work can be delivered in the form of exercises or homework, short tests ("Testate") or projects. The goal of bonus work is to prepare students for examinations step by step. Bonus work can be graded and improve the final grade of the module according to predefined rules. The module exam must be passed independent of the bonus work. The final grade can be improved by the bonus system by at most 0.7.

# Chapter 2

# Focus Areas

## 2.1 Communication and Networks

| Focus Area | Communication and Networks |
|---|---|
| Koordination | Prof. Dr. Sybille Hellebrand<br>Computer Engineering<br>Electrical Engineering |
| Included Modules | • Advanced Distributed Algorithms and Data Structures (S. 26)<br>• Cooperative Mobile Systems (S. 62)<br>• Empiric performance evaluation (S. 86)<br>• Foundations of Cryptography (S. 97)<br>• Future Internet (S. 100)<br>• Integrated Circuits for Wireless Communication (S. 109)<br>• Machine Learning I (S. 121)<br>• Mobile Communication (S. 127)<br>• Network Simulation (S. 134)<br>• Optical Communication A (S. 136)<br>• Optical Communication B (S. 139)<br>• Optical Communication C (S. 142)<br>• Optimal and Adaptive Filters (S. 145)<br>• Real World Crypto Engineering (S. 151)<br>• Routing and Data Management in Networks (S. 162)<br>• Fast Integrated Circuits for Wireline Communication (S. 91)<br>• Topics in Signal Processing (S. 197)<br>• Vehicular Networking (S. 201)<br>• Web Security (S. 210)<br>• Wireless Communications (S. 212) |

| Description |
| --- |
| |

## 2.2 Computer Systems

| Focus Area | Computer Systems |
|---|---|
| Koordination | Prof. Dr. Sybille Hellebrand<br>Computer Engineering<br>Electrical Engineering |
| Included Modules | • Algorithms and Tools for Test and Diagnosis of Systems on Chip (S. 37)<br>• Algorithms for Synthesis and Optimization of Integrated Circuits (S. 40)<br>• Approximate Computing (S. 43)<br>• Architectures of Parallel Computer Systems (S. 46)<br>• Databases and Information Systems (S. 65)<br>• Empiric performance evaluation (S. 86)<br>• High-Performance Computing (S. 106)<br>• Intelligence in Embedded Systems (S. 112)<br>• Introduction to Quantum Computation (S. 118)<br>• Machine Learning I (S. 121)<br>• Reconfigurable Computing (S. 153)<br>• VLSI Testing (S. 207) |
| Description | |
| | |

## 2.3 Control and Automation

| Focus Area | Control and Automation |
|---|---|
| Koordination | Prof. Dr. Sybille Hellebrand<br>Computer Engineering<br>Electrical Engineering |
| Included Modules | • Advanced Control (S. 23)<br>• Advanced System Theory (S. 29)<br>• Advanced Topics in Robotics (S. 32)<br>• Biomedical Measuring Technologies (S. 48)<br>• Dynamic Programming and Stochastic Control (S. 77)<br>• Controlled AC Drives (S. 59)<br>• Machine Learning I (S. 121)<br>• Reinforcement Learning (S. 156)<br>• Robotics (S. 159)<br>• System Identification (S. 182)<br>• Topics in Automatic Control (S. 191)<br>• Ultrasonic Measurement Technology (S. 199)<br>• Environmental Monitoring and Measuring Technologies (S. 89) |
| Description | |
| | |

## 2.4 Embedded Systems

| Focus Area | Embedded Systems |
|---|---|
| Koordination | Prof. Dr. Sybille Hellebrand<br>Computer Engineering<br>Electrical Engineering |
| Included Modules | • Advanced VLSI Design (S. 35)<br>• Algorithms and Tools for Test and Diagnosis of Systems on Chip (S. 37)<br>• Algorithms for Synthesis and Optimization of Integrated Circuits (S. 40)<br>• Approximate Computing (S. 43)<br>• Architectures of Parallel Computer Systems (S. 46)<br>• Cooperative Mobile Systems (S. 62)<br>• Integrated Circuits for Wireless Communication (S. 109)<br>• Intelligence in Embedded Systems (S. 112)<br>• Machine Learning I (S. 121)<br>• Model-Based Systems Engineering (S. 130)<br>• Model-Driven Software Development (S. 132)<br>• Network Simulation (S. 134)<br>• Reconfigurable Computing (S. 153)<br>• Fast Integrated Circuits for Wireline Communication (S. 91)<br>• Software Quality Assurance (S. 171)<br>• VLSI Testing (S. 207)<br>• Vehicular Networking (S. 201) |

| Description |
| --- |
| |

## 2.5 Nano/Microelectronics

| Focus Area | Nano/Microelectronics |
|---|---|
| Koordination | Prof. Dr. Sybille Hellebrand<br>Computer Engineering<br>Electrical Engineering |
| Included Modules | • Advanced VLSI Design (S. 35)<br>• Algorithms and Tools for Test and Diagnosis of Systems on Chip (S. 37)<br>• Introduction to High-Frequency Engineering (S. 115)<br>• Semiconductor Device Integration (S. 168)<br>• High Frequency Engineering (S. 103)<br>• Integrated Circuits for Wireless Communication (S. 109)<br>• Machine Learning I (S. 121)<br>• Fast Integrated Circuits for Wireline Communication (S. 91)<br>• Technology of Highly Integrated Circuits (S. 185)<br>• VLSI Testing (S. 207) |
| Description | |
| | |

## 2.6 Signal, Image and Speech Processing

| Focus Area | Signal, Image and Speech Processing |
|---|---|
| Koordination | Prof. Dr. Sybille Hellebrand<br>Computer Engineering<br>Electrical Engineering |
| Included Modules | • Advanced System Theory (S. 29)<br>• Digital Image Processing I (S. 68)<br>• Digital Image Processing II (S. 71)<br>• Digital Speech Signal Processing (S. 74)<br>• Cognitive Sensor Systems (S. 50)<br>• Machine Learning I (S. 121)<br>• Machine Learning II (S. 124)<br>• Statistics in Measurement (S. 180)<br>• Optimal and Adaptive Filters (S. 145)<br>• Statistical Natural Language Processing (S. 177)<br>• Statistical and Machine Learning (S. 174)<br>• Cognitive Systems Engineering (S. 52)<br>• Topics in Audio, Speech, and Language Processing (S. 188)<br>• Topics in Pattern Recognition and Machine Learning (S. 194)<br>• Topics in Signal Processing (S. 197)<br>• Video Technology (S. 204)<br>• Wireless Communications (S. 212) |

| Description |
| --- |
| |

# Chapter 3

# Modules

## 3.1 Elective Module: Advanced Control

| | |
|---|---|
| Module name | Advanced Control / Advanced Control |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Advanced Control : 3 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Advanced Control: Lecture ( 30h / 120h / EN / WS / 100 )
Advanced Control: Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Advanced Control: Undergraduate-level systems theory and automatic control.

**Content**

Advanced Control: This course builds on undergraduate-level systems theory and automatic control courses and focuses on the design of discrete-time control systems, using transfer function and state space methods. The course is primarily intended to serve engineering students, but can also be useful to students in physics and other natural sciences.

**Learning objectives**

After successfully completing the module, students are able to
- study the dynamics of discrete-time feedback systems,
- design appropriate control systems.

**Implementation method**

Advanced Control:
- Lectures using blackboard and, at times, transparencies

- Tutorials with study guides and computer simulations

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. Daniel E. Quevedo

**Learning material, literature**

Advanced Control: The course uses a selection of material from the books included in the list below. In addition, lecture notes and study guides are provided.
- K. J. Astrom and B. Wittenmark, Computer controlled systems. Theory and design. Englewood Cliffs, N.J.: Prentice Hall, second ed., 1990.
- G. C. Goodwin, S. F. Graebe, and M. E. Salgado, Control System Design. Prentice-Hall, 2001.
- J. B. Rawlings and D. Q. Mayne, Model Predictive Control: Theory and Design. Madison, WI: Nob Hill Publishing, 2009.
- B. D. O. Anderson and J. Moore, Optimal Filtering. Englewood Cliffs, NJ: Prentice Hall, 1979.
- K. J. Astrom, Introduction to Stochastic Control Theory. New York, N.Y.: Academic Press, 1970.

| **Remarks** |
| --- |
| none |

## 3.2 Elective Module: Advanced Distributed Algorithms and Data Structures

| | |
|---|---|
| Module name | Advanced Distributed Algorithms and Data Structures / Advanced Distributed Algorithms and Data Structures |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Advanced Distributed Algorithms and Data Structures : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Advanced Distributed Algorithms and Data Structures: Lecture ( 45h / 105h / EN / WS / 30 )
Advanced Distributed Algorithms and Data Structures: Tutorial ( 30h / 0h / EN / WS / 30 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Advanced Distributed Algorithms and Data Structures: Algorithms and data structures, distributed algorithms and data structures

**Content**

Advanced Distributed Algorithms and Data Structures: The lecture presents advanced methods that allow the design of highly scalable distributed algorithms and data structures. It splits into separate areas that are currently very relevant in the area of distributed systems. This includes locality-preserving systems, robust information systems, and programmable matter.

**Learning objectives**

Students get to know advanced methods and algorithms for currently very relevant distributed systems. They are able to adapt algorithms to new situations and to determine their complexity. They can implement basic distributed algorithms.

**Implementation method**

Advanced Distributed Algorithms and Data Structures: Lecture with tutorials and software project

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. rer. nat. Christian Scheideler

**Learning material, literature**

Advanced Distributed Algorithms and Data Structures: Lectures notes

| **Remarks** |
| --- |
| none |

## 3.3 Elective Module: Advanced System Theory

| | |
|---|---|
| Module name | Advanced System Theory / Advanced System Theory |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Advanced System Theory : 3 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Advanced System Theory: Lecture ( 30h / 120h / EN / WS / 100 )
Advanced System Theory: Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Advanced System Theory: Recommended is a basic understanding of differential equations, linear algebra, and Laplace transforms, as they are covered in a typical undergraduate course on system theory.

**Content**

Advanced System Theory: Building on an undergraduate system theory course, this course studies the dynamical behavior of linear systems with greater mathematical rigor. The course is primarily intended to serve students in engineering, but it can also be useful to students in physics and other natural sciences.

**Learning objectives**

After attending this module, students will be familiar with the most important concepts and results in linear system theory. Students will develop confidence in their ability to solve mathematical problems of analysis and design. Many of their timeless insights and intuitions about the dynamical behavior of systems will be drawn from this course.
This course presents material broad enough so that students will have a clear understanding of the dynamical behavior of linear systems, including their power and limitations. This will allow students

to apply the theory to other fields.

**Implementation method**

Advanced System Theory: Lectures and exercises (including some computer simulations)

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Peter Schreier

**Learning material, literature**

Advanced System Theory: Handouts and tutorial questions, literature references will be given in the first lecture.

| **Remarks** |
| --- |
| none |

## 3.4 Elective Module: Advanced Topics in Robotics

| | |
|---|---|
| Module name | Advanced Topics in Robotics / Advanced Topics in Robotics |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Advanced Topics in Robotics : 3 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Advanced Topics in Robotics: Lecture ( 30h / 120h / EN / WS / 0 )
Advanced Topics in Robotics: Tutorial ( 30h / 0h / EN / WS / 0 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Advanced Topics in Robotics: None

**Content**

Advanced Topics in Robotics: The course Advanced Topics in Robotics is based on the course Robotics. The students are introduced to current research topics in the field of autonomous and teleoperated mobile robots to solve interdisciplinary issues. The challenges encountered in developing intelligent mobile systems are analyzed and current solutions presented.

**Learning objectives**

After successfully completing the module the students
- are able to name and analyze the basic robot architectures for mobile robots,
- have a good command of the methods for the navigation and control of mobile robots and
- are able to implement, test and apply them.

**Implementation method**

Advanced Topics in Robotics:
- The theoretical and methodical fundamentals will be introduced during the lecture.
- The methods presented will be practiced during the subsequent exercise / lab part.
- Finally, the participants will implement, test, and apply simple algorithms.
- The necessary programming skills will be taught during the practical, this is explicitly not considered a programming course.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Bärbel Mertsching

**Learning material, literature**

Advanced Topics in Robotics: Allocation of lecture notes; information on textbooks stocked in the textbook collection will be announced later.
- Mertsching, Bärbel: Robotics (lecture notes)
- McKerrow, Phillip J.: Introduction to Robotics. Addison-Wesley, 1991

• Siegwart, Roland; Nourbakhsh, Illah R. and Scaramuzza, David: Introduction to Autonomous Mobile Robots. The MIT Press, 2011, ISBN-13: 978-0262015356

| **Remarks** |
| --- |
| none |

## 3.5 Elective Module: Advanced VLSI Design

| | |
|---|---|
| Module name | Advanced VLSI Design / Advanced VLSI Design |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Advanced VLSI Design : 3 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Advanced VLSI Design: Lecture ( 30h / 120h / EN / WS / 200 )
Advanced VLSI Design: Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

Wird nachgetragen

**Course prerequisites**

To be completed

**Recommended proficiencies**

Advanced VLSI Design: To be completed

**Content**

Advanced VLSI Design: To be completed

**Learning objectives**

**Implementation method**

Advanced VLSI Design: To be completed

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks

of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Dr. rer. nat. Wolfgang Müller

**Learning material, literature**

Advanced VLSI Design: To be completed

**Remarks**

To be completed

## 3.6 Elective Module: Algorithms and Tools for Test and Diagnosis of Systems on Chip

| | |
|---|---|
| Module name | Algorithms and Tools for Test and Diagnosis of Systems on Chip / Algorithms and Tools for Test and Diagnosis of Systems on Chip |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Algorithms and Tools for Test and Diagnosis of Systems on Chip : 3 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Algorithms and Tools for Test and Diagnosis of Systems on Chip: Lecture ( 30h / 120h / EN / WS / 20 )
Algorithms and Tools for Test and Diagnosis of Systems on Chip: Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Algorithms and Tools for Test and Diagnosis of Systems on Chip: Digital Design, Introduction to Algorithms, VLSI Testing

**Content**

Algorithms and Tools for Test and Diagnosis of Systems on Chip: The course “Algorithms and Tools for Test and Diagnosis of Systems on Chip” deals with advanced topics in test and diagnosis of integrated systems. The focus is on algorithms and tools for computer-aided preparation and application of test and diagnosis procedures.

**Learning objectives**

The module “Algorithms and Tools for Test and Diagnosis of Systems on a Chip” deals with recent approaches in test and diagnosis of integrated systems. The student work with research papers to extract and understand the underlying models and algorithms. They learn to explain the specific challenges of

nanoscale integration and evaluate test strategies accordingly.

**Implementation method**

Algorithms and Tools for Test and Diagnosis of Systems on Chip:
- Lecture based on slide presentation, extensions on blackboard
- Self-study on recent approaches based on recent conference and journal publications
- Oral presentation
- Manuscript

**Assessment modalities (duration)**

Seminar Presentation and Paper
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. Sybille Hellebrand

**Learning material, literature**

Algorithms and Tools for Test and Diagnosis of Systems on Chip:
- Slides
- Publications
- Michael L. Bushnell, Vishwani D. Agrawal, "Essentials of Electronic Testing for Digital, Memory, and Mixed-Signal VLSI Circuits," Kluwer Academic Publishers, ISBN: 0792379918
- Laung-Terng Wang, Cheng-Wen Wu, Xiaoqing Wen, "VLSI Test Principles and Architectures: Design for Testability," Morgan Kaufmann Series in Systems on Silicon, ISBN: 0123705975

**Remarks**

none

## 3.7 Elective Module: Algorithms for Synthesis and Optimization of Integrated Circuits

| | |
|---|---|
| Module name | Algorithms for Synthesis and Optimization of Integrated Circuits / Algorithms for Synthesis and Optimization of Integrated Circuits |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Algorithms for Synthesis and Optimization of Integrated Circuits : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Algorithms for Synthesis and Optimization of Integrated Circuits: Lecture ( 45h / 105h / EN / SS / 30 )
Algorithms for Synthesis and Optimization of Integrated Circuits: Tutorial ( 30h / 0h / EN / SS / 30 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Algorithms for Synthesis and Optimization of Integrated Circuits: Knowledge of "Digital Design" is beneficial.

**Content**

Algorithms for Synthesis and Optimization of Integrated Circuits: The course provides the most remarkable features of digital synthesis, and explains the details of transforming hardware description languages into circuit descriptions. Besides, the major techniques for logic optimization are discussed, and then the efficient use of current design tools are exercised in practical sessions.

**Learning objectives**

After attending the course, the students are able to
• select among the available optimisation methods in design of digital circuits,

- identify major problems in design of integrated circuits and recognize circuit design tradeoffs
- examine current digital design tools and methods

**Implementation method**

Algorithms for Synthesis and Optimization of Integrated Circuits:
- Lecture with projector and board
- Interactive exercises in the lecture room
- Computer-based exercises with hardware synthesis tools

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Dr. Hassan Ghasemzadeh Mohammadi

**Learning material, literature**

Algorithms for Synthesis and Optimization of Integrated Circuits:
- Lecture slides and exercise sheets
- Exercise sheets and technical documentation for the for the computer-based exercises
- Micheli, Giovanni De. Synthesis and optimization of digital circuits. McGraw-Hill Higher Education, 1994.
- Information about alternative and additional literature as well as teaching material on the course's website and in the lecture slides

**Remarks**

none

## 3.8 Elective Module: Approximate Computing

| | |
|---|---|
| Module name | Approximate Computing / Approximate Computing |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Approximate Computing : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Approximate Computing: Lecture ( 45h / 105h / EN / WS / 100 )
Approximate Computing: Tutorial ( 30h / 0h / EN / WS / 25 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Approximate Computing:
- Bachelor-level knowledge in digital design and computer architecture
- Bachelor-level knowledge in mathematics, in particular linear algebra and probability theory

**Content**

Approximate Computing: Approximate Computing is an emerging paradigm that trades-off computational accuracy for a significant reduction in energy, execution time, or chip area. This research-oriented course introduces to the field of Approximate Computing and its most remarkable aspects, and explains the main methods used to implement efficient computing systems by reducing accuracy. The course discusses approximations at all levels of a computing system, from applications down to hardware technologies. In exercise/tutorial sessions the efficiency of these techniques in various domains are examined, including deep learning and digital signal processing.

**Learning objectives**

After attending this course, the students are able
- to name and explain approximation techniques at all levels of a computing system,
- to identify major engineering/research problems when building approximate computing systems,
- to judge the suitability of approximation techniques for different application domains, and
- to apply approximation techniques to realize efficient hardware accelerators, in particular for deep

learning and digital signal processing

**Implementation method**

Approximate Computing:
- Lecture with projector and black/white board
- Interactive exercises/discussions in the lecture room
- Computer-based tutorials

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Dr. Hassan Ghasemzadeh Mohammadi

**Learning material, literature**

Approximate Computing:
- Lecture slides, exercise sheets, and tutorial assignments
- Adrian Sampson, Luis Ceze, and Dan Grossman: Good-Enough Computing. *IEEE Spectrum*, 50(10):54–59, 2013.
- Ravi Nair. Big Data Needs Approximate Computing: Technical Perspective. *Communications of the ACM*, 58(1): 104, 2015.
- Sparsh Mittal. A Survey of Techniques for Approximate Computing. *ACM Computing Surveys*, 48(4), 2016.
- Qiang Xu, Todd Mytkowitz, and Nam Sung Kim. Approximate Computing: A Survey. *IEEE Design & Test*, 33(1):8-22, 2016.
- Additional resources and links to current research papers are provided in the lecture

**Remarks**

none

## 3.9 Elective Module: Architectures of Parallel Computer Systems

| | |
|---|---|
| Module name | Architectures of Parallel Computer Systems / Architectures of Parallel Computer Systems |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Architecture of Parallel Computer Systems : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Architecture of Parallel Computer Systems: Lecture ( 45h / 105h / DE / SS / 20 )
Architecture of Parallel Computer Systems: Tutorial ( 30h / 0h / DE / SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Architecture of Parallel Computer Systems: Principles of computer architectures

**Content**

Architecture of Parallel Computer Systems: The lecture considers computer architectures of actual parallel computer systems and the usage of this systems. The focus of the lecture is on high-performance computers (supercomputers).

**Learning objectives**

wird nachgetragen

**Implementation method**

Architecture of Parallel Computer Systems: Presentation of slides. Exercises on available high performance computers to practise the usage of the systems and deepen the knowledge of the lecture.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Dr. Jens Simon

**Learning material, literature**

Architecture of Parallel Computer Systems: slides

**Remarks**

none

## 3.10 Elective Module: Biomedical Measuring Technologies

| | |
|---|---|
| Module name | Biomedical Measuring Technologies / Biomedical Measuring Technologies |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Biomedical Measuring Technologies : 2 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Biomedical Measuring Technologies: Lecture ( 30h / 120h / DE / SS / 0 )
Biomedical Measuring Technologies: Tutorial ( 30h / 0h / DE / SS / 0 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Biomedical Measuring Technologies: None

**Content**

Biomedical Measuring Technologies: The lecture concentrates on determining measurements characterizing the physiological state of a human. Main methods are described and characterized, e.g., tomography.

**Learning objectives**

Students are able to understand the root causes and mechanisms of bioelectrical and biomagnetic signals and their propagation in a biological body. They understand the basics and applicability of electrodiagnostic procedures and can characterize important tomographic methods.

**Implementation method**

Biomedical Measuring Technologies: Lecture with slides and practical lab work.

| **Assessment modalities (duration)** |
| --- |
| Oral exam (ca. 40 Minutes)<br>The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest. |

| **Partial module exams** |
| --- |
| none |

| **Course achievement / qualifying participation** |
| --- |
| none |

| **Prerequisites for participation in module exam** |
| --- |
| none |

| **Prerequisites for obtaining credits** |
| --- |
| Passing of module exam. |

| **Weight for overall grade** |
| --- |
| The module is weighted with 6 credits. |

| **Person responsible for the module** |
| --- |
| Prof. Dr.-Ing. Bernd Henning |

| **Learning material, literature** |
| --- |
| Biomedical Measuring Technologies: none |

| **Remarks** |
| --- |
| none |

## 3.11 Elective Module: Cognitive Sensor Systems

| | |
|---|---|
| Module name | Cognitive Sensor Systems / Cognitive Sensor Systems |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Cognitive Sensor Systems : 3 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Cognitive Sensor Systems: Lecture ( 30h / 120h / DE / WS / 100 )
Cognitive Sensor Systems: Tutorial ( 30h / 0h / DE / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Cognitive Sensor Systems: None

**Content**

Cognitive Sensor Systems: The lecture discusses how (possibly massive) amounts of information can be suitably reduced. Tasks include detection, classification or identification. Techniques from multivariate data analysis and artificial neural networks are relevant tools.

**Learning objectives**

Students learn to analyse complex tasks in complex multi-variate data analysis and to develop own solutions. They will exercise using artificial neural networks for pattern recognition and interpolation.

**Implementation method**

Cognitive Sensor Systems: Lecture with interactive whiteboard, practical lab exercises, students prepare small presentations and lead discussions.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Bernd Henning

**Learning material, literature**

Cognitive Sensor Systems: Supplementary material and textbooks.

**Remarks**

none

## 3.12 Elective Module: Cognitive Systems Engineering

| | |
|---|---|
| Module name | Cognitive Systems Engineering / Cognitive Systems Engineering |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Cognitive Systems Engineering : 3 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Cognitive Systems Engineering: Lecture ( 30h / 120h / DE / WS / 100 )
Cognitive Systems Engineering: Tutorial ( 30h / 0h / DE / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Cognitive Systems Engineering: To be completed

**Content**

Cognitive Systems Engineering: To be completed

**Learning objectives**

==¿ Text will be added

**Implementation method**

Cognitive Systems Engineering: To be completed

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks

of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Bärbel Mertsching

**Learning material, literature**

Cognitive Systems Engineering: To be completed

**Remarks**

none

## 3.13 Mandatory Module: Computer Science I

| | |
|---|---|
| Module name | Computer Science I / Computer Science I |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Networked Embedded Systems : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Networked Embedded Systems: Lecture ( 45h / 105h / EN / WS / 60 )
Networked Embedded Systems: Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Networked Embedded Systems: System software and system-level programming

**Content**

Networked Embedded Systems: The objective of this course is gain insights into the operation and programming of embedded systems. A strong focus is on wireless sensor networks. We study the fundamentals of such sensor networks. In the sopce of the exercises, we discuss selected topics in more detail.

**Learning objectives**

The learning objective is to unserstand the fundamental concepts of networded embedded systems. Students understand these concepts and are able to apply this knowledge.

**Implementation method**

Networked Embedded Systems: Lecture with practical exercises

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. Falko Dressler

**Learning material, literature**

Networked Embedded Systems: Slides, textbooks, papers

**Remarks**

none

## 3.14 Mandatory Module: Computer Science II

| | |
|---|---|
| Module name | Computer Science II / Computer Science II |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Advanced Computer Architecture : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Advanced Computer Architecture: Lecture ( 45h / 105h / EN / WS / 50 )
Advanced Computer Architecture: Tutorial ( 30h / 0h / EN / WS / 25 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Advanced Computer Architecture: Basic knowledge in computer architecture.

**Content**

Advanced Computer Architecture: The course teaches concepts and methods used in modern processor architecture to exploit the available parallelism at the levels of instructions, data and threads.

**Learning objectives**

After attending the course, the students
- are able to explain principles of modern memory hierarchies,
- to analyze different levels of parallelism,
- to assess the suitability of different architectural concepts and thus
- to evaluate modern developments in computer architecture.

**Implementation method**

Advanced Computer Architecture:
- Lecture with projector and board

- Interactive exercises in the lecture room item Computer-based exercises with simulation tools
- Analysis of case studies

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. Marco Platzner

**Learning material, literature**

Advanced Computer Architecture:
- Lecture slides and exercise sheets
- Exercise sheets and technical documentation for the for the computer-based exercises
- Hennessey, Patterson: Computer Architecture: A Quantitative Approach (5th edition or newer), Morgan Kauf- mann, 2012.
- Information about alternative and additional literature as well as teaching material on the course's

| |
|---|
| website and in the lecture slides |

| **Remarks** |
|---|
| none |

## 3.15 Elective Module: Controlled AC Drives

| | |
|---|---|
| Module name | Controlled AC Drives / Controlled AC Drives |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Controlled AC Drives : 3 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Controlled AC Drives: Lecture ( 30h / 120h / EN / WS / 0 )
Controlled AC Drives: Tutorial ( 30h / 0h / EN / WS / 0 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Controlled AC Drives:

**Content**

Controlled AC Drives: The course introduces the principle of flux-oriented control of three-phase AC motors, which is today's standard of electrical drives in industry. Unlike the course of the bachelor's program, focus is put on the dynamics behavior and on the control structures. As most important examples, the permanent magnet synchronous motor and the induction motor are treated.

**Learning objectives**

The module introduces the principle of flux-oriented control of three-phase AC motors, which is today's standard of electrical drives in industry. Unlike the course of the bachelor's program, focus is put on the dynamics behavior and on the control structures.
The students will understand the most important types of AC drives, their properties and should be able to select and to design such drives by themselves.

| **Implementation method** |
| --- |
| Controlled AC Drives: Parts of the course are organized as computer-based exercises |

| **Assessment modalities (duration)** |
| --- |
| Oral exam (ca. 40 Minutes)<br>The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest. |

| **Partial module exams** |
| --- |
| none |

| **Course achievement / qualifying participation** |
| --- |
| none |

| **Prerequisites for participation in module exam** |
| --- |
| none |

| **Prerequisites for obtaining credits** |
| --- |
| Passing of module exam. |

| **Weight for overall grade** |
| --- |
| The module is weighted with 6 credits. |

| **Person responsible for the module** |
| --- |
| Prof. Dr.-Ing. Joachim Böcker |

| **Learning material, literature** |
| --- |
| Controlled AC Drives: Lecture notes, slides. Other literature will be given in the lecture. |

| **Remarks** |
| --- |
| none |

## 3.16 Elective Module: Cooperative Mobile Systems

| | |
|---|---|
| Module name | Cooperative Mobile Systems / Cooperative Mobile Systems |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Cooperative Mobile Systems : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Cooperative Mobile Systems: Lecture ( 30h / 105h / EN / SS / 40 )
Cooperative Mobile Systems: Tutorial ( 45h / 0h / EN / SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Cooperative Mobile Systems: System software and system-level programming

**Content**

Cooperative Mobile Systems: Vehicle-to-everything communication can serve as the basis for novel applications enabling cooperation among mobile systems of the future. Trucks, cars, bikes, pedestrians, and cities are all part of such a system. This course will cover the basis and the application of communication concepts to the design of such cooperative mobile systems. A practical part covers the application of learned theoretical concepts to the design of novel cooperative mobile systems, as well as the study of such systems via simulative performance evaluation.

**Learning objectives**

Students will be able to understand how vehicle-to-everything communication can serve as the basis for applications enabling cooperation among trucks, cars, bikes, pedestrians, and cities. They will also be able to apply this knowledge to the design of future cooperative mobile systems - both in theory and in practice.

| **Implementation method** |
| --- |
| Cooperative Mobile Systems: Lecture with practical exercises |

| **Assessment modalities (duration)** |
| --- |
| Oral exam (ca. 40 Minutes)<br>The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest. |

| **Partial module exams** |
| --- |
| none |

| **Course achievement / qualifying participation** |
| --- |
| Qualifying Participation: written exercises<br>The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest. |

| **Prerequisites for participation in module exam** |
| --- |
| Passing of course achievement. |

| **Prerequisites for obtaining credits** |
| --- |
| Passing of module exam. |

| **Weight for overall grade** |
| --- |
| The module is weighted with 6 credits. |

| **Person responsible for the module** |
| --- |
| Jun.-Prof. Dr.-Ing. Christoph Sommer |

| **Learning material, literature** |
| --- |
| Cooperative Mobile Systems: Slides, textbooks, papers |

| **Remarks** |
| --- |
| none |

## 3.17 Elective Module: Databases and Information Systems

| | |
|---|---|
| Module name | Databases and Information Systems / Databases and Information Systems |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Databases and Information Systems : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Databases and Information Systems: Lecture ( 45h / 105h / EN / WS / 120 )
Databases and Information Systems: Tutorial ( 30h / 0h / EN / WS / 30 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Databases and Information Systems: Studentes are required to have previous knowledge of relational database systems and SQL comparable to the course "Datanbanksysteme" and programming knowledge and skills comparable to the courses "Programming" and "Grundlagen der Programmiersprachen".

**Content**

Databases and Information Systems: Data storage and data management play a central role in enterprises since a large part of the companies' knowledge is stored as data. For large data volumes, it is essential that future application developers know concepts beyond that of traditional database systems, in particular for NoSQL and non-standard data models, main-memory databases, compression, indexing, and efficient search, in order to develop applications or information systems that lead to acceptable response times. This module focusses on querying and processing of massive data, including tree structured data, text, streaming data, on NoSQL, and on main-memory databases. This module covers algorithms, technologies and practical skills in these areas.

**Learning objectives**

After completing the module students can comprehend, design, implement and assess (with respect to time and space complexity) XML processing in software systems. They known pivotal search and query techniques to acquire information in uncompressed and compressed XML data. They can appropriately

process infinite data streams. They can acquire new research results from scientific publications.

**Implementation method**

Databases and Information Systems: The fundamental concepts are presented in a lecture. Additioanlly, theoretical concepts are deepened in small groups during class-based tutorials. This method is used in particular for core concepts of databases (searching in and querying Big Data, distributed databases, and mobile data and manangement). Additionally, practical skills are acquired through computer-based exercises, where the students have to develop their own information systems, search or compression algorthms, based on the introduction given in the lecture.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

| **Person responsible for the module** |
| --- |
| Prof. Dr. Stefan Böttcher |

| **Learning material, literature** |
| --- |
| Databases and Information Systems: Links to material will be provided during the lecture |

| **Remarks** |
| --- |
| none |

## 3.18 Elective Module: Digital Image Processing I

| | |
|---|---|
| Module name | Digital Image Processing I / Digital Image Processing I |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Digital Image Processing I : 1 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Digital Image Processing I: Lecture ( 30h / 120h / EN / WS / 0 )
Digital Image Processing I: Tutorial ( 30h / 0h / EN / WS / 0 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Digital Image Processing I: None

**Content**

Digital Image Processing I: The course "Digital Image Processing I" provides a fundamental introduction to digital image processing.

**Learning objectives**

After successfully completing the module the students
• are able to describe the basics of image generation and image digitization and
• are able to implement, test and apply methods for the enhancement of images in the spatial and frequency domain, image segmentation and data reduction independently for complex image processing tasks

**Implementation method**

Digital Image Processing I:
• The theoretical and methodic fundamentals will be introduced during the lecture.
• The methods presented will be practiced during the subsequent exercise / lab part.
• Finally, the participants will implement, test, and apply simple image processing algorithms.

• The necessary programming skills will be taught during the practical, this is explicitly not considered a programming course.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Bärbel Mertsching

**Learning material, literature**

Digital Image Processing I: Lecture notes, exercise sheets and advanced literature (excerpt):
• Mertsching, Bärbel: Digital Image Processing I (lecture notes)
• Forsyth, David and Ponce, Jean: Computer Vision - A Modern Approach. Prentice Hall, 2nd ed., 2011. ASIN: B006V372KG
• Gonzalez, Rafael C. and Woods, Richard E.: Digital Image Processing. Prentice Hall, 3rd ed., 2007. ISBN-13: 978-013168728
• Jähne, Bernd: Digitale Bildverarbeitung. Springer, 7.Aufl., 2012. ISBN-13: 978-3642049514

| **Remarks** |
| --- |
| none |

## 3.19 Elective Module: Digital Image Processing II

| | |
|---|---|
| Module name | Digital Image Processing II / Digital Image Processing II |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Digital Image Processing II : 2 |

| **Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )** |
|---|
| Digital Image Processing II: Lecture ( 30h / 120h / EN / SS / 0 )<br>Digital Image Processing II: Tutorial ( 30h / 0h / EN / SS / 0 ) |

| **Choices in Module** |
|---|
| none |

| **Course prerequisites** |
|---|
| none |

| **Recommended proficiencies** |
|---|
| Digital Image Processing II: Basic knowledge of image processing |

| **Content** |
|---|
| Digital Image Processing II: The course “Digital Image Processing II” follows the fundamental course “Digital Image Processing I” and describes methods for feature extraction and object recognition. |

| **Learning objectives** |
|---|
| After successfully completing the module the students<br>• are able use the basic methods for image segmentation,<br>• have a good command of the probabilistic methods for the description of image features and object recognition,<br>• are able to transfer the acquired knowledge of image processing to the processing of other multi-dimensional signals and<br>• are able to describe the state-of-the-art of the presented topics |

**Implementation method**

Digital Image Processing II:
• The theoretical and methodic fundamentals will be introduced during the lecture.
• During the subsequent exercise / lab part the participants will implement, test, and apply the presented methods

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Bärbel Mertsching

**Learning material, literature**

Digital Image Processing II: Lecture notes, exercise sheets and advanced literature (excerpt):
• Mertsching, Bärbel: Digital Image Processing I (lecture notes)
• Forsyth, David and Ponce, Jean: Computer Vision - A Modern Approach. Prentice Hall, 2nd ed., 2011. ASIN: B006V372KG
• Gonzalez, Rafael C. and Woods, Richard E.: Digital ImageProcessing. Prentice Hall, 3rd ed., 2007. ISBN-13: 978-0131687288

- Jähne, Bernd: Digitale Bildverarbeitung. Springer, 7.Aufl., 2012. ISBN-13: 978-3642049514

| **Remarks** |
| --- |
| none |

## 3.20 Elective Module: Digital Speech Signal Processing

| | |
|---|---|
| Module name | Digital Speech Signal Processing / Digital Speech Signal Processing |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Digital Speech Signal Processing : 2 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Digital Speech Signal Processing: Lecture ( 30h / 120h / DE / SS / 30 )
Digital Speech Signal Processing: Tutorial ( 30h / 0h / DE / SS / 30 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Digital Speech Signal Processing: Prior knowledge from the module Higher Mathematics is helpful.

**Content**

Digital Speech Signal Processing: The course introduces the basic techniques and theories of digital speech signal processing. A focal point of the first part of the lecture is the topic "Listening and Speaking", which is concerned with psychological effects of human sound perception and speech production. Subsequently, time discrete signals and systems, as well as computer based data processing are discussed. Further topics are non-parametric short-time analysis of speech signals, speech coding and IP-phones.

**Learning objectives**

After attending the course, the students will be able to
• analyze digital signals, e.g., audio signals, in the time or frequency domain,
• represent audio signals efficiently and
• implement widely-used algorithms for speech analysis and speech processing in the frequency or time domain.

**Implementation method**

Digital Speech Signal Processing:
- Lectures using the blackboard and presentations,
- Alternating theoretical and practical exercise classes with exercise sheets and computer and
- Demonstration of real technical systems in the lecture hall.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Reinhold Häb-Umbach

**Learning material, literature**

Digital Speech Signal Processing: Allocation of a script; information on textbooks ; matlab scripts

| **Remarks** |
| --- |
| none |

## 3.21 Elective Module: Dynamic Programming and Stochastic Control

| | |
|---|---|
| Module name | Dynamic Programming and Stochastic Control / Dynamic Programming and Stochastic Control |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Dynamic Programming and Stochastic Control : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Dynamic Programming and Stochastic Control: Lecture ( 30h / 120h / EN / WS / 0 )
Dynamic Programming and Stochastic Control: Tutorial ( 30h / 0h / EN / WS / 0 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Dynamic Programming and Stochastic Control:
• Basic knowledge on control of discrete-time systems, e.g. as covered in the course Regelungstechnik - Automatic Control
• An introductory course on probability and random processes, e.g. the course Stochastik für Ingenieure

**Content**

Dynamic Programming and Stochastic Control: Dynamic programming is a method for solving decision making problems consisting of a number of stages, by breaking down the problem into simpler sub-problems. These methods have wide applicability in areas such as optimization, control, communications, and machine learning. This course will cover the modelling and solution of problems of sequential decision making under uncertainty. We will consider problems with both a finite and an infinite number of stages, as well as cases with perfect and imperfect observations of the system. Numerical techniques for solving these problems will be described, including suboptimal methods for when the state and/or action spaces are large.

**Learning objectives**

After attending this course, students will have understood the basics of dynamic programming and stochastic control. Students will learn the dynamic programming optimality principle and how it can be used to solve multi-stage decision making problems. They will learn how to formulate and solve, using dynamic programming, problems in different areas such as control, communications, signal processing, and machine learning.

**Implementation method**

Dynamic Programming and Stochastic Control: Lectures and exercises

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Dr. Alex Leong

**Learning material, literature**

Dynamic Programming and Stochastic Control: D. Bertsekas, Dynamic Programming and Optimal Control, Vol I, 3rd Ed, Athena
Some other material will be taken from:

- D. Bertsekas, Dynamic Programming and Optimal Control, Vol II, 4th Ed, Athena Scientific, 2012
- M. Puterman, Markov Decision Processes, John Wiley and Sons, 1994
- B. Anderson and J. Moore, Optimal Filtering, Prentice-Hall, 1979
- various research papers

**Remarks**

none

## 3.22 Mandatory Module: Electrical Engineering I

| | |
|---|---|
| Module name | Electrical Engineering I / Electrical Engineering I |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Statistical Sgnal Processing : 1<br>• Verarbeitung statistischer Signale : 1 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Statistical Sgnal Processing: Lecture ( 30h / 120h / EN / WS / 60 )
Statistical Sgnal Processing: Tutorial ( 30h / 0h / EN / WS / 20 )
Verarbeitung statistischer Signale: Lecture ( 30h / 120h / DE / WS / 0 )
Verarbeitung statistischer Signale: Tutorial ( 30h / 0h / DE / WS / 0 )

**Choices in Module**

One of the listed courses must be selected.

**Course prerequisites**

none

**Recommended proficiencies**

Statistical Sgnal Processing: Undergraduate courses in signal processing and probability

Verarbeitung statistischer Signale: Basics in stochastic signal description.

**Content**

Statistical Sgnal Processing: Statistical signal processing comprises the techniques that engineers and statisticians use to draw inference from imperfect and incomplete measurements. This course covers a selection of topics from the major domains of detection, estimation, and time series analysis.

Verarbeitung statistischer Signale: Statistics in many fields of computer engineering. Estimators and detectors. Statistical time series. Statistical significance.

**Learning objectives**

After attending this course, students will be familiar with the basic principles of statistical signal processing. They will understand how to apply statistical signal processing techniques to relevant fields in electrical engineering (such as communications). Students will develop confidence in their ability to solve mathematical problems of analysis and design. They will be able to apply the principles they have

learned in this course to other areas.

**Implementation method**

Statistical Sgnal Processing: Lectures and exercises (including some computer simulations)

Verarbeitung statistischer Signale: Lecture with blackboard, homework assignments, practical work with matlab.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Peter Schreier

**Learning material, literature**

Statistical Sgnal Processing: Handouts and tutorial questions, literature references will be given in the first lecture.

Verarbeitung statistischer Signale: Script and textbooks.
- N. Henze, Stochastik für Einsteiger, 8. Auflage, Vieweg-Teubner Verlag, 2010

• E. Hänsler, Statistische Signale — Grundlagen und Anwendungen, 3. Auflagen, Springer, 2001
• S. M. Kay, Fundamentals of Statistical Signal Processing — Estimation Theory, Prentice Hall, 1993
• J. L. Mela, D. L. Cohn, Decision and Estimation Theory, McGraw-Hill, Kogakusha, 1987.
• A. Papoulis, Probability, Random Variables, and Stochastic Processes, 2. Ausgabe, McGraw-Hill, New York, 1984.

**Remarks**

none

## 3.23 Mandatory Module: Electrical Engineering II

| | |
|---|---|
| Module name | Electrical Engineering II / Electrical Engineering II |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Circuit and System Design : 1 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Circuit and System Design: Lecture ( 30h / 120h / EN / WS / 60 )
Circuit and System Design: Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Circuit and System Design: It builds on basic knowledge of electronic devices and system theory.

**Content**

Circuit and System Design: The lecture gives an introduction to analysis and design of analog and digital circuits and systems.

**Learning objectives**

After completing the module, the students will be able to
- describe appropriate methods for analysis and design of analog systems
- describe appropriate methods for analysis and design of digital systems
- assess the limitations of the different methods
- understand and calculate the behaviour of simple analog and digital circuits
- use a numeric simulation tool for electronic systems and circuit simulation

**Implementation method**

Circuit and System Design:
- Powerpoint and Whiteboard
- Mathematical exercises and design exercises with modern IC design software

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Christoph Scheytt

**Learning material, literature**

Circuit and System Design: See course webspage.

| **Remarks** |
| --- |
| none |

## 3.24 Elective Module: Empiric performance evaluation

| | |
|---|---|
| Module name | Empiric performance evaluation / Empiric performance evaluation |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Empiric performance evaluation : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Empiric performance evaluation: Lecture ( 45h / 105h / EN / SS / 15 )
Empiric performance evaluation: Tutorial ( 30h / 0h / EN / SS / 15 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Empiric performance evaluation: Bachelor-level stochastics.

**Content**

Empiric performance evaluation: This lecture discusses methods and procedures to conduct experimental and simulation-based performance evaluations, along with a statistically solid evaluation of results. The techniques of this class are applicable to a wide range of systems.

**Learning objectives**

Participants can determine whether a given system or modell is amenable to a particular performance evaluation method. They can design an experiment or a simulation and execute it; they can choose a suitable stochastic model and interprete the experimental results correctly. They can derive statistically justified conclusions, e.g., which system can be regarded as the best system out of a given collection.

**Implementation method**

Empiric performance evaluation: Lecture with slides and blackboard; homework assignments.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. rer. nat. Holger Karl

**Learning material, literature**

Empiric performance evaluation: Slides, homework assignments, textbook Kelton & Law, Simulation Modelling and Analysis.

| **Remarks** |
| --- |
| none |

## 3.25 Elective Module: Environmental Monitoring and Measuring Technologies

| | |
|---|---|
| Module name | Environmental Monitoring and Measuring Technologies / Environmental Monitoring and Measuring Technologies |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Environmental Monitoring and Measuring Technologies : 3 |

| **Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )** |
|---|
| Environmental Monitoring and Measuring Technologies: Lecture ( 30h / 120h / DE / WS / 100 )<br>Environmental Monitoring and Measuring Technologies: Tutorial ( 30h / 0h / DE / WS / 20 ) |

| **Choices in Module** |
|---|
| none |

| **Course prerequisites** |
|---|
| none |

| **Recommended proficiencies** |
|---|
| Environmental Monitoring and Measuring Technologies: None |

| **Content** |
|---|
| Environmental Monitoring and Measuring Technologies: Measuring the environment. |

| **Learning objectives** |
|---|
| Students will be able to analyse mechanisms under increasing environmental problems, chose suitable measurements techniques, and characterize and analyze measurement results. |

| **Implementation method** |
|---|
| Environmental Monitoring and Measuring Technologies: Lecture with slides; practical work in small groups. |

| **Assessment modalities (duration)** |
| --- |
| Oral exam (ca. 40 Minutes)<br>The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest. |

| **Partial module exams** |
| --- |
| none |

| **Course achievement / qualifying participation** |
| --- |
| none |

| **Prerequisites for participation in module exam** |
| --- |
| none |

| **Prerequisites for obtaining credits** |
| --- |
| Passing of module exam. |

| **Weight for overall grade** |
| --- |
| The module is weighted with 6 credits. |

| **Person responsible for the module** |
| --- |
| Prof. Dr.-Ing. Bernd Henning |

| **Learning material, literature** |
| --- |
| Environmental Monitoring and Measuring Technologies: Script and textbooks. |

| **Remarks** |
| --- |
| none |

## 3.26 Elective Module: Fast Integrated Circuits for Wireline Communication

| | |
|---|---|
| Module name | Fast Integrated Circuits for Wireline Communication / Fast Integrated Circuits for Wireline Communication |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Fast Integrated Circuits for Wireline Communication : 3 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Fast Integrated Circuits for Wireline Communication: Lecture ( 30h / 120h / DE / WS / 100 )
Fast Integrated Circuits for Wireline Communication: Tutorial ( 30h / 0h / DE / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Fast Integrated Circuits for Wireline Communication: None

**Content**

Fast Integrated Circuits for Wireline Communication: In modern fiber-optic communication systems data rates of several 100 Gb/s per optical channel and several Tb/s per fiber are transmitted. In a similar way nowadays the data transmission between electronic chips reaches data rates of more than 10 Gb/s over a single package pin which has to be transmitted over low-cost serial cable and printed circuit boards. In the future the progress in digital CMOS technologies these data rates will be continuously increased. Goal of the lecture is to convey a methodical design process of fast integrated electronic circuits for digital wireline communications.

**Learning objectives**

With successful completion of the module the students will be able to
- describe architectures and circuits of fast digital data transmission links,
- describe and calculate fundamental signal transmission properties of digital systems,

- apply design methods to design basic integrated broadband circuits,

**Implementation method**

Fast Integrated Circuits for Wireline Communication:
- Powerpoint and Whiteboard
- Mathematical exercises and design exercises with modern IC design software

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Christoph Scheytt

**Learning material, literature**

Fast Integrated Circuits for Wireline Communication: Lecture and exercise slides, Literature
- Paul Gray et al. “Analysis And Design of Analog Integrated Circuits”, Wiley & Sons 2001
- Eduard Säckinger “Broadband Circuits for Optical Fiber Communication”, Wiley & Sons 2005

• Behzad Razavi “Design of ICs for Optical Communications”, McGraw-Hill, 2003

| **Remarks** |
| --- |
| none |

## 3.27 Mandatory Module: Final Project

| | |
|---|---|
| Module name | Final Project / Final Project |
| Workload | 900 h |
| Credits | 30 LP |
| Semester | • Master Thesis : 4<br>• Work Plan : 4 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Master Thesis: ( 0h / 750h / EN / SS / 0 )
Work Plan: ( 0h / 150h / EN / SS / 0 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Master Thesis: Depending on chosen topic.

Work Plan: Depending on chosen topic.

**Content**

Master Thesis: In the Master thesis, a problem is solved using scientific methods within a given time. The thesis' topic comes from the scientific context of the departments or leverage the multitude of collaborations with industry. Apart from practical relevance, a Master thesis ensures the ability to work scientifically and based on solid methods.

Work Plan: Based on a topic defined jointly with the advisor of the thesis, the student familiarizes herself/himself with the area by doing a literature search and surveying existing results and approaches. On this basis, a work plan has to be prepared that documents the intended results and milestones for the thesis.

**Learning objectives**

In their final project, students work on and solve a problem using scientific methods in a given amount of time. They should use knowledge and competences acquired during their studies, in particular, how to plan and structure a project into individual steps and how to present results of their work in written

and oral form.

**Implementation method**

Master Thesis: Independent work, supported by individual tutoring.

Work Plan: Direct contact with advisor.

**Assessment modalities (duration)**

Final thesis
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifizierte Teilnahme: Workplan
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 60 credits.

**Person responsible for the module**

Prof. Dr. Sybille Hellebrand

| **Learning material, literature** |
| --- |
| Master Thesis: Depending on topic and as recommended by advisor.<br>Work Plan: Depending on topic and as recommended by advisor. |

| **Remarks** |
| --- |
| Die Masterarbeit muss aus dem Vertiefungsgebiet sein. |

## 3.28 Elective Module: Foundations of Cryptography

| | |
|---|---|
| Module name | Foundations of Cryptography / Foundations of Cryptography |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Foundations of Cryptography : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Foundations of Cryptography: Lecture ( 45h / 105h / EN / SS / 25 )
Foundations of Cryptography: Tutorial ( 30h / 0h / EN / SS / 25 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Foundations of Cryptography: Basic Knowledge in IT-Security and cryptography useful but not necessary, basic concepts of complexity theory and probability theory

**Content**

Foundations of Cryptography: The most important primitives of modern cryptography will be presented. These include encryption schemes, digital signatures, identification protocols, and multiparty computations. In each case we will define precise security notions. Starting from precisely stated assumptions, we develop constructions that provably satisfy these security definitions.

**Learning objectives**

Students understand fundamental concepts and methods of modern cryptography. They are able to choose appropriate cryptographic tools for various security problems. Students are able to combine and modify basic cryptographic primitives, they are able to define new security concepts, they are able to the the security of new constructions with respect to the security concepts.

**Implementation method**

Foundations of Cryptography: Lectures, exercises, reading groups

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. rer. nat. Johannes Blömer

**Learning material, literature**

Foundations of Cryptography: Oded Gorldreich, Foundations of Cryptography I,II, Jonathan Katz, Yehuda Lindell, Introduction to Modern Cryptogtraphy
Slides from the lectures

| **Remarks** |
| --- |
| none |

## 3.29 Elective Module: Future Internet

| | |
|---|---|
| Module name | Future Internet / Future Internet |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Future Internet : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Future Internet: Lecture ( 45h / 105h / EN / SS / 20 )
Future Internet: Tutorial ( 30h / 0h / EN / SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Future Internet: Basic knowledge of computer networks is required, e.g., a Bachelor-level class "Computer networks".

**Content**

Future Internet: This lecture deals with up-to-date, close-to-research developments in the Future Internet context as well as data center (networking) context. The lecture is dynamically updated to reflect current research and is predominantly based on research publications.

**Learning objectives**

Participants of this class are introduced to the current state of the art in Internet research. They know weaknesses of today's architecture, can criticize them and contrast them with current proposals as well as discuss and assess advantages and disadvantages. For different usage scenarios, they can predict the suitability of different solution proposals. Methodically, they can design and execute networking experiments. Participants can create new Internet protocols and synthesize them into new architectures; they can compare such creations with competing approaches and assess and decide for a superior solution. Since the lecture is based on scientific publications, participants are able to make use of original work that has not been didactically prepared.

**Implementation method**

Future Internet: Lecture with slides and blackboard; homework assignments. The homework assignments will include architecture experiments, e.g., based on OpenFlow.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. rer. nat. Holger Karl

| **Learning material, literature** |
| --- |
| Future Internet: Slide set, but mostly based on current publications. No perfect textbook available; parts of the class are covered by Stallings, Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud. |

| **Remarks** |
| --- |
| none |

## 3.30 Elective Module: High Frequency Engineering

| | |
|---|---|
| Module name | High Frequency Engineering / High Frequency Engineering |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • High Frequency Engineering : 3 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

High Frequency Engineering: Lecture ( 30h / 120h / EN / WS / 100 )
High Frequency Engineering: Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

High Frequency Engineering: Higher Mathematics, Physics, and the Foundations of Electrical Engineering

**Content**

High Frequency Engineering: The course "High Frequency Engineering" has the goal to enable the listeners for developing tasks e. g. of the high-frequency part of a mobile phone. High-frequency engineering aspects have to be considered also in common digital cirquits. The main issues of this lecture are passive cirquits, high-frequency properties of transistor cirquits, linear and nonlinear amplifiers, noisy multi-port devices, mixers, oscillators, synchronization and phase locked loop.

**Learning objectives**

The module "High Frequency Engineering" has the goal to enable the listeners for developing tasks e. g. of the high-frequency part of a mobile phone. After attending the course, the students will be able to

- understand and apply the physics of high-frequency components, cirquits and systems,
- develop systems and cirquits in the high-frequency and highest-frequency domain and
- develop and make up electronic cirquits under consideration of high-frequency aspects.

**Implementation method**

High Frequency Engineering:
- Lectures using presentations via transparencies,
- Exercise classes with exercise sheets and demonstrations on computer.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Reinhold Noé

**Learning material, literature**

High Frequency Engineering: Meinke, H.; Gundlach, F.: Taschenbuch der Hochfrequenztechnik, Springer, 2006 German only

| **Remarks** |
| --- |
| none |

## 3.31 Elective Module: High-Performance Computing

| | |
|---|---|
| Module name | High-Performance Computing / High-Performance Computing |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • High-Performance Computing : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

High-Performance Computing: Lecture ( 30h / 105h / EN / WS / 40 )
High-Performance Computing: Tutorial ( 45h / 0h / EN / WS / 40 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

High-Performance Computing:
- Programming skills in C/C++
- Computer architecture

**Content**

High-Performance Computing: This course teaches the foundations of high-performance computing with an emphasis on the programming of parallel computer systems and novel hardware accelerators.

**Learning objectives**

After attending this course, the students are able to
- name models and programming patterns for HPC and to select patterns for a given application,
- name and apply the basic constructs of frequently used HPC libraries, in particular, MPI, OpenMP and OpenCL,
- analyze the performance of applications by using profiling tools and use the gathered information to create a systematic optimization strategy,
- apply the taught concepts and methods for parallelizing and optimizing existing applications

**Implementation method**

High-Performance Computing:
- Lecture with projected slides and blackboard notes
- Interactive assignments in lecture room
- Practical programming projects on parallel computer systems (teamwork in small groups)

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. Christian Plessl

| **Learning material, literature** |
| --- |
| High-Performance Computing:<br>• Lecture slides<br>• Assignment sheets<br>• Task descriptions and technical documentation for programming projects<br>• Lehrbuch: Pacheco: An Introduction to Parallel Programming. Morgan Kaufmann, 2011. |

| **Remarks** |
| --- |
| none |

## 3.32 Elective Module: Integrated Circuits for Wireless Communication

| | |
|---|---|
| Module name | Integrated Circuits for Wireless Communication / Integrated Circuits for Wireless Communication |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Integrated Circuits for Wireless Communication : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Integrated Circuits for Wireless Communication: Lecture ( 30h / 120h / EN / SS / 100 )
Integrated Circuits for Wireless Communication: Tutorial ( 30h / 0h / EN / SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Integrated Circuits for Wireless Communication: Schaltungstechnik and Circuit and System Design, respectively

**Content**

Integrated Circuits for Wireless Communication: Mobile communications, wireless networks, and RFID technology are application examples of wireless communications. Wireless communications has found widespread use in everyday life and will become even more important in the future.
The design of electronic circuits for radio frequencies requires a good system knowledge with respect to typical transmitter and receiver architectures in wireless communications, components, and radio signal properties. Furthermore a thorough understanding of integrated circuit design as well as precise high-frequency modeling of passive and active devices are required.
Goal of the lecture is to convey a methodical approach to the design of integrated circuits for wireless communications. A part of the exercises will pertain to calculation of circuit design problems another will be performed in small teams as a hands-on exercise using modern IC design software.
The lecture is based on the compulsory lectures "Schaltungstechnik" rsp. "Circuit and System Design" and addresses the following topics:
- Transmitter and receiver architectures for wireless communications
- System Theory Basics

  - Signals and noise
  - Modulation and demodulation
  - Transmission properties of wireless communcations systems
- Semiconductor technologies and integrated high-frequency devices
- Amplifiers (low-noise and variable-gain amplifiers)
- Mixers
- Oscillators
- Frequency synthesizer PLLs

**Learning objectives**

The students will be able
- to describe architectures and circuits of wireless communication systems
- to describe and calculate fundamental signal transmission properties of wireless systems
- to apply design methods to design components of radio frequency ICs

**Implementation method**

Integrated Circuits for Wireless Communication:
- Lecture with Powerpoint presentation and handwritten mathematical derivations using tablet and beamer
- Exercises partly as handwritten calculation exercises using tablet and beamer and partly as practical IC design exercises using modern IC design software

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Christoph Scheytt

**Learning material, literature**

Integrated Circuits for Wireless Communication: Lecture and exercise slides will be made available through PAUL system.
Recommended books:
• Behzad Razavi "RF Microelectronics", Prentice Hall, 2011
• Thomas Lee "The Design of CMOS Radio-Frequency Integrated Circuits", Cambridge University Press 2003

**Remarks**

none

## 3.33 Elective Module: Intelligence in Embedded Systems

| | |
|---|---|
| Module name | Intelligence in Embedded Systems / Intelligence in Embedded Systems |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Intelligence in Embedded Systems : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Intelligence in Embedded Systems: Lecture ( 45h / 105h / EN / SS / 25 )
Intelligence in Embedded Systems: Tutorial ( 30h / 0h / EN / SS / 25 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Intelligence in Embedded Systems:

**Content**

Intelligence in Embedded Systems: Intelligent embedded systems are technical systems that use different sensors and actors to perceive their environment and interact with it in a (partly) autonomous way. Often their behavior is controlled by methods and algorithms from artificial intelligence (AI). Such methods enable for instance that systems plan their behavior in a goal directed manner or optimize it via self-adaptation and learning. Systems of that kind are becoming increasingly important, not only on a scientific level but also in a social context: Autonomous or semi-autonomous systems such as service robots, self-driving cars or medical help and diagnosis systems will have a deep impact on our future private and professional life.
This course covers important aspects for the development of intelligent embedded systems and conveys corresponding theoretical and methodological foundations. This includes lectures on architectures, intelligent sensor processing, environment modelling, intelligent behavior control and self-adaptation.

**Learning objectives**

Students know and explain methods and algorithms for intelligent sensor processing and control of actions (e.g. computer vision, sensor fusion, maps, navigation, planning and machine learning). They understand and solve problems arising when realizing them in embedded systems with restricted resources.

Furthermore, they are able to understand, use and adapt new methods and algorithms especially in the context of embedded systems.

**Implementation method**

Intelligence in Embedded Systems:
- Lecture with slides
- Interactive exercises, where students deepen their understanding and apply their knolwledge obtained in the lectures

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Dr. Bernd Kleinjohann

| **Learning material, literature** |
| --- |
| Intelligence in Embedded Systems: Lecture slides, publications, books:<br>• St. Russel, P. Norvig: Artificial Intelligence: A Modern Approach<br>• R. Arkin: Behavior-Based Robotics<br>Other literature (books, publications) will be announced in the lecture. |

| **Remarks** |
| --- |
| none |

## 3.34 Elective Module: Introduction to High-Frequency Engineering

| | |
|---|---|
| Module name | Introduction to High-Frequency Engineering / Introduction to High-Frequency Engineering |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Introduction to High-Frequency Engineering : 3 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Introduction to High-Frequency Engineering: Lecture ( 30h / 120h / DE / WS / 100 )
Introduction to High-Frequency Engineering: Tutorial ( 30h / 0h / DE / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Introduction to High-Frequency Engineering: Higher Mathematics and Foundations of Electrical Engineering

**Content**

Introduction to High-Frequency Engineering: The course “Introduction to High-Frequency Engineering” provides basic knowledge of high-frequency engineering in particular with respect to signal propagation along transmission lines on circuit boards and integrated circuits.

**Learning objectives**

The course Introduction to “High-Frequency Engineering” provides basic knowledge of high-frequency engineering. The students learn to describe circuits comprising distributed and lumped components, to analyze, and to design the latter.

**Implementation method**

Introduction to High-Frequency Engineering:
• Lectures with black board presentation, supported by animated graphics and transparencies,
• Presence exercises with task sheets to be solved by the students together, supported by the teacher, and partially using CAD software.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Andreas Thiede

**Learning material, literature**

Introduction to High-Frequency Engineering: A. Thiede, Einführung in die Hochfrequenztechnik, Vorlesungsskript Universität Paderborn
Continuative and deepening literature
• P. Vielhauer, Lineare Netzwerke, Verlag Technik und Hüthig (65 YCF 1469)
• M. Hoffmann, Hochfrequenztechnik, Springer Verlag (51 YDA 1913)
• O. Zinke, H. Brunswig, Hochfrequenztechnik, Bd.1+2, Springer Verlag (51 YDA 1086)

- G. Gonzalez, Microwave Transistor Amplifiers, Prentice Hall (51 YEP 3142)
- P.C.L. Yip, High-Frequency Circuit Design and Measurements, Chapman & Hall (51 YDA 1751)
- R.E. Collin, Foundations for Microwave Engineering, Mc Graw-Hill (51 YGA 1240)

| **Remarks** |
| --- |
| none |

## 3.35 Elective Module: Introduction to Quantum Computation

| | |
|---|---|
| Module name | Introduction to Quantum Computation / Introduction to Quantum Computation |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Introduction to Quantum Computation : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Introduction to Quantum Computation: Lecture ( 45h / 105h / EN / SS / 0 )
Introduction to Quantum Computation: Tutorial ( 30h / 0h / EN / SS / 0 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Introduction to Quantum Computation: Linear Algebra, algorithms.

**Content**

Introduction to Quantum Computation: This lecture introduces the fundamental concepts of quantum computation and information from a computer science perspective. This includes an introduction to quantum mechanics, quantum entanglement, quantum algorithms, quantum error correction, and quantum information theory.

**Learning objectives**

Students are able to:
- Describe and apply the postulates of quantum mechanics
- Understand the use of entanglement as a resource
- Design and analyze fundamental quantum algorithms
- Apply the theory of error-correcting codes
- Understand and apply basic quantum information theory concepts such as entropy

**Implementation method**

Introduction to Quantum Computation: Slides and blackboard writing. All important concepts and techniques are further deepened with examples in exercises.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Dr. Sevag Gharibian

**Learning material, literature**

Introduction to Quantum Computation: Michael A. Nielsen, Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press
Lecture slides, exercises

| **Remarks** |
| --- |
| none |

## 3.36 Elective Module: Machine Learning I

| | |
|---|---|
| Module name | Machine Learning I / Machine Learning I |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Machine Learning I : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Machine Learning I: Lecture ( 45h / 105h / EN / WS oder SS / 60 )
Machine Learning I: Tutorial ( 30h / 0h / EN / WS oder SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Machine Learning I: Basic knowledge in mathematics (linear algebra, statistics), programming and algorithms.

**Content**

Machine Learning I: Due to the ever increasing amount of data that is routinely produced in our information society, the topic of machine learning has become increasingly important in the recent years, not only as a scientific discipline but also as a key technology of modern software and intelligent systems. This lecture provides an introduction to the topic of machine learning, with a specific focus on supervised learning for classification and regression. The lecture covers theoretical foundations of generalisation as well as practical topics and concrete learning algorithms.

**Learning objectives**

The students understand the statistical foundations of generalisation, i.e., the induction of models from data, as well as practical tools for model validation. They are able to apply basic methods of supervised learning to problems of classification and regression.

**Implementation method**

Machine Learning I: Theoretical foundations and concepts of machine learning will be taught in the form of a lecture and deepened in practical exercise courses, group work as well as individual homework.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. Eyke Hüllermeier

**Learning material, literature**

Machine Learning I: Script and a List of book recommendations:
- Y.S. Abu-Mostafa, M. Magdon-Ismail, H.T. Lin. Learning from Data, AMLBook, 2012.
- P. Flach. Machine Learning, Cambridge Univ. Press, 2012.
- E. Alpaydin. Machine Learning, Oldenbourg, 2008.
- C.M. Bishop. Pattern Recognition and Machine Learning, Springer, 2006.

| **Remarks** |
| --- |
| none |

## 3.37 Elective Module: Machine Learning II

| | |
|---|---|
| Module name | Machine Learning II / Machine Learning II |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Machine Learning II : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Machine Learning II: Lecture ( 45h / 105h / EN / WS oder SS / 20 )
Machine Learning II: Tutorial ( 30h / 0h / EN / WS oder SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Machine Learning II: Basic knowledge in machine learning (as conveyed, for example, by the Machine Learning I lecture).

**Content**

Machine Learning II: This lecture, which is conceived as a continuation of the Machine Learning I, covers advanced topics in contemporary machine learning research, such as reinforcement learning, online learning and bandit algorithms, multi-task learning, multi-target and structured output prediction, preference learning, learning from weak supervision, and uncertainty in machine learning. The focus of the lecture will be on methods and algorithms, though theoretical issues and applications will be addressed, too.

**Learning objectives**

The students have an overview of methods for multi-class classification, the learning of nonlinear models, and extensions of the simple setting of supervised learning. They understand algorithmic concepts of corresponding methods and are able to apply them to real problems.

**Implementation method**

Machine Learning II: Theoretical foundations and concepts of machine learning will be taught in the form of a lecture and deepened in practical exercise courses, group work as well as individual homework.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. Eyke Hüllermeier

**Learning material, literature**

Machine Learning II: Script and a list of book recommendations:
- Y.S. Abu-Mostafa, M. Magdon-Ismail, H.T. Lin. Learning from Data, AMLBook, 2012.
- P. Flach. Machine Learning, Cambridge Univ. Press, 2012.
- E. Alpaydin. Machine Learning, Oldenbourg, 2008.
- C.M. Bishop. Pattern Recognition and Machine Learning, Springer, 2006.

| **Remarks** |
| --- |
| none |

## 3.38 Elective Module: Mobile Communication

| | |
|---|---|
| Module name | Mobile Communication / Mobile Communication |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Mobile Communication : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Mobile Communication : Lecture ( 45h / 105h / EN / WS / 20 )
Mobile Communication : Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Mobile Communication : Basic knowledge of computer networks is required, e.g., a Bachelor-level class "Computer networks".

**Content**

Mobile Communication : The lecture discusses foundations of mobile communication (e.g., wireless channel models) and fundamental techniques (e.g., spread spectrum communication), important protocol mechanisms (e.g., medium access in wireless systems), mobile communication systems, and MobileIP. In addition to technological and conceptual aspects, we shall also discuss approaches and methods for performance evaluation of mobile communication systems.

**Learning objectives**

Participants of this class know challenges and problems arising in design and operation of mobile communication systems. They can differentiate between challenges based in physics and those arising from a particular system design; they can choose suitable protocols or design new ones. They are able to select mechanisms from different architectural layers, integrate them into a new complete architecture and justify their selection and integration decisions. They are also able to quantitatively evaluate protocol mechanisms.

**Implementation method**

Mobile Communication : Lecture with slides and blackboard; homework assignments with (among others) some programming assignments to simulate wireless systems.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. rer. nat. Holger Karl

**Learning material, literature**

Mobile Communication : Slide set; chapters from various textbooks (J. Schiller, Mobile Communication, Addison Wesley, 2nd edition; D. Tse und P. Viswanath, Fundamentals of Wireless Communication, Cambridge University Press, 2005).

| **Remarks** |
| --- |
| none |

## 3.39 Elective Module: Model-Based Systems Engineering

| | |
|---|---|
| Module name | Model-Based Systems Engineering / Model-Based Systems Engineering |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Model-Based Systems Engineering : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Model-Based Systems Engineering: Lecture ( 45h / 0h / DE / SS / 0 )
Model-Based Systems Engineering: Tutorial ( 30h / 0h / DE / SS / 0 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Model-Based Systems Engineering:

**Content**

Model-Based Systems Engineering:

**Learning objectives**

**Implementation method**

Model-Based Systems Engineering:

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

| **Partial module exams** |
| --- |
| none |

| **Course achievement / qualifying participation** |
| --- |
| none |

| **Prerequisites for participation in module exam** |
| --- |
| none |

| **Prerequisites for obtaining credits** |
| --- |
| Passing of module exam. |

| **Weight for overall grade** |
| --- |
| The module is weighted with 6 credits. |

| **Person responsible for the module** |
| --- |
| Prof. Dr.-Ing. Roman Dumitrescu |

| **Learning material, literature** |
| --- |
| Model-Based Systems Engineering: none |

| **Remarks** |
| --- |
| none |

## 3.40 Elective Module: Model-Driven Software Development

| | |
|---|---|
| Module name | Model-Driven Software Development / Model-Driven Software Development |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Model-Driven Software Development : 3 |

| **Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )** |
|---|
| Model-Driven Software Development: Lecture ( 45h / 105h / EN / WS / 100 )<br>Model-Driven Software Development: Tutorial ( 30h / 0h / EN / WS / 20 ) |

| **Choices in Module** |
|---|
| none |

| **Course prerequisites** |
|---|
| none |

| **Recommended proficiencies** |
|---|
| Model-Driven Software Development: wird noch ergaenzt |

| **Content** |
|---|
| Model-Driven Software Development: Model-driven software development aims at the development of software solely based on models. Ideally, the final system is completely generated and analysed based on the model. The lecture Model-Driven Software Development introduces in details methods and processes for model-driven development. |

| **Learning objectives** |
|---|
| See detailed description of associated course. |

| **Implementation method** |
|---|
| Model-Driven Software Development: wird noch ergaenzt |

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Dr. Matthias Meyer

**Learning material, literature**

Model-Driven Software Development: wird noch ergaenzt

**Remarks**

none

## 3.41 Elective Module: Network Simulation

| | |
|---|---|
| Module name | Network Simulation / Network Simulation |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Network Simulation : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Network Simulation: Lecture ( 30h / 105h / EN / SS / 20 )
Network Simulation: Tutorial ( 45h / 0h / EN / SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Network Simulation: System software and system-level programming

**Content**

Network Simulation: This course offers the chance to get in touch with the network simulation framework OMNeT++. Simulation is one possibility (others are experiments or mathematical analysis) to evaluate the performance of systems which might even not be available in reality.
After getting a basic introduction to simulation and modeling, we will study a small example project already using OMNeT++. Finally, we will work in small groups of 2-3 people on interesting research-focused projects of the areas vehicular communication and wireless sensor networks.

**Learning objectives**

The learning objective is to unserstand the fundamental concepts of network simulation. Students understand these concepts and are able to apply this knowledge.

**Implementation method**

Network Simulation: Lecture with practical exercises

**Assessment modalities (duration)**

The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

Written exam (60 minutes, 50% of module grade) and final project (50% of module grade)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. Falko Dressler

**Learning material, literature**

Network Simulation: Slides, textbooks, papers

**Remarks**

none

## 3.42 Elective Module: Optical Communication A

| | |
|---|---|
| Module name | Optical Communication A / Optical Communication A |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Optical Communication A : 1 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Optical Communication A: Lecture ( 30h / 120h / EN / WS / 100 )
Optical Communication A: Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Optical Communication A: Higher Mathematics, Physics, and the Foundations of Electrical Engineering.

**Content**

Optical Communication A: The course "Optical Communications A" introduces into modern optical communications on which internet and telephony rely. This lecture will impart also knowledge on ultra-broadband communication systems. Every optical waveguide is about 1000 times as broadband as most efficient microwave communication satellites. Optical transmission can be explained by the wave model whereas effects like emission, absorption and amplification of photons are modeled by the particle aspect. This dualism and basic knowledge of communications and electronics lead to an understanding of optical communications. Wavelength multiplex has an eminent importance because of it's high capacity beyond 10Tbit/s or transoceanic spans.

**Learning objectives**

After attending the course, the students will be able to
• describe, model and apply the function of components, systems and effects of optical communications and
• apply knowledge of optoelectronics.

**Implementation method**

Optical Communication A:
- Lectures using presentations via transparencies,
- Exercise classes with exercise sheets and demonstrations on computer.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Reinhold Noé

**Learning material, literature**

Optical Communication A: R. Noé, Essentials of Modern Optical Fiber Communication, Springer-Verlag, 2010 Scriptum for a major part of the lectures Optical Communications A, B, C, D as well an Optical Transmission Technology, English only

| **Remarks** |
| --- |
| none |

## 3.43 Elective Module: Optical Communication B

| | |
|---|---|
| Module name | Optical Communication B / Optical Communication B |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Optical Communication B : 2 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Optical Communication B: Lecture ( 30h / 120h / EN / SS / 100 )
Optical Communication B: Tutorial ( 30h / 0h / EN / SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Optical Communication B: Higher Mathematics, Physics, and the Foundations of Electrical Engineering. Optical Communications A recommended.

**Content**

Optical Communication B: The course “Optical Communications B” gives an introduction into mode coupling in optical communications. A mode is a wave which has a unique propagation constant at a given frequency. In case of mode coupling, there is a power exchange between different modes, which happens according to the setup in co- or contradirectional way. In this course, there are mechanisms and applications explained.

**Learning objectives**

After attending the course, the students will be able to
- understand the meaning and importance of wave modes and mode coupling in optical communications,
- make up and understand mathematical models of optical components and systems and
- understand and abstract how optical components work

**Implementation method**

Optical Communication B:
- Lectures using presentations via transparencies,
- Exercise classes with exercise sheets and demonstrations on computer.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Reinhold Noé

**Learning material, literature**

Optical Communication B: R. Noé, Essentials of Modern Optical Fiber Communication, Springer-Verlag, 2010 Scriptum for a major part of the lectures Optical Communications A, B, C, D as well an Optical Transmission Technology, English only

| **Remarks** |
| --- |
| none |

## 3.44 Elective Module: Optical Communication C

| | |
|---|---|
| Module name | Optical Communication C / Optical Communication C |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Optical Communication C : 3 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Optical Communication C: Lecture ( 30h / 120h / EN / WS / 100 )
Optical Communication C: Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Optical Communication C: Higher Mathematics, Physics, and the Foundations of Electrical Engineering. Optical Communications A recommended.

**Content**

Optical Communication C: The course “Optical Communications C” has the subject of modulation formats. Besides the classical On/Off-keying (OOK), there are different ways to modulate an optical signal either to improve the signal to noise ratio or to transmit more than one bit per symbol as quarternary modulation (four signal states) or polarization mode multiplex. In this lecture, also advanced modu-lation formats are treated.

**Learning objectives**

After attending the course, the students will be able to
- know and evaluate different modulation schemes in Optical Communications in their meaning,
- see the importance of efficient modulation schemes in Optical Communications and
- realize and develop efficient optical communication systems.

**Implementation method**

Optical Communication C:
- Lectures using presentations via transparencies, or directly on the computer
- Exercise classes with exercise sheets and demonstrations on computer.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Reinhold Noé

**Learning material, literature**

Optical Communication C: R. Noé, Essentials of Modern Optical Fiber Communication, Springer-Verlag, 2010 Scriptum for a major part of the lectures Optical Communications A, B, C, D as well an Optical Transmission Technology, English only

| **Remarks** |
| --- |
| none |

## 3.45 Elective Module: Optimal and Adaptive Filters

| | |
|---|---|
| Module name | Optimal and Adaptive Filters / Optimal and Adaptive Filters |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Optimal and Adaptive Filters : 3 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Optimal and Adaptive Filters: Lecture ( 30h / 120h / EN / WS / 100 )
Optimal and Adaptive Filters: Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Optimal and Adaptive Filters: Prior knowledge from the modules Higher Mathematics and Digital Signal Processing is helpful.

**Content**

Optimal and Adaptive Filters: The course “Optimal and adaptive filters” gives an introduction to the basic techniques and theories of adaptive filters. Based upon the basics of estimation theory optimal filters are discussed. Subsequently the topics Wiener filter theory, deterministic optimization under constraints and stochastic gradient methods are regarded. Concluding the Least Squares approach for solving filter tasks and the Kalman filter are introduced. The latter is regarded as a brief introduction to state based filters.

**Learning objectives**

The module “Optimal and adaptive filters” gives an introduction to the basic techniques and theories of adaptive filters. After attending the course, the students will be able to analyze tasks in the field of adaptive filters and to formulate requirements mathematically, develop filter using cost functions and implement selected adaptive filters in the frequency or time domain.

**Implementation method**

Optimal and Adaptive Filters:
- Lectures using the blackboard and presentations,
- Alternating theoretical and practical exercise classes with exercise sheets and computer and
- Demonstration of real technical systems in the lecture hall.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Reinhold Häb-Umbach

**Learning material, literature**

Optimal and Adaptive Filters: Allocation of a script; information on textbooks; matlab scripts

| **Remarks** |
| --- |
| none |

## 3.46 Mandatory Module: Project group

| | |
|---|---|
| Module name | Project group / Project group |
| Workload | 540 h |
| Credits | 18 LP |
| Semester | • Project group : 2 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Project group: Meetings, presentation and discussion of partial results ( 240h / 300 h / EN / SS / 12 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Project group: Secure knowledge of Bachelor-level topics; depending on the group topic, a small amount of Master-level classes may be required as well.

**Content**

Project group: A project group consists of a group of student (typically 8–12) who jointly work on a topic from current research; the group lasts for one calendar year. As a team, the participants elaborate a problem, find solutions, realize them and present their results in regular meetings. Additionally, a project group comprises a seminar phase where team members educate themselves to an expert-level knowledge for relevant areas and provide this knowledge to the group.
New projet groups start each semester. Their topics are presented publicly at the end of the previous semester and students can register with a group in which they are interested.

**Learning objectives**

Methodically, students lean
• how to structure a complex problem setting into smaller, manageable tasks,
• to identify missing knowledge and skills and how to obtain them independently, possibly even across disciplines,
• to specify complex problems,
• to develop a suitable project plan, to control it and adapt it if needs be,
• to validate their results their specifications, to evaluate them and critically judge them,

- to keep thinking on the basis of their results and to develop new questions and development options.

**Implementation method**

Project group: Self-organised team work, based on a given task from up-to-date research. The group is assisted topic-wise and methodically by the supervisors. A seminar is integrated to provide technical expertise needed to achieve the project goals. Regular meetings of the group with the supervisors to present intermediate results, work plans, etc; nevertheless, the groups are encouraged to work self-organized as much as possible.

**Assessment modalities (duration)**

Project
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 9 credits.

**Person responsible for the module**

Prof. Dr. rer. nat. Holger Karl

| **Learning material, literature** |
| --- |
| Project group: Will be published on the course website. |

| **Remarks** |
| --- |
| none |

## 3.47 Elective Module: Real World Crypto Engineering

| | |
|---|---|
| Module name | Real World Crypto Engineering / Real World Crypto Engineering |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Real World Crypto Engineering : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Real World Crypto Engineering: Lecture ( 45h / 105h / EN / SS / 40 )
Real World Crypto Engineering: Tutorial ( 30h / 0h / EN / SS / 40 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Real World Crypto Engineering:

**Content**

Real World Crypto Engineering:

**Learning objectives**

**Implementation method**

Real World Crypto Engineering: Lectures, exercises

**Assessment modalities (duration)**

Written exam (90 - 120 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Juraj Somorovsky

**Learning material, literature**

Real World Crypto Engineering: none

**Remarks**

none

## 3.48 Elective Module: Reconfigurable Computing

| | |
|---|---|
| Module name | Reconfigurable Computing / Reconfigurable Computing |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Reconfigurable Computing : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Reconfigurable Computing: Lecture ( 30h / 105h / EN / WS / 50 )
Reconfigurable Computing: Tutorial ( 45h / 0h / EN / WS / 25 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Reconfigurable Computing: Knowledge of "Digital Design" and "Computer Architecture" is beneficial.

**Content**

Reconfigurable Computing: This lecture provides an understanding of architectures and design methods for reconfigurable hardware systems and presents applications in the areas of high performance computing and embedded systems.

**Learning objectives**

After attending the course, the students
- are able to explain the architectures of reconfigurable hardware devices,
- to name and analyze the main design methods and
- to judge the suitability of reconfigurable hardware for different application domains.

**Implementation method**

Reconfigurable Computing:
- Lecture with projector and board
- Interactive exercises in the lecture room

- Computer-based exercises with reconfigurable systems

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. Marco Platzner

**Learning material, literature**

Reconfigurable Computing:
- Lecture slides and exercise sheets
- Exercise sheets and technical documentation for the for the computer-based exercises
- S. Hauck and A. DeHon (editors): Reconfigurable Computing, Volume 1: The Theory and Practice of FPGA-Based Computation, Morgan Kaufmann, 2008
- Information about alternative and additional literature as well as teaching material on the course's website and in the lecture slides

| **Remarks** |
| --- |
| none |

## 3.49 Elective Module: Reinforcement Learning

| | |
|---|---|
| Module name | Reinforcement Learning / Reinforcement Learning |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Reinforcement Learning : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Reinforcement Learning: Lecture ( 30h / 120h / EN / SS / 50 )
Reinforcement Learning: Tutorial ( 30h / 0h / EN / SS / 25 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Reinforcement Learning: It is recommended to have a sound basic knowledge in the field of system and control theory. Ideally, the students have knowledge in the field of un-/supervised machine learning and numerical optimization. In addition, at least some experience with Python will be advantageous for the exercise and tutorial tasks.

**Content**

Reinforcement Learning: The course covers the basics of reinforcement learning (RL) in an engineering context. RL stands for a series of methods of machine learning in which an agent independently learns a strategy (policy) to maximize the rewards received during interaction with an (unknown) system. This can be, for example, a control loop in which an adaptive controller tries to determine an optimal control law from previous observations of the control and measurement variables, which maximizes certain benchmark criteria with regard to controller performance. Well-known fields of application include the operation of autonomous vehicles and industrial robots or the identification of optimal strategies in the context of leisure games.
The course has an application-oriented focus in the engineering sciences but is also designed for students of natural sciences (e.g. computer science, mathematics). In addition to teaching the methodological fundamentals within the lecture, great importance is attached to practical implementation and programming tasks during the exercise and tutorial hours.

**Learning objectives**

Domain-specific competences: After attending the course, the students are able to
- differentiate, apply and analyze basic RL methods,
- name and explain differences as well as advantages and disadvantages of RL compared to neighboring approaches (e.g. model-predictive control),
- educate themselves independently in this branch of science on the basis of the methods learned for the analysis and synthesis of RL techniques.

Interdisciplinary competences: The students
- can apply or transfer the acquired knowledge to interdisciplinary problems,
- have gained practical experience in programming which they can use across domains and
- are able to critically evaluate methods and results.

**Implementation method**

Reinforcement Learning:
- Lecture based on slides, which also serve as lecture notes.
- Presence exercises with tutorial sheets (with many programming tasks)

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

| **Weight for overall grade** |
| --- |
| The module is weighted with 6 credits. |

| **Person responsible for the module** |
| --- |
| Dr.-Ing. Oliver Wallscheid |

| **Learning material, literature** |
| --- |
| Reinforcement Learning:<br>• Richard S. Sutton, Andrew G. Barto, "Reinforcement Learning", 2. Ed., MIT Press, 2018<br>• David Silver, "Reinforcement Learning"(Skriptum), University College London, 2015 |

| **Remarks** |
| --- |
| none |

## 3.50 Elective Module: Robotics

| | |
|---|---|
| Module name | Robotics / Robotics |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Robotics : 2 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Robotics: Lecture ( 30h / 120h / EN / SS / 100 )
Robotics: Tutorial ( 30h / 0h / EN / SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Robotics: None

**Content**

Robotics: The course "Robotics" introduces basic concepts and techniques in the field of mobile robotics. The challenges for the development of autonomous intelligent systems will be analyzed and the current solutions will be presented.

**Learning objectives**

After successfully completing the module the students
• know how to transfer basic methods from control and system theory to robotics and
• are able to apply the adequate methods to describe as well as plan and control the movements of robot arms and mobile robots.

**Implementation method**

Robotics:
• The theoretical and methodical fundamentals will be introduced during the lecture.
• The methods presented will be practiced during the subsequent exercise / lab part.
• Finally, the participants will implement, test, and apply simple algorithms.

• The necessary programming skills will be taught during the practical, this is explicitly not considered a programming course.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Bärbel Mertsching

**Learning material, literature**

Robotics: Allocation of lecture notes; information on textbooks stocked in the textbook collection will be announced later.
• Mertsching, Bärbel: Robotics (lecture notes)
• McKerrow, Phillip J.: Introduction to Robotics. Addison-Wesley, 1991
• Siegwart, Roland; Nourbakhsh, Illah R. and Scaramuzza, David: Introduction to Autonomous Mobile Robots. The MIT Press, 2011, ISBN-13: 978-0262015356

| **Remarks** |
| --- |
| none |

## 3.51 Elective Module: Routing and Data Management in Networks

| | |
|---|---|
| Module name | Routing and Data Management in Networks / Routing and Data Management in Networks |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Routing and Data Management in Networks : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Routing and Data Management in Networks: Lecture ( 45h / 105h / EN / SS / 40 )
Routing and Data Management in Networks: Tutorial ( 30h / 0h / EN / SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Routing and Data Management in Networks: Algorithm design, theoretical correctness and efficiency proofs, tools from combinatorics and probability theory.

**Content**

Routing and Data Management in Networks: Routing and data management are fundamental tasks to be solved in order to ensure efficient use of large networks, e.g. the Internet, peer-to-peer systems, or wireless mobile ad-hoc networks. This lecture deals with algorithms and their analysis for routing and data management in such systems and describes, in particular, methods for dealing with their dynamics (movement of nodes, joining and exiting nodes). In particular, local, distributed algorithms, often as online algorithms, are considered.

**Learning objectives**

The students get to know fundamental techniques in the area of routing and data management of large networks. They can decide in which situation which data management, scheduling, or routing algorithm is most appropriate. They can adapt algorithms to a new situation.

**Implementation method**

Routing and Data Management in Networks:
- Lecture with beamer and blackboard
- Practice in small groups
- Expected activities of the students: Solving homework exercises, contributing to the tutorials

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. Friedhelm Meyer auf der Heide

| **Learning material, literature** |
| --- |
| Routing and Data Management in Networks: Introduction to Parallel Algorithms and Architectures: Arrays, Trees, Hypercubes, Frank Thomson Leighton, M. Kaufmann Publishers, 1992. Research papers, script, slide set of the lecture, exercise sheets |

| **Remarks** |
| --- |
| none |

## 3.52 Mandatory Module: Scientific Work Style

| | |
|---|---|
| Module name | Scientific Work Style / Scientific Work Style |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Languages, Writing and Presentation skills : 2<br>• Seminar : 2 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Languages, Writing and Presentation skills: ( 30h / 30 h / DE / SS / 0 )
Seminar: Seminar ( 30h / 90 h / EN / SS / 15 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Languages, Writing and Presentation skills: None.

Seminar: None in general; depending on the particular topic, some prior contact with the area can be helpful (e.g., in Bachelor classes).

**Content**

Languages, Writing and Presentation skills: Students are free to choose, depending on their interests, prior knowledge, and talents, a course on modern languages, scientific writing or presentation skills. The choice can be made from the courses offered by the University of Paderborn.

Seminar: Goal of a seminar is in-depth, autonomous work in a complex, scientific topic, the necessary literature research, and the presentation of the results in speech and writing. They also serve to familiarize students with the main mechanisms used by the scientific community (conferences, peer reviews, ...). Seminars are offered by all lecturers; topics are taken from their research areas and change from semester to semester.

**Learning objectives**

The goal of this module is to enable students (a) to autonomously familiarize themselves with complex technical and scientific material and (b) to effectively and efficiently communicate such material in speech and writing. To this end, the module comprises a seminar on scientific topics from computer engineering and an elective class on language, technical writing, presentation techniques, etc.

**Implementation method**

Languages, Writing and Presentation skills: Depends on chosen course.

Seminar: Seminars are based on a list of topics, from which participants can choose. A seminar encompasses meetings where topic assignment, literature research, selecting relevant literature, presentation techniques, technical writing etc. are discussed. In close interaction between participants and advisors, a couple of milestones are undertaken to develop a seminare writeup and a presentation, which is later on presented to the group and discussed.

**Assessment modalities (duration)**

Seminar Presentation and Paper
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifizierte Teilnahme:
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

| **Weight for overall grade** |
| --- |
| The module is weighted with 6 credits. |

| **Person responsible for the module** |
| --- |
| Prof. Dr.-Ing. Katrin Temmen |

| **Learning material, literature** |
| --- |
| Languages, Writing and Presentation skills: Depends on chosen course.<br>Seminar: Current scientific publications. |

| **Remarks** |
| --- |
| none |

## 3.53 Elective Module: Semiconductor Device Integration

| | |
|---|---|
| Module name | Semiconductor Device Integration / Semiconductor Device Integration |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Semiconductor Device Integration : 2 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Semiconductor Device Integration: Lecture ( 30h / 120h / DE / SS / 0 )
Semiconductor Device Integration: Tutorial ( 30h / 0h / DE / SS / 0 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Semiconductor Device Integration: Semiconductor Devices

**Content**

Semiconductor Device Integration: The course "Semiconductor Device Fabrication" focuses on the integration process of semiconductor devices. Starting from the cleaning process of the silicon crystal to the fabrication of integrated semiconductor circuits. This includes thermal oxidation, lithography, etching, doping, deposition and cleaning. Combinations of these steps to form the integration of MOS-transistors and CMOS-circuits are shown and can be experienced during the tutorials. The wafer dicing, bonding and packaging of microelectronic circuits complete the course.

**Learning objectives**

**Implementation method**

Semiconductor Device Integration:
- Lecture based on slide presentation, extensions on blackboard
- Exercises in small groups based on exercise sheets with students presenting their own solutions

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Ulrich Hilleringmann

**Learning material, literature**

Semiconductor Device Integration:
- Handouts of lecture slides
- Hilleringmann: Silizium-Halbleitertechnologie
- Schumicki, Seegebrecht: Prozesstechnologie
- Widmann, Mader: Technologie hochintegrierter Schaltungen
- Additional links to books and other material available at the webpage

| **Remarks** |
| --- |
| none |

## 3.54 Elective Module: Software Quality Assurance

| | |
|---|---|
| Module name | Software Quality Assurance / Software Quality Assurance |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Software Quality Assurance : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Software Quality Assurance: Lecture ( 45h / 105h / EN / SS / 90 )
Software Quality Assurance: Tutorial ( 30h / 0h / EN / SS / 30 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Software Quality Assurance: Programming, Modeling, Model-based software development

**Content**

Software Quality Assurance: The aim of the lecture is to cover approaches, technologies and strategies related to quality assurance for software systems. These include on the one hand constructive approaches such as design patterns, anti-patterns, domain-specific languages, model driven development, model quality analysis, and architectural styles, and on the other hand analytic approaches such as static reviewing techniques and dynamic testing techniques.. Furthermore, approaches for the improvement of the software development process and international standards like ISO 9001, 9126, CMM etc. are covered.

**Learning objectives**

The students are able to explain quality characteristics of software development processes, software models as well as software systems. They have understood constructive and analytical techniques used to ensure quality properties, and they are able to apply them. They can describe standards for measuring process and product quality. They are able to understand new research approaches in the area of process and product quality.

**Implementation method**

Software Quality Assurance: Partially slides and partially board writing. All essential concepts and techniques will be repeatedly applied in examples during the tutorial. In a lab part, the techniques will be employed using tools, particularly testing tools.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. Gregor Engels

| **Learning material, literature** |
| --- |
| Software Quality Assurance: Daniel Galin: Software Quality Assurance: From Theory to Implementation, Pearson / Addison Wesley, 2004 Slides, Exercises |

| **Remarks** |
| --- |
| none |

## 3.55 Elective Module: Statistical and Machine Learning

| | |
|---|---|
| Module name | Statistical and Machine Learning / Statistical and Machine Learning |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Statistical and Machine Learning : 2 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Statistical and Machine Learning: Lecture ( 30h / 120h / EN / SS / 100 )
Statistical and Machine Learning: Tutorial ( 30h / 0h / EN / SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Statistical and Machine Learning: Elementary knowledge in statistics, as is taught in the course Statistical Signal Processing, is helpful.

**Content**

Statistical and Machine Learning: The course on "Statistical and Machine Learning" presents an introduction into the components and algorithms prevalent in statistical pattern recognition. Both parametric and non-parametric density estimation and classification techniques will be presented, as well as supervised and unsupervised learning paradigms. The presented techniques can be applied to a variety of classification problems, both for one-dimensional input data (e.g., speech), two-dimensional (e.g., image) or symbolic input data (e.g., documents).

**Learning objectives**

After completion of the module students will be able to
• Choose an appropriate decision rule for a given classification problem
• Apply supervised or unsupervised learning techniques to data of various kinds and critically assess the outcome of the learning algorithms
• Work with dedicated pattern classification software (e.g., for artificial neural networks, support vector machines) on given data sets and optimize parameter settings
• Find, for a given training set size, an appropriate choice of classifier complexity and feature vector

dimensionality

**Implementation method**

Statistical and Machine Learning:
• Lectures predominantly using the blackboard or overhead projector, occasional presentations of (powerpoint) slides,
• Exercise classes with exercise sheets and demonstrations on computer and
• Implementation of learning and classification algorithms on a computer by the students themselves; use of algorithms on real-world data or data generated on the computer, evaluation of the simulation results

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Reinhold Häb-Umbach

| **Learning material, literature** |
| --- |
| Statistical and Machine Learning: Course script and summary slides are provided tot he students. Exercises and solutions to exercises, as well as sample implementations of algorithms are provided to the students.<br>Further literature<br>• R.O. Duda, P.E. Hart, D.G.˜ Stork, Pattern Classification, Wiley, 2001<br>• K. Fukunaga, Introduction to Statistical Pattern Recognition, Academic Press, 1990 |

| **Remarks** |
| --- |
| none |

## 3.56 Elective Module: Statistical Natural Language Processing

| | |
|---|---|
| Module name | Statistical Natural Language Processing / Statistical Natural Language Processing |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Statistical Natural Language Processing : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Statistical Natural Language Processing: Lecture ( 30h / 105h / EN / WS / 30 )
Statistical Natural Language Processing: Tutorial ( 45h / 0h / EN / WS / 30 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Statistical Natural Language Processing: Vector spaces, grammar of natural languages, probability theory

**Content**

Statistical Natural Language Processing: The goal of this lecture is to present students with the foundational tools and methods necessary to implement natural language processing pipelines. The course includes content pertaining to text preprocessing, parsing, distributional semantics, dedicated machine learning approaches and applications such as question answering.

**Learning objectives**

Students can list relevant problems and identify solution requirements for the following areas:
- Text preprocessing
- Language modelling
- Spelling correction
- Text and document classification
- Distributional Semantics
- Question Answering

They are aware of basic techniques in these areas, can identify limitations and shortcomings of these

techniques when applied to concrete problem situations, and develop modifications of these techniques for specific areas. They can evaluate such modifications qualitatively and quantitatively.

**Implementation method**

Statistical Natural Language Processing: The weekly lectures (2SWS) cover new content on a weekly basis. In addition to the formal considerations, we will cover applications and corresponding limitations of the methods presented throughout the course. The exercises (1SWS) are both theoretical and practical in nature. The learners are to show that they understood the concepts and can apply them to practical problems. The mini-project (2SWS) give the students a holistic view of how to solve complex problems using Semantic Web technologies.

**Assessment modalities (duration)**

Written exam (90 - 120 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

| **Person responsible for the module** |
| --- |
| Prof. Dr. Axel Ngonga |

| **Learning material, literature** |
| --- |
| Statistical Natural Language Processing: Slides and homework assignments |

| **Remarks** |
| --- |
| none |

## 3.57 Elective Module: Statistics in Measurement

| | |
|---|---|
| Module name | Statistics in Measurement / Statistics in Measurement |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Statistics in Measurement : 2 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Statistics in Measurement: Lecture ( 30h / 120h / DE / SS / 100 )
Statistics in Measurement: Tutorial ( 30h / 0h / DE / SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Statistics in Measurement: Knowledge of module “Messtechnik” is helpful.

**Content**

Statistics in Measurement: The lecture discusses how random fluctuations can be treated by statistical methods, e.g., spectral analysis or correlation techniques. Errors regarding time and quantization are discussed. Practical use in communication and automation is highlighted. Accompanying exercises with lab and Matlab.

**Learning objectives**

Students can analyse and ascertain complex measurement tasks with stochastically varying values. They will develop own solutions. They can evaluate algorithms regarding computational efficiency, effectiveness, error behaviors and bounds.

**Implementation method**

Statistics in Measurement: Lecture with interactive whiteboard, homework assignments and lab exercises for practical measurement experiments.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Bernd Henning

**Learning material, literature**

Statistics in Measurement: Supplementary material and textbooks.

**Remarks**

none

## 3.58 Elective Module: System Identification

| | |
|---|---|
| Module name | System Identification / System Identification |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • System Identification : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

System Identification: Lecture ( 30h / 120h / DE / WS / 20 )
System Identification: Tutorial ( 30h / 0h / DE / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

System Identification:

**Content**

System Identification: The course deals with the experimental identification of quantitative models describing the behavior of a given system. This includes both the selection of the model class, the determination of the parameters of the model and, if necessary, the state estimation. Depending on the field of application, a variety of model properties and, as a result, identification techniques can be distinguished: static vs. dynamic, deterministic vs. stochastic, discrete-time vs. continuous-time etc. The course gives an introduction to the most important methods of system identification, whereby the application-oriented realization (also with the use of software tools) is focused.

**Learning objectives**

- Introduction: Application fields of system identification and basic terms
- Repetition of basics: Dynamic models in state space, time discretization, stochastic processes
- Identification of deterministic, static processes (function fitting)
- Systematic evaluation of the identification results (accuracy analysis)
- Numerical optimization methods for (non-)linear problems
- Identification of dynamic processes in the state space by means of iterative optimization
- State and parameter estimation using Kalman filtering

- Practical aspects of implementation (e.g. optimal system excitation)

**Implementation method**

System Identification:
- Lecture with script, slide set and blackboard
- Exercises on the blackboard and in the PC pool room (Matlab / Simulink)
- Homework exercises and short term paper (both voluntary)

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Dr.-Ing. Oliver Wallscheid

**Learning material, literature**

System Identification:
• Isermann, R.: Identification of Dynamic Systems, Springer-Verlag, Berlin Heidelberg, 2011
• Ljung, L: System Identifiation - Theory for the User (2nd ed.), Prentice Hall, Upper Saddle River, NJ, 1999
• Schröder, D.: Intelligente Verfahren: Identifikation und Regelung nichtlinearer Systeme, Springer-Verlag, Berlin Heidelberg, 2010
• Walter, E.: Identification of Parametric Models, Springer-Verlag, Berlin Heidelberg, 1997

**Remarks**

none

## 3.59 Elective Module: Technology of Highly Integrated Circuits

| | |
|---|---|
| Module name | Technology of Highly Integrated Circuits / Technology of Highly Integrated Circuits |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Technology of Highly Integrated Circuits : 3 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Technology of Highly Integrated Circuits: Lecture ( 30h / 120h / EN / WS / 100 )
Technology of Highly Integrated Circuits: Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Technology of Highly Integrated Circuits:

**Content**

Technology of Highly Integrated Circuits: The course "Technology of highly integrated circuits" focuses on very large-scale integration of semiconductor devices. Starting from standard CMOS-Processing, problems of increasing the integration density and their solutions will be discussed. Here the Local Oxidation of Silicon, Silicon on Insulator and process steps for very large-scale integration are explained. Subsequently integration techniques for bipolar transistors are illustrated.

**Learning objectives**

After attending the course, the students will be able to
- choose Local Oxidation of Silicon method for integration of transistors and calculate layer thicknesses
- explain the integration of nano-scale transistors
- explain transistor manufracturing with SOI-Technology.
- develop processes for circuits with bipolar transistors.
- explain circuits in BiCMOS-Technology.

**Implementation method**

Technology of Highly Integrated Circuits:
- Lecture based on slide presentation, extensions on blackboard
- Exercises in small groups based on exercise sheets with students presenting their own solutions

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Ulrich Hilleringmann

**Learning material, literature**

Technology of Highly Integrated Circuits:
- Handouts of lecture slides
- Hilleringmann, U.: Silizium-Halbleitertechnologie, Teubner Verlag
- Additional links to books and other material available at the webpage

| **Remarks** |
| --- |
| none |

## 3.60 Elective Module: Topics in Audio, Speech, and Language Processing

| | |
|---|---|
| Module name | Topics in Audio, Speech, and Language Processing / Topics in Audio, Speech, and Language Processing |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Topics in Audio, Speech, and Language Processing : arbitrary |

| **Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )** |
|---|
| Topics in Audio, Speech, and Language Processing: Lecture ( 30h / 120h / EN / SS / 20 )<br>Topics in Audio, Speech, and Language Processing: Tutorial ( 30h / 0h / EN / SS / 20 ) |

| **Choices in Module** |
|---|
| none |

| **Course prerequisites** |
|---|
| None |

| **Recommended proficiencies** |
|---|
| Topics in Audio, Speech, and Language Processing: None |

| **Content** |
|---|
| Topics in Audio, Speech, and Language Processing: The course “Topics in Audio, Speech, and Language Processing” highlights current research topics in audio, speech, and language processing. From the methodological side we will discuss signal processing and machine learning aspects, and in particular their interaction, which is typical for many real-world applications. The selection of topics may change from year to year. Example topics are<br>• Multi-channel signal processing for microphone arrays<br>• Sampling rate synchronisation<br>• Machine learning for speech enhancement<br>• Blind source separation for speech and audio<br>• “Deep learning” for acoustic and language modeling in automatic speech recognition<br>• Neural architectues für speech recognition, speech synthesis, machine translation, etc.<br>• Natural language processing |

**Learning objectives**

After completion of the module students
• Can assess the challenges and realized solutions of modern speech and audio processing systems
• Know the specific properties of speech, audio and language and know how those are exploited in specific signal processing and machine learning algorithms
• Understand the interplay of algorithmic performance, complexity and latency and identify appropriate operating points
• Apply the learnt signal processing and machine learning algorithms to other tasks in speech and audio processing, and beyond
• Understand current scientific literature in the field of audio, speech, and language processing and assess their importance for the field

**Implementation method**

Topics in Audio, Speech, and Language Processing:
• Lectures predominantly using the blackboard or overhead projector, occasional presentations of (powerpoint) slides,
• Exercise classes with exercise sheets and demonstrations on computer
• Instructions how to read and analyze scientific publications in this field
• Autonomous analysis of publications and presentation of results and gained insight

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

| **Weight for overall grade** |
| --- |
| The module is weighted with 6 credits. |

| **Person responsible for the module** |
| --- |
| Prof. Dr.-Ing. Reinhold Häb-Umbach |

| **Learning material, literature** |
| --- |
| Topics in Audio, Speech, and Language Processing: Will be distributed in the course. |

| **Remarks** |
| --- |
| none |

## 3.61 Elective Module: Topics in Automatic Control

| | |
|---|---|
| Module name | Topics in Automatic Control / Topics in Automatic Control |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Topics in Automatic Control : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Topics in Automatic Control: Lecture ( 30h / 120h / EN / WS oder SS / 20 )
Topics in Automatic Control: Tutorial ( 30h / 0h / EN / WS oder SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Topics in Automatic Control:

**Content**

Topics in Automatic Control: This course covers a selection of current topics in systems control and requires active student participation throughout. For that purpose, students will be given support with reading, analyzing and expanding results in recent papers from the systems control literature. The choice of topics depends upon current research interests and changes every semester.
Example Topics:
- Networked Control Systems
- Security and Privacy of Dynamical Systems
- Model Predictive Control
- Learning and Control

**Learning objectives**

In this course, students will familiarize themselves with some current research topics in automatic control. They will learn to read and understand scientific publications and to critically evaluate results.

**Implementation method**

Topics in Automatic Control:
- Lecture with student participation
- Student presentations

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. Daniel E. Quevedo

**Learning material, literature**

Topics in Automatic Control: References will be given during first lecture.

| Remarks |
| --- |
| none |

## 3.62 Elective Module: Topics in Pattern Recognition and Machine Learning

| | |
|---|---|
| Module name | Topics in Pattern Recognition and Machine Learning / Topics in Pattern Recognition and Machine Learning |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Topics in Pattern Recognition and Machine Learning : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Topics in Pattern Recognition and Machine Learning: Lecture ( 30h / 120h / EN / WS / 20 )
Topics in Pattern Recognition and Machine Learning: Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

This is an advanced course! For a successful participation it is required that you have already basic knowledge in statistical methods and machine learning. If you are new to the field, please attend first a basic course on machine learning, such as the course "Statistical and Machine Learning" (L.048.92005) offered by myself in the summer semester, and then come back to this course on Topics in Pattern Recognition and Machine Learning next winter term!

**Recommended proficiencies**

Topics in Pattern Recognition and Machine Learning: Elementary knowledge in Probability Theroy, as is taught in the course Statistical Signal Processing. Basic knowledge in statistical and machine learning.

**Content**

Topics in Pattern Recognition and Machine Learning: The course on "Topics in Pattern Recognition and Machine Learning" first briefly summarizes the main concepts of statistical pattern recognition and machine learning. Next selected topics will be presented in detail. The choice of topics depends on current research activities and thus may change over time. Examples of such topics to be studied in detail include
• Model estimation in the presence of hidden variables, in order to reveal suspected latent structure buried in the data
• Bias-Variance dilemma and the tradeoff between degree of detail and generalizability of models
• Grafical models

• Sequential data and hidden Markov models
• Specific classification tasks, such as automatic speech recognition
While the first part of the course will follow a regular lecture format, the second part will include active student participation. Students will be asked to read, analyze and present recently published papers from the pattern recognition and machine learning literature. This will often also include the implementation of proposed algorithms in Matlab.

**Learning objectives**

After completion of the module students will be able to
• Choose an appropriate classifier for a given classification problem and be able to learn the parameters of the classifier from training data
• Choose an appropriate regression method for function approximation and learn its parameters from training data
• Search for latent variables and structure in given data
• Make an informative choice for the model order to find a good compromise between degree of detail and generalizabliliy
• Comprehend and analyze recent publications from the field of pattern recognition and machine learning

**Implementation method**

Topics in Pattern Recognition and Machine Learning:
• Lectures predominantly using the blackboard or overhead projector, occasional presentations of (powerpoint) slides,
• Exercise classes with exercise sheets and demonstrations on computer
• Instructions how to read and analyze scientific publications in this field
• Autonomous analysis of publications and presentation of results and gained insight

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Reinhold Häb-Umbach

**Learning material, literature**

Topics in Pattern Recognition and Machine Learning: Literature
- R.O. Duda, P.E. Hart, D.G. Stork, Pattern Classification, Wiley, 2001
- K. Fukunaga, Introduction to Statistical Pattern Recognition, Academic Press, 1990
- C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006

**Remarks**

none

## 3.63 Elective Module: Topics in Signal Processing

| | |
|---|---|
| Module name | Topics in Signal Processing / Topics in Signal Processing |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Topics in Signal Processing : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Topics in Signal Processing: Lecture ( 30h / 120h / EN / WS / 20 )
Topics in Signal Processing: Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Topics in Signal Processing: Signal and system theory, at least a basic understanding of probability and linear algebra

**Content**

Topics in Signal Processing: This course covers a selection of current topics in signal processing. One part of this course will follow a regular lecture format, while the other part will require student participation. The course will first review relevant aspects of linear algebra and probability theory. Then students will learn how to read, analyze, and present recent papers from the signal processing literature.

**Learning objectives**

In this course, students will familiarize themselves with some current research topics in signal processing. They will learn to read and understand scientific publications and to critically evaluate results.

**Implementation method**

Topics in Signal Processing:
• Lecture with student participation

- Student presentations

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Peter Schreier

**Learning material, literature**

Topics in Signal Processing: References will be given during first lecture.

**Remarks**

none

## 3.64 Elective Module: Ultrasonic Measurement Technology

| | |
|---|---|
| Module name | Ultrasonic Measurement Technology / Ultrasonic Measurement Technology |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Ultrasonic Measurement Technology : 2 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Ultrasonic Measurement Technology: Lecture ( 30h / 120h / DE / SS / 100 )
Ultrasonic Measurement Technology: Tutorial ( 30h / 0h / DE / SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Ultrasonic Measurement Technology: None

**Content**

Ultrasonic Measurement Technology: Mechanical waves in solids, fluids, gases. Main acoustic measurement principles. Applications for ultrasound tomography.

**Learning objectives**

This module treats mechanicals waves in solids, fluids, and gases. Main acoustic measurement principles and their application in industry are explained. Students will be able to apply ultrasound-based measurement techniques to determine both acoustic and non-acoustic properties.

**Implementation method**

Ultrasonic Measurement Technology: Lectures with slides; practical work in small groups.

| **Assessment modalities (duration)** |
| --- |
| Oral exam (ca. 40 Minutes)<br>The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest. |

| **Partial module exams** |
| --- |
| none |

| **Course achievement / qualifying participation** |
| --- |
| none |

| **Prerequisites for participation in module exam** |
| --- |
| none |

| **Prerequisites for obtaining credits** |
| --- |
| Passing of module exam. |

| **Weight for overall grade** |
| --- |
| The module is weighted with 6 credits. |

| **Person responsible for the module** |
| --- |
| Prof. Dr.-Ing. Bernd Henning |

| **Learning material, literature** |
| --- |
| Ultrasonic Measurement Technology: Script and textbooks. |

| **Remarks** |
| --- |
| none |

## 3.65 Elective Module: Vehicular Networking

| | |
|---|---|
| Module name | Vehicular Networking / Vehicular Networking |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Vehicular Networking : arbitrary |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Vehicular Networking: Lecture ( 45h / 105h / EN / SS / 40 )
Vehicular Networking: Tutorial ( 30h / 0h / EN / SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Vehicular Networking: System software and system-level programming

**Content**

Vehicular Networking: Today's automotive industry is increasingly relying on computer science in product innovation. Young professionals are expected to have specialized knowledge in the fields of electronics, software and vehicular networks – both in-car networks and networks of moving cars. This lecture teaches important concepts from these domains, starting with in-car networks (from individual electronic control units, modern bus systems, system and network architectures, to driver assistance functions, security and safety). The lecture then moves to networks of moving cars (from communication technology and system architectures, to the design of advanced traffic information systems, security and safety). Particular emphasis is given to the relevant question of balancing users' privacy with their safety and security.

**Learning objectives**

The learning objective is to unserstand the fundamental concepts of vehicular networking. Students understand these concepts and are able to apply this knowledge.

**Implementation method**

Vehicular Networking: Lecture with practical exercises

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. Falko Dressler

**Learning material, literature**

Vehicular Networking: Slides, textbooks, papers

| **Remarks** |
| --- |
| none |

## 3.66 Elective Module: Video Technology

| | |
|---|---|
| Module name | Video Technology / Video Technology |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Video Technology : 2 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Video Technology: Lecture ( 30h / 120h / DE / SS / 100 )
Video Technology: Tutorial ( 30h / 0h / DE / SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Video Technology: Prior knowledge from the modules Higher Mathematics, Digital Signal Processing and Transmission Techniques is helpful.

**Content**

Video Technology: The course "Video Technology" gives an introduction to the basic techniques and theories of taking , processing and reproduction of motion pictures and transmitting them via analogue and digital links. Starting with the basics of scanning necessary bandwidth and standards of intended systems are discussed. Depending on the colour vision system of the human eye science of colour and analogue and digital colour coding are described.
Electronic camera systems and modern reproduction sets complements the theory.
Digital picture transmission systems combined with data reduction (MPEG) are the main emphasis of modern transmission like DVB (Digital Video Broadcasting).
Video tape recording (VTR), optical (DVD) and electrical picture storing systems are described. New 3 dimensional picture taking and viewing will be shown.

**Learning objectives**

After attending the course, the students will be able to
- analyze tasks in the field of basics of picture scannings and to formulate requirements mathematically,
- describing of picture data reduction systems

- declaring picture transmission systems.
- describing basic principles of color

The students
- are able to check theoretical results using practical realizations,
- are able to undertake theoretical approaches a systematic analysis using methodical procedures and
- are, due to the precise treatment of the contents, in a position to continue their learning themselves

**Implementation method**

Video Technology:
- Lectures using the blackboard and presentations,
- Alternating theoretical and practical exercise classes with blackboard
- Demonstration of real technical systems in the lecture hall.

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Reinhold Häb-Umbach

**Learning material, literature**

Video Technology:
- Schönfelder, H, Fernsehtechnik im Wandel, Springer Verlag, Heidelberg 1996
- Schiller, Martin et.al , INTERNET: Werkzeuge und Dienste, Springer Verlag, Berlin 1994
- Mäusl, R. , Digitale Modulationsverfahren, Hüthig-Verlag, Heidelberg 1985
- Schönfelder, H., Bildkommunikation, Springer Verlag, Heidelberg 1988
- Jens-Rainer Ohm, Digitale Bildcodierung, Springer Verlag, Berlin 1995
- Reimers, U. (Hrsg.), Digitale Fernsehtechnik (4. Auflage), Datenkompression und Übertragung für DVB, Springer Verlag, Berlin 1995 / 2008
- Hentschel, H.J., Theorie und Praxis der Lichttechnik, Hüthig-Verlag, Heidelberg 1982
- Lang, H., Farbmetrik und Farbensehen, Oldenbourg Verlag, München 1978
- Tauer, Holger, Stereo 3D: Grundlagen, Technik und Bildgestaltung, Verlag Schiele & Schön, Berlin 2011

**Remarks**

none

## 3.67 Elective Module: VLSI Testing

| | |
|---|---|
| Module name | VLSI Testing / VLSI Testing |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • VLSI Testing : 1 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

VLSI Testing: Lecture ( 30h / 120h / EN / WS / 40 )
VLSI Testing: Tutorial ( 30h / 0h / EN / WS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

VLSI Testing: Digital Design

**Content**

VLSI Testing: The course "VLSI Testing" focuses on techniques for detecting hardware defects in microelectronic circuits. Algorithms for test data generation and test response evaluation as well as hardware structures for design for test (DFT) and on-chip test implementation (BIST) are presented.

**Learning objectives**

After attending the course, the students will be able to
- describe fault models, DFT techniques, and test tools,
- explain and apply the underlying models and algorithms for fault simulation and test generation,
- analyze systems with respect to their testability and to derive appropriate test strategies.

**Implementation method**

VLSI Testing:
- Lecture based on slide presentation, extensions on blackboard

- Exercises in small groups based on exercise sheets with students presenting their own solutions
- Hands-on exercises using various software tools

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr. Sybille Hellebrand

**Learning material, literature**

VLSI Testing:
- Handouts of lecture slides
- M. L. Bushnell, V. D. Agrawal, Essentials of Electronic Testing for Digital, Memory & Mixed-Signal VLSI Circuits, Boston, Dordrecht, London: Kluwer Academic Publishers, 2000
- L.-T. Wang, C.-W. Wu, X. Wen, VLSI Test Principles and Architectures: Design for Testability, Morgan Kaufmann Series in Systems on Silicon, ISBN: 0123705975
- Additional links to books and other material available in koala

| **Remarks** |
| --- |
| none |

## 3.68 Elective Module: Web Security

| | |
|---|---|
| Module name | Web Security / Web Security |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Web Security : arbitrary |

| **Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )** |
|---|
| Web Security: Lecture ( 45h / 105h / EN / SS / 40 )<br>Web Security: Tutorial ( 30h / 0h / EN / SS / 40 ) |

| **Choices in Module** |
|---|
| none |

| **Course prerequisites** |
|---|
| none |

| **Recommended proficiencies** |
|---|
| Web Security: Knowledge in programming, IT Security and basic knowledge in Cryptography |

| **Content** |
|---|
| Web Security: |

| **Learning objectives** |
|---|
| After successful completion, students have a comprehensive understanding of the technical aspects of web applications, web services, and various authentication mechanisms. They have learned that the web technologies used today are complex and that their complexity poses many security problems. Students have an overview of current web attacks and know how to prevent them practically. |

| **Implementation method** |
|---|
| Web Security: Lecture with exercises |

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

Qualifying Participation: written exercises
The responsible lecturer announces the requirements for course achievements in the first three weeks of the lecture period at latest.

**Prerequisites for participation in module exam**

Passing of course achievement.

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Juraj Somorovsky

**Learning material, literature**

Web Security:
- Lecture slides
- Scientific papers

**Remarks**

none

## 3.69 Elective Module: Wireless Communications

| | |
|---|---|
| Module name | Wireless Communications / Wireless Communications |
| Workload | 180 h |
| Credits | 6 LP |
| Semester | • Wireless Communications : 2 |

**Course: Teaching Form ( Contact hours / Self study / Language / Date / Group size )**

Wireless Communications: Lecture ( 30h / 120h / EN / SS / 100 )
Wireless Communications: Tutorial ( 30h / 0h / EN / SS / 20 )

**Choices in Module**

none

**Course prerequisites**

none

**Recommended proficiencies**

Wireless Communications: Elementary knowledge digital communications, as is taught in Bachelor studies of Electrical Engineering or related disciplines, are helpful.

**Content**

Wireless Communications: The course on "Wireless Communications" presents an introduction to the principles and techniques for reliable communication over time and/or frequency selective fading channels. The course starts with a detailed discussion of the physical and statistical modeling of wireless communication channels. Next, the most important transmission and receiver techniques will be described, including
• Time diversity: maximum ratio combiner, error rate computation for coherent and incoherent detection, interleaving
• Antenna diversity: tranmit diversity, receive diversity and MIMO techniques
• Frequency diversity: single carrier transmission with sequence detection, direct sequence spread spectrum, multi-carrier techniques
Emphasis will be given on an intuitive understanding of receiver principles from a linear vector space point of view.
Further, an introduction to current cellular systems will be provided: GSM, UMTS and LTE.

**Learning objectives**

After completion of the module students will be able to
• Develop a discrete-time statistical channel model for a given physical description of a wireless communication channel
• Explain the techniques and algorithms used in the Physical Layer of a wireless communication system
• Understand the fundamental design options an decisions taken to realize reliable communication over time variant and frequency selective or nonselective fading channels
• Appreciate and categorize the techniques used in modern cellular communication systems to realize reliable communication
• Trade off the advantages and disadvantages of different transmission techniques with respect to bandwidth and power efficiency as well as number of users to be served
• Select and design an appropriate transmission technique for a wireless channel
• simulate and analyze simple communication systems using modern software tools
The students
• Can transfer and apply the concept of linear vector spaces to signal processing tasks other than for wireless communications
• Can apply the skills about the generation of data, simulation of systems and analysis of experimental results using modern software tools, that have been acquired in this course, to other disciplines
• Can work cooperatively in a team and subdivide an overall task into manageable subtasks and work packages

**Implementation method**

Wireless Communications:
• Lectures predominantly using the blackboard or overhead projector, as well as presentations of (powerpoint) slides ,
• Exercise classes with exercise sheets and demonstrations on computer and
• Implementation of discrete-time channel models and building blocks of a wireless communication system using modern software tools; evaluation and presentation of the simulation results

**Assessment modalities (duration)**

Oral exam (ca. 40 Minutes)
The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

**Partial module exams**

none

**Course achievement / qualifying participation**

none

**Prerequisites for participation in module exam**

none

**Prerequisites for obtaining credits**

Passing of module exam.

**Weight for overall grade**

The module is weighted with 6 credits.

**Person responsible for the module**

Prof. Dr.-Ing. Reinhold Häb-Umbach

**Learning material, literature**

Wireless Communications: Course script and summary slides are provided to the students. Exercises and solutions to exercises, as well as sample implementations of algorithms are provided to the students. Further literature

- D. Tse and P. Viswanath, Fundamentals of Wireless Communication, Cambridge University Press, 2005.
- K.-D. Kammeyer, Nachrichtenübertragung, Teubner, 2004.

**Remarks**

none

# Appendix A

# Summary Tables

## A.1 Focus Areas and Modules

| | Communication and Networks (S. 13) | Computer Systems (S. 15) | Control and Automation (S. 16) | Embedded Systems (S. 17) | Nano/Microelectronics (S. 19) | Signal, Image and Speech Processing (S. 20) |
|---|---|---|---|---|---|---|
| Abschlussarbeit (S. 94) | - | - | - | - | - | - |
| Advanced Control (S. 23) | - | - | X | - | - | - |
| Advanced Distributed Algorithms and Data Structures (S. 26) | X | - | - | - | - | - |
| Advanced System Theory (S. 29) | - | - | X | - | - | X |
| Advanced Topics in Robotics (S. 32) | - | - | X | - | - | - |
| Advanced VLSI Design (S. 35) | - | - | - | X | X | - |
| Algorithms and Tools for Test and Diagnosis of Systems on Chip (S. 37) | - | X | - | X | X | - |
| Algorithms for Synthesis and Optimization of Integrated Circuits (S. 40) | - | X | - | X | - | - |

| | Communication and Networks (S. 13) | Computer Systems (S. 15) | Control and Automation (S. 16) | Embedded Systems (S. 17) | Nano/Microelectronics (S. 19) | Signal, Image and Speech Processing (S. 20) |
|---|---|---|---|---|---|---|
| Approximate Computing (S. 43) | - | X | - | X | - | - |
| Architektur paralleler Rechnersysteme (S. 46) | - | X | - | X | - | - |
| Biomedizinische Messtechnik (S. 48) | - | - | X | - | - | - |
| Cooperative Mobile Systems (S. 62) | X | - | - | X | - | - |
| Databases and Information Systems (S. 65) | - | X | - | - | - | - |
| Digital Image Processing I (S. 68) | - | - | - | - | - | X |
| Digital Image Processing II (S. 71) | - | - | - | - | - | X |
| Digitale Sprachsignalverarbeitung (S. 74) | - | - | - | - | - | X |
| Dynamic Programming and Stochastic Control (S. 77) | - | - | X | - | - | - |
| Einführung in die Hochfrequenztechnik (S. 115) | - | - | - | - | X | - |
| Elektrotechnik I (S. 80) | - | - | - | - | - | - |
| Elektrotechnik II (S. 83) | - | - | - | - | - | - |
| Empiric performance evaluation (S. 86) | X | X | - | - | - | - |
| Foundations of Cryptography (S. 97) | X | - | - | - | - | - |
| Future Internet (S. 100) | X | - | - | - | - | - |
| Gergelte Drehstromantriebe (S. 59) | - | - | X | - | - | - |
| Halbleiterprozesstechnik (S. 168) | - | - | - | - | X | - |
| High Frequency Engineering (S. 103) | - | - | - | - | X | - |
| High-Performance Computing (S. 106) | - | X | - | - | - | - |
| Informatik I (S. 54) | - | - | - | - | - | - |
| Informatik II (S. 56) | - | - | - | - | - | - |
| Integrierte Schaltungen für die drahtlose Kommunikation (S. 109) | X | - | - | X | X | - |

| | Communication and Networks (S. 13) | Computer Systems (S. 15) | Control and Automation (S. 16) | Embedded Systems (S. 17) | Nano/Microelectronics (S. 19) | Signal, Image and Speech Processing (S. 20) |
|---|---|---|---|---|---|---|
| Intelligence in Embedded Systems (S. 112) | - | X | - | X | - | - |
| Introduction to Quantum Computation (S. 118) | - | X | - | - | - | - |
| Kognitive Sensorsysteme (S. 50) | - | - | - | - | - | X |
| Machine Learning I (S. 121) | X | X | X | X | X | X |
| Machine Learning II (S. 124) | - | - | - | - | - | X |
| Messstochastik (S. 180) | - | - | - | - | - | X |
| Mobile Communication (S. 127) | X | - | - | - | - | - |
| Model-Based Systems Engineering (S. 130) | - | - | - | X | - | - |
| Model-Driven Software Development (S. 132) | - | - | - | X | - | - |
| Network Simulation (S. 134) | X | - | - | X | - | - |
| Optical Communication A (S. 136) | X | - | - | - | - | - |
| Optical Communication B (S. 139) | X | - | - | - | - | - |
| Optical Communication C (S. 142) | X | - | - | - | - | - |
| Optimale und adaptive Filter (S. 145) | X | - | - | - | - | X |
| Projektgruppe (S. 148) | - | - | - | - | - | - |
| Real World Crypto Engineering (S. 151) | X | - | - | - | - | - |
| Reconfigurable Computing (S. 153) | - | X | - | X | - | - |
| Reinforcement Learning (S. 156) | - | - | X | - | - | - |
| Robotics (S. 159) | - | - | X | - | - | - |
| Routing and Data Management in Networks (S. 162) | X | - | - | - | - | - |
| Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation (S. 91) | X | - | - | X | X | - |
| Software Quality Assurance (S. 171) | - | - | - | X | - | - |

| | Communication and Networks (S. 13) | Computer Systems (S. 15) | Control and Automation (S. 16) | Embedded Systems (S. 17) | Nano/Microelectronics (S. 19) | Signal, Image and Speech Processing (S. 20) |
|---|---|---|---|---|---|---|
| Statistical Natural Language Processing (S. 177) | - | - | - | - | - | X |
| Statistische und maschinelle Lernverfahren (S. 174) | - | - | - | - | - | X |
| Systemidentifikation (S. 182) | - | - | X | - | - | - |
| Technische kognitive Systeme (S. 52) | - | - | - | - | - | X |
| Technologie hochintegrierter Schaltungen (S. 185) | - | - | - | - | X | - |
| Topics in Audio, Speech, and Language Processing (S. 188) | - | - | - | - | - | X |
| Topics in Automatic Control (S. 191) | - | - | X | - | - | - |
| Topics in Pattern Recognition and Machine Learning (S. 194) | - | - | - | - | - | X |
| Topics in Signal Processing (S. 197) | X | - | - | - | - | X |
| Ultraschall-Messtechnik (S. 199) | - | - | X | - | - | - |
| Umweltmesstechnik (S. 89) | - | - | X | - | - | - |
| Vehicular Networking (S. 201) | X | - | - | X | - | - |
| Videotechnik (S. 204) | - | - | - | - | - | X |
| VLSI Testing (S. 207) | - | X | - | X | X | - |
| Web Security (S. 210) | X | - | - | - | - | - |
| Wireless Communications (S. 212) | X | - | - | - | - | X |
| Wissenschaftliches Arbeiten (S. 165) | - | - | - | - | - | - |