TUHH

Hamburg University of Technology

# Module Manual

Master of Science

# Computer Science

Cohort: Winter Term 2017

Updated: 28th September 2018

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# Module Manual

Master

# Computer Science

Cohort: Winter Term 2017

Updated: 28th September 2018

## Program description

### Content

# Core qualification

## Module M0523: Business & Management

| | |
|---|---|
| **Module Responsible** | Prof. Matthias Meyer |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | None |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | • Students are able to find their way around selected special areas of management within the scope of business management.<br>• Students are able to explain basic theories, categories, and models in selected special areas of business management.<br>• Students are able to interrelate technical and management knowledge. |
| *Skills* | • Students are able to apply basic methods in selected areas of business management.<br>• Students are able to explain and give reasons for decision proposals on practical issues in areas of business management. |
| **Personal Competence** | |
| *Social Competence* | • Students are able to communicate in small interdisciplinary groups and to jointly develop solutions for complex problems |
| *Autonomy* | • Students are capable of acquiring necessary knowledge independently by means of research and preparation of material. |
| **Workload in Hours** | Depends on choice of courses |
| **Credit points** | 6 |

**Courses**

**Information regarding lectures and courses can be found in the corresponding module handbook published separately.**

# Module M0524: Nontechnical Elective Complementary Courses for Master

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|---|---|
| **Module Responsible** | Dagmar Richter |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | None |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | **The Nontechnical Academic Programms (NTA)**<br><br>imparts skills that, in view of the TUHH's training profile, professional engineering studies require but are not able to cover fully. Self-reliance, self-management, collaboration and professional and personnel management competences. The department implements these training objectives in its **teaching architecture**, in its **teaching and learning arrangements**, in **teaching areas** and by means of teaching offerings in which students can qualify by opting for **specific competences** and a **competence level** at the Bachelor's or Master's level. The teaching offerings are pooled in two different catalogues for nontechnical complementary courses.<br><br>**The Learning Architecture**<br><br>consists of a cross-disciplinarily study offering. The centrally designed teaching offering ensures that courses in the nontechnical academic programms follow the specific profiling of TUHH degree courses.<br><br>The learning architecture demands and trains independent educational planning as regards the individual development of competences. It also provides orientation knowledge in the form of "profiles".<br><br>The subjects that can be studied in parallel throughout the student's entire study program - if need be, it can be studied in one to two semesters. In view of the adaptation problems that individuals commonly face in their first semesters after making the transition from school to university and in order to encourage individually planned semesters abroad, there is no obligation to study these subjects in one or two specific semesters during the course of studies.<br><br>**Teaching and Learning Arrangements**<br><br>provide for students, separated into B.Sc. and M.Sc., to learn with and from each other across semesters. The challenge of dealing with interdisciplinarity and a variety of stages of learning in courses are part of the learning architecture and are deliberately encouraged in specific courses.<br><br>**Fields of Teaching**<br><br>are based on research findings from the academic disciplines cultural studies, social studies, arts, historical studies, communication studies, migration studies and sustainability research, and from engineering didactics. In addition, from the winter semester 2014/15 students on all Bachelor's courses will have the opportunity to learn about business management and start-ups in a goal-oriented way.<br><br>The fields of teaching are augmented by soft skills offers and a foreign language offer. Here, the focus is on encouraging goal-oriented communication skills, e.g. the skills required by outgoing engineers in international and intercultural situations.<br><br>**The Competence Level** |

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| | of the courses offered in this area is different as regards the basic training objective in the Bachelor's and Master's fields. These differences are reflected in the practical examples used, in content topics that refer to different professional application contexts, and in the higher scientific and theoretical level of abstraction in the B.Sc.<br><br>This is also reflected in the different quality of soft skills, which relate to the different team positions and different group leadership functions of Bachelor's and Master's graduates in their future working life.<br><br>**Specialized Competence (Knowledge)**<br><br>Students can<br><br>• explain specialized areas in context of the relevant non-technical disciplines,<br>• outline basic theories, categories, terminology, models, concepts or artistic techniques in the disciplines represented in the learning area,<br>• different specialist disciplines relate to their own discipline and differentiate it as well as make connections,<br>• sketch the basic outlines of how scientific disciplines, paradigms, models, instruments, methods and forms of representation in the specialized sciences are subject to individual and socio-cultural interpretation and historicity,<br>• Can communicate in a foreign language in a manner appropriate to the subject. |
| *Skills* | **Professional Competence (Skills)**<br><br>In selected sub-areas students can<br><br>• apply basic and specific methods of the said scientific disciplines,<br>• aquestion a specific technical phenomena, models, theories from the viewpoint of another, aforementioned specialist discipline,<br>• to handle simple and advanced questions in aforementioned scientific disciplines in a sucsessful manner,<br>• justify their decisions on forms of organization and application in practical questions in contexts that go beyond the technical relationship to the subject. |
| **Personal Competence** | |
| *Social Competence* | **Personal Competences (Social Skills)**<br><br>Students will be able<br><br>• to learn to collaborate in different manner,<br>• to present and analyze problems in the abovementioned fields in a partner or group situation in a manner appropriate to the addressees,<br>• to express themselves competently, in a culturally appropriate and gender-sensitive manner in the language of the country (as far as this study-focus would be chosen),<br>• to explain nontechnical items to auditorium with technical background knowledge. |
| | **Personal Competences (Self-reliance)**<br><br>Students are able in selected areas<br><br>• to reflect on their own profession and professionalism in the context of real-life fields of |

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| *Autonomy* | application<br>• to organize themselves and their own learning processes<br>• to reflect and decide questions in front of a broad education background<br>• to communicate a nontechnical item in a competent way in writen form or verbaly<br>• to organize themselves as an entrepreneurial subject country (as far as this study-focus would be chosen) |
| **Workload in Hours** | Depends on choice of courses |
| **Credit points** | 6 |

| **Courses** |
|---|
| **Information regarding lectures and courses can be found in the corresponding module handbook published separately.** |

# Module M0804: Research Project and Seminar

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Project Work (L1761) | Projection Course | 10 | 15 |
| Seminar (L0817) | Seminar | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Karl-Heinz Zimmermann |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basic knowledge and techniques in the chosen field of specialization. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to acquire advanced knowledge in a specific field of Computer Science or a closely related subject. |
| *Skills* | Students are able to work self-dependent in a field of Computer Science or a closely related field. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 372, Study Time in Lecture 168 |
| **Credit points** | 18 |
| **Examination** | Study work |
| **Examination duration and scale** | Presentation of a current research topic (25-30 min and 5 min discussion). |
| **Assignment for the Following Curricula** | Computer Science: Core qualification: Compulsory<br>Computational Science and Engineering: Core qualification: Compulsory<br>Information and Communication Systems: Core qualification: Compulsory |

## Course L1761: Project Work

| | |
|---|---|
| **Typ** | Projection Course |
| **Hrs/wk** | 10 |
| **CP** | 15 |
| **Workload in Hours** | Independent Study Time 310, Study Time in Lecture 140 |
| **Lecturer** | Dozenten des SD E |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | Current research topics of the chosen specialization. |
| **Literature** | Aktuelle Literatur zu Forschungsthemen aus der gewählten Vertiefungsrichtung.<br>/<br>Current literature on research topics of the chosen specialization. |

| Course L0817: Seminar | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Dozenten des SD E |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | • Seminar presentations by enrolled students about the research work carried out by the students<br>• Active participation in discussions |
| **Literature** | Wird vom Veranstalter bekanntgegeben. |

# Specialization Computer and Software Engineering

## Module M0753: Software Verification

### Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Software Verification (L0629) | Lecture | 2 | 3 |
| Software Verification (L0630) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Sibylle Schupp |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Automata theory and formal languages<br>• Computational logic<br>• Object-oriented programming, algorithms, and data structures<br>• Functional programming or procedural programming<br>• Concurrency |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students apply the major verification techniques in model checking and deductive verification. They explain in formal terms syntax and semantics of the underlying logics, and assess the expressivity of different logics as well as their limitations. They classify formal properties of software systems. They find flaws in formal arguments, arising from modeling artifacts or underspecification. |
| *Skills* | Students formulate provable properties of a software system in a formal language. They develop logic-based models that properly abstract from the software under verification and, where necessary, adapt model or property. They construct proofs and property checks by hand or using tools for model checking or deductive verification, and reflect on the scope of the results. Presented with a verification problem in natural language, they select the appropriate verification technique and justify their choice. |
| **Personal Competence** | |
| *Social Competence* | Students discuss relevant topics in class. They defend their solutions orally. They communicate in English. |
| *Autonomy* | Using accompanying on-line material for self study, students can assess their level of knowledge continuously and adjust it appropriately. Working on exercise problems, they receive additional feedback. Within limits, they can set their own learning goals. Upon successful completion, students can identify and precisely formulate new problems in academic or applied research in the field of software verification. Within this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports. They can devise plans to arrive at new solutions or assess existing ones. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration** | 90 min |

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| **and scale** | |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems: Compulsory<br>International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory |

| **Course L0629: Software Verification** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sibylle Schupp |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Syntax and semantics of logic-based systems<br>• Deductive verification<br>  ◦ Specification<br>  ◦ Proof obligations<br>  ◦ Program properties<br>  ◦ Automated vs. interactive theorem proving<br>• Model checking<br>  ◦ Foundations<br>  ◦ Property languages<br>  ◦ Tool support<br>• Timed automata<br>• Recent developments of verification techniques and applications |
| **Literature** | • C. Baier and J-P. Katoen, Principles of Model Checking, MIT Press 2007.<br>• M. Huth and M. Bryan, Logic in Computer Science. Modelling and Reasoning about Systems, 2nd Edition, 2004.<br>• Selected Research Papers |

| **Course L0630: Software Verification** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sibylle Schupp |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M1336: Soft Computing

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Soft Computing (L1869) | Lecture | 4 | 6 |

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|---|---|
| **Module Responsible** | Prof. Karl-Heinz Zimmermann |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | |
| *Skills* | |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 25 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory<br>Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory |

## Course L1869: Soft Computing

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|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 4 |
| **CP** | 6 |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Lecturer** | Prof. Karl-Heinz Zimmermann |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | |
| **Literature** | |

# Module M1270: Technical Complementary Course I for CSMS (according to Subject Specific Regulations)

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|

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|---|---|
| **Module Responsible** | Prof. Karl-Heinz Zimmermann |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | None |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students acquire advanced knowledge in a technical subject available at TUHH. |
| *Skills* | The students acquire professional competence in a technical subject available at TUHH. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Depends on choice of courses |
| **Credit points** | 6 |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory |

# Module M0667: Algorithmic Algebra

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Algorithmic Algebra (L0422) | Lecture | 3 | 5 |
| Algorithmic Algebra (L0423) | Recitation Section (small) | 1 | 1 |

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|---|---|
| **Module Responsible** | Dr. Prashant Batra |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Mathe I-III (Real analysis,computing in Vector spaces , principle of complete induction) Diskrete Mathematik I (gropus, rings, ideals, fields; euclidean algorithm) |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can discuss logical connections between the following concepts and explain them by means of examples: Smith normal form, Chinese remainder theorem, grid point sets, integer solution of inequality systems. |
| | Students are able to access independently further logical connections between the concepts with which they have become familiar and are able to verify them. |
| *Skills* | Students are able to develop a suitable solution approach to given problems, to pursue it and to evaluate the results critically, such as in solving multivariate equation systems and in grid point theory. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory |

## Course L0422: Algorithmic Algebra

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|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 3 |
| **CP** | 5 |
| **Workload in Hours** | Independent Study Time 108, Study Time in Lecture 42 |
| **Lecturer** | Dr. Prashant Batra |
| **Language** | DE |
| **Cycle** | WiSe |

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| **Content** | Extended euclidean algorithm, solution of the Bezout-equation<br><br>Division with remainder (over rings)<br><br>fast arithmetic algorithms (conversion, fast multiplications)<br><br>discrete Fourier-transformation over rings<br><br>Computation with modular remainders, solving of remainder systems (chinese remainder theorem), solvability of integer linear systems over the integers<br><br>linearization of polynomial equations-- matrix approach<br><br>Sylvester-matrix, elimination<br><br>elimination in rings, elimination of many variables<br><br>Buchberger algorithm, Gröbner basis<br><br>Minkowskis Lattice Point theorem and integer-valued optimization<br><br>LLL-algorithm for construction of 'short' lattice vectors in polynomial time |
| **Literature** | von zur Gathen, Joachim; Gerhard, Jürgen<br>Modern computer algebra. 3rd ed. (English) Zbl 1277.68002<br>Cambridge: Cambridge University Press (ISBN 978-1-107-03903-2/hbk; 978-1-139-85606-5/ebook).<br><br>Yap, Chee Keng<br>Fundamental problems of algorithmic algebra. (English) Zbl 0999.68261<br>Oxford: Oxford University Press. xvi, 511 p. $ 87.00 (2000).<br><br>Free download for students from author's website: http://cs.nyu.edu/yap/book/berlin/<br><br>Cox, David; Little, John; O'Shea, Donal<br>Ideals, varieties, and algorithms. An introduction to computational algebraic geometry and commutative algebra. 3rd ed. (English) Zbl 1118.13001<br>Undergraduate Texts in Mathematics. New York, NY: Springer (ISBN 978-0-387-35650-1/hbk; 978-0-387-35651-8/ebook). xv, 551 p.<br><br>eBook: http://dx.doi.org/10.1007/978-0-387-35651-8<br><br>Concrete abstract algebra : from numbers to Gröbner bases / Niels **Lauritzen**<br>**Verfasser:** **Lauritzen,** Niels<br>**Ausgabe:** Reprinted with corr.<br>**Erschienen:** Cambridge [u.a.] : Cambridge Univ. Press, 2006<br>**Umfang:** XIV, 240 S. : graph. Darst.<br>**Anmerkung:** Includes bibliographical references and index<br>**ISBN:** 0-521-82679-9, 978-0-521-82679-2 (hbk.) : GBP 55.00<br>0-521-53410-0, 978-0-521-53410-9 (pbk.) : USD 39.99<br><br>Koepf, Wolfram<br>Computer algebra. An algorithmic oriented introduction. (Computeralgebra. Eine algorithmisch orientierte Einführung.) (German) Zbl 1161.68881<br>Berlin: Springer (ISBN 3-540-29894-0/pbk). xiii, 515 p.<br><br>springer eBook: http://dx.doi.org/10.1007/3-540-29895-9 |

| | |
|---|---|
| | Kaplan, Michael<br>Computer algebra. (Computeralgebra.) (German) Zbl 1093.68148<br>Berlin: Springer (ISBN 3-540-21379-1/pbk). xii, 391 p.<br><br>springer eBook:<br><br>http://dx.doi.org/10.1007/b137968 |

| **Course L0423: Algorithmic Algebra** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Dr. Prashant Batra |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0836: Communication Networks I - Analysis and Structure

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Analysis and Structure of Communication Networks (L0897) | Lecture | 2 | 2 |
| Selected Topics of Communication Networks (L0899) | Project-/problem-based Learning | 2 | 2 |
| Communication Networks Excercise (L0898) | Project-/problem-based Learning | 1 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Andreas Timm-Giel |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Fundamental stochastics<br>• Basic understanding of computer networks and/or communication technologies is beneficial |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to describe the principles and structures of communication networks in detail. They can explain the formal description methods of communication networks and their protocols. They are able to explain how current and complex communication networks work and describe the current research in these examples. |
| *Skills* | Students are able to evaluate the performance of communication networks using the learned methods. They are able to work out problems themselves and apply the learned methods. They can apply what they have learned autonomously on further and new communication networks. |
| **Personal Competence** | |
| *Social Competence* | Students are able to define tasks themselves in small teams and solve these problems together using the learned methods. They can present the obtained results. They are able to discuss and critically analyse the solutions. |
| *Autonomy* | Students are able to obtain the necessary expert knowledge for understanding the functionality and performance capabilities of new communication networks independently. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Examination** | Presentation |
| **Examination duration and scale** | 1.5 hours colloquium with three students, therefore about 30 min per student. Topics of the colloquium are the posters from the previous poster session and the topics of the module. |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory<br>Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory |

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| | Mechatronics: Technical Complementary Course: Elective Compulsory<br>Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory |

| Course L0897: Analysis and Structure of Communication Networks | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Andreas Timm-Giel |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | |
| **Literature** | • Skript des Instituts für Kommunikationsnetze<br>• Tannenbaum, Computernetzwerke, Pearson-Studium<br><br>Further literature is announced at the beginning of the lecture. |

| Course L0899: Selected Topics of Communication Networks | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Dr. Maciej Mühleisen |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Example networks selected by the students will be researched on in a PBL course by the students in groups and will be presented in a poster session at the end of the term. |
| **Literature** | • see lecture |

| Course L0898: Communication Networks Excercise | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Dr. Maciej Mühleisen |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Part of the content of the lecture Communication Networks are reflected in computing tasks in groups, others are motivated and addressed in the form of a PBL exercise. |
| **Literature** | • announced during lecture |

# Module M0926: Distributed Algorithms

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Distributed Algorithms (L1071) | Lecture | 2 | 3 |
| Distributed Algorithms (L1072) | Recitation Section (large) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Volker Turau |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Algorithms and data structures<br>• Distributed systems<br>• Discrete mathematics<br>• Graph theory |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students know the main abstractions of distributed algorithms (synchronous/asynchronous model, message passing and shared memory model). They are able to describe complexity measures for distributed algorithms (round , message and memory complexity). They explain well known distributed algorithms for important problems such as leader election, mutual exclusion, graph coloring, spanning trees. They know the fundamental techniques used for randomized algorithms. |
| *Skills* | Students design their own distributed algorithms and analyze their complexity. They make use of known standard algorithms. They compute the complexity of randomized algorithms. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 45 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory |

| Course L1071: Distributed Algorithms | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Volker Turau |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | • Leader Election<br>• Colorings & Independent Sets<br>• Tree Algorithms<br>• Minimal Spanning Trees<br>• Randomized Distributed Algorithms<br>• Mutual Exclusion |
| **Literature** | 1. David Peleg: Distributed Computing - A Locality-Sensitive Approach. SIAM Monograph, 2000<br>2. Gerard Tel: Introduction to Distributed Algorithms, Cambridge University Press, 2nd edition, 2000<br>3. Nancy Lynch: Distributed Algorithms. Morgan Kaufmann, 1996<br>4. Volker Turau: Algorithmische Graphentheorie. Oldenbourg Wissenschaftsverlag, 3. Auflage, 2004. |

| Course L1072: Distributed Algorithms | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Volker Turau |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0586: Efficient Algorithms

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Efficient Algorithms (L0120) | Lecture | 2 | 3 |
| Efficient Algorithms (L1207) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Siegfried Rump |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Programming in Matlab and/or C<br>Basic knowledge in discrete mathematics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are able to explain the basic theory and methods of network algorithms and in particular their data structures. They are able to analyze the computational behavior and computing time of linear programming algorithms as well network algorithms. Moreover the students can distinguish between efficiently solvable and NP-hard problems. |
| *Skills* | The students are able to analyze complex tasks and can determine possibilities to transform them into networking algorithms. In particular they can efficiently implement basic algorithms and data structures of LP- and network algorithms and identify possible weaknesses. They are able to distinguish between different efficient data structures and are able to use them appropriately. |
| **Personal Competence** | |
| *Social Competence* | The students have the skills to solve problems together in small groups and to present the achieved results in an appropriate manner. |
| *Autonomy* | The students are able to retrieve necessary informations from the given literature and to combine them with the topics of the lecture. Throughout the lecture they can check their abilities and knowledge on the basis of given exercises and test questions providing an aid to optimize their learning process. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 30 min |
| | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory |

| | |
|---|---|
| **Assignment for the Following Curricula** | Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory |

| **Course L0120: Efficient Algorithms** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Siegfried Rump |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | - Linear Programming<br>- Data structures<br>- Leftist heaps<br>- Minimum spanning tree<br>- Shortest path<br>- Maximum flow<br>- NP-hard problems via max-cut |
| **Literature** | R. E. Tarjan: Data Structures and Network Algorithms. CBMS 44, Society for Industrial and Applied Mathematics, Philadelphia, PA, 1983.<br>Wesley, 2011 http://algs4.cs.princeton.edu/home/<br>V. Chvátal, ``Linear Programming", Freeman, New York, 1983. |

| **Course L1207: Efficient Algorithms** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Siegfried Rump |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M1271: Technical Complementary Course II for CSMS (according to Subject Specific Regulations)

| Courses | | | |
|---|---|---|---|
| **Title** | **Typ** | **Hrs/wk** | **CP** |

| | |
|---|---|
| **Module Responsible** | Prof. Karl-Heinz Zimmermann |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | None |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Die Studierenden können die wesentlichen Inhalte des technischen Faches im Rahmen eines Vortrages oder einer Diskussion wiedergeben. |
| *Skills* | The students acquire professional competence in a technical subject available at TUHH. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Depends on choice of courses |
| **Credit points** | 6 |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation Intelligence Engineering: Elective Compulsory |

# Module M1337: Codes and Cryptosystems

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Codes and Cryptosystems (L1870) | Lecture | 4 | 6 |

| | |
|---|---|
| **Module Responsible** | Prof. Karl-Heinz Zimmermann |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | |
| *Skills* | |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 25 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory |

## Course L1870: Codes and Cryptosystems

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 4 |
| **CP** | 6 |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Lecturer** | Prof. Karl-Heinz Zimmermann |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | |

# Module M1318: Wireless Sensor Networks

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Selected Topics of Wireless Sensor Networks (L1819) | Project-/problem-based Learning | 1 | 2 |
| Wireless Sensor Networks (L1815) | Lecture | 2 | 2 |
| Wireless Sensor Networks (L1816) | Recitation Section (small) | 1 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Bernd-Christian Renner |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | |
| *Skills* | |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory<br>Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory |

| Course L1819: Selected Topics of Wireless Sensor Networks | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Bernd-Christian Renner |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Selected topics on sensor network research will be researched in a PBL course by the students in groups and will be presented in a poster session at the end of the term. Topics are:<br>• Energy-efficient / low-power Medium Access<br>• Energy-efficient / low-power Routing (Data Collection and Data Dissemination)<br>• Energy Harvesting<br>• Intermittently Powered Sensor Nodes<br>• Energy-Aware Load Adaptation and Scheduling<br>• Additional Topics will be provided on demand / depending on the number of participants |
| **Literature** | Will be provided individually |

| Course L1815: Wireless Sensor Networks | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Bernd-Christian Renner |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | |

| Course L1816: Wireless Sensor Networks | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Bernd-Christian Renner |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0943: Network Security

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Network Security (L1105) | Lecture | 3 | 3 |
| Network Security (L1106) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Dieter Gollmann |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Discrete Mathematics, Computer Networks (TCP/IP) |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can<br>• explain the fundamental security services that can be implemented with the methods of modern cryptography,<br>• describe current standardized network security protocols and mechanisms,<br>• follow current methods for the formal analysis of security protocols. |
| *Skills* | Students are capable of<br>• performing an analysis of network security solutions.<br>• identifying suitable security solutions for given requirements.<br>• recognizing the limitations of existing standard solutions,<br>• performing a formal analysis of security protocos. |
| **Personal Competence** | |
| *Social Competence* | None |
| *Autonomy* | Students are capable of acquiring knowledge independently from professional publications, technical standards, and other sources, and are capable of applying newly acquired knowledge to new problems. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 minutes |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems: Elective Compulsory |

| Course L1105: Network Security | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 3 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 48, Study Time in Lecture 42 |
| **Lecturer** | Prof. Dieter Gollmann |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Security objectives<br>• Security services and cryptographic mechanisms<br>• Key establishment: Diffie-Hellman, Kerberos<br>• IPsec protocols, mobile IPv6<br>• SSL/TLS<br>• GSM/UMTS/LTE security protocols<br>• WLAN security<br>• Firewalls and Intrusion Detection Systems<br>• Formal analysis of security protocols |
| **Literature** | W. Stallings: Cryptography and Network Security: Principles and Practice, 6th edition (2013)<br><br>A. Menezes, P. van Oorschot, S. Vanstone: Handbook of Applied Cryptography, CRC Press (1997)<br><br>D. Gollmann: Computer Security, 3rd edition, Wiley (2011)<br><br>V. Niemi, K. Nyberg: UMTS Security, Wiley (2003) |

| Course L1106: Network Security | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Dieter Gollmann |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0556: Computer Graphics

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Computer Graphics (L0145) | Lecture | 2 | 3 |
| Computer Graphics (L0768) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Tobias Knopp |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Students are expected to have a solid knowledge of object-oriented programming as well as of linear algebra and geometry. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students have acquired a theoretical basis in computer graphics and have a clear understanding of the process of computer animation. |
| *Skills* | Students have acquired<br>• solid skills in modelling and shading,<br>• solid skills in computer animation techniques, and<br>• a thorough command of Maya, a first-class animation system. |
| **Personal Competence** | |
| *Social Competence* | Students are trained in communicating abstract ideas and are familiar with planning and conducting projects within a small team. |
| *Autonomy* | Students are able to direct complex computer animation projects. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory |

| Course L0145: Computer Graphics | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Tobias Knopp |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Computer graphics and animation are leading to an unprecedented visual revolution. The course deals with its technological foundations:<br>• Object-oriented Computer Graphics<br>• Projections and Transformations<br>• Polygonal and Parametric Modelling<br>• Illuminating, Shading, Rendering<br>• Computer Animation Techniques<br>• Kinematics and Dynamics Effects<br><br>Students will be be working on a series of mini-projects which will eventually evolve into a final project. Learning computer graphics and animation resembles learning a musical instrument. Therefore, doing your projects well and in time is essential for performing well on this course. |
| **Literature** | Alan H. Watt:<br>3D Computer Graphics.<br>Harlow: Pearson (3rd ed., repr., 2009).<br><br>Dariush Derakhshani:<br>Introducing Autodesk Maya 2014.<br>New York, NY : Wiley (2013). |

| Course L0768: Computer Graphics | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Tobias Knopp |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M1307: Cryptography

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Cryptography (L1806) | Lecture | 2 | 3 |
| Cryptography (L1807) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Chris Brzuska |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Prerequisites:<br>Mathematical reasoning will be used throughout the course and is essential. It is helpful if you have been to introduction to IT Security and know that the concept of an algorithm can be formalized (e.g., via the concept of a Turing Maschine) and used to measure running time. It is also useful if you know the complexity classes P and NP. We will need some basic probability analysis, too. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Knowledge of cryptographic primitives such as one-way-functions, digitalen signatures, encryption, key exchange, zero-knowledge proofs as well as implications between the primitives, knowledge of formal security definitions of cryptographic prmitives, connections between cryptography and complexity theory, in particular to the P vs. NP problem. |
| *Skills* | Ability to discuss and develop security models for cryptographic pimitives. Constructing reductions between cryptographic primitives and ability to say whether small tweaks might harm the security of a cryptographic primitive. |
| **Personal Competence** | |
| *Social Competence* | Ability to critically question schemes and methods that seem intuitively secure. |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems: Elective Compulsory<br>Technomathematics: Specialisation II. Informatics: Elective Compulsory |

| Course L1806: Cryptography | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Chris Brzuska |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | Content:<br>This course is about the foundations of cryptography. We introduce cryptographic security models and concepts and understand the relations between them. We then apply the learnt concepts and techniques to real-world problems. In particular, we cover:<br>- One-way functions<br>- Pseudorandomness<br>- Pseudorandom generators<br>- Pseudorandom functions<br>- symmetric encryption<br>- asymmetric encryption<br>- message authentication codes<br>- signature schemes<br>- secure channels<br>- recent attacks on real-life protocols such as TLS, IPsec,... |
| **Literature** | Literatur:<br><br>- Foundations of Cryptography: Volume 1, Basic Tools, Oded Goldreich, Cambridge University Press 2007, ISBN-10: 0521035368, ISBN-13: 978-0521035361<br><br>- Foundations of Cryptography: Volume 2, Basic Applications, Oded Goldreich, Cambridge University Press 2009, ISBN-10: 052111991X, ISBN-13: 978-0521119917 |

| Course L1807: Cryptography | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Chris Brzuska |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | |
| **Literature** | Literatur:<br><br>- Foundations of Cryptography: Volume 1, Basic Tools, Oded Goldreich, Cambridge University Press 2007, ISBN-10: 0521035368, ISBN-13: 978-0521035361<br><br>- Foundations of Cryptography: Volume 2, Basic Applications, Oded Goldreich, Cambridge University Press 2009, ISBN-10: 052111991X, ISBN-13: 978-0521119917 |

# Module M1248: Compilers for Embedded Systems

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Compilers for Embedded Systems (L1692) | Lecture | 3 | 4 |
| Compilers for Embedded Systems (L1693) | Laboratory | 1 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Heiko Falk |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Module "Embedded Systems"<br>C/C++ Programming skills |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The relevance of embedded systems increases from year to year. Within such systems, the amount of software to be executed on embedded processors grows continuously due to its lower costs and higher flexibility. Because of the particular application areas of embedded systems, highly optimized and application-specific processors are deployed. Such highly specialized processors impose high demands on compilers which have to generate code of highest quality. After the successful attendance of this course, the students are able<br>• to illustrate the structure and organization of such compilers,<br>• to distinguish and explain intermediate representations of various abstraction levels, and<br>• to assess optimizations and their underlying problems in all compiler phases.<br><br>The high demands on compilers for embedded systems make effective code optimizations mandatory. The students learn in particular,<br>• which kinds of optimizations are applicable at the source code level,<br>• how the translation from source code to assembly code is performed,<br>• which kinds of optimizations are applicable at the assembly code level,<br>• how register allocation is performed, and<br>• how memory hierarchies can be exploited effectively.<br><br>Since compilers for embedded systems often have to optimize for multiple objectives (e.g., average- or worst-case execution time, energy dissipation, code size), the students learn to evaluate the influence of optimizations on these different criteria. |
| *Skills* | After successful completion of the course, students shall be able to translate high-level program code into machine code. They will be enabled to assess which kind of code optimization should be applied most effectively at which abstraction level (e.g., source or assembly code) within a compiler.<br><br>While attending the labs, the students will learn to implement a fully functional compiler including optimizations. |
| **Personal Competence** | |
| *Social Competence* | Students are able to solve similar problems alone or in a group and to present the results accordingly. |
| *Autonomy* | Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes. |

| | |
|---|---|
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Mechatronics: Specialisation System Design: Elective Compulsory<br>Mechatronics: Technical Complementary Course: Elective Compulsory |

| **Course L1692: Compilers for Embedded Systems** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 3 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 78, Study Time in Lecture 42 |
| **Lecturer** | Prof. Heiko Falk |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | • Introduction and Motivation<br>• Compilers for Embedded Systems - Requirements and Dependencies<br>• Internal Structure of Compilers<br>• Pre-Pass Optimizations<br>• HIR Optimizations and Transformations<br>• Code Generation<br>• LIR Optimizations and Transformations<br>• Register Allocation<br>• WCET-Aware Compilation<br>• Outlook |
| **Literature** | • Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2nd Edition, Springer, 2012.<br>• Steven S. Muchnick. Advanced Compiler Design and Implementation. Morgan Kaufmann, 1997.<br>• Andrew W. Appel. Modern compiler implementation in C. Oxford University Press, 1998. |

| Course L1693: Compilers for Embedded Systems | |
|---|---|
| **Typ** | Laboratory |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Heiko Falk |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M1304: Security in Embedded Hardware

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Security in Embedded Hardware (L1804) | Lecture | 2 | 3 |
| Security in Embedded Hardware (L1805) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Daniel Ziener |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Computer Engineering<br>Basic knowledge in embedded systems |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Course coverage:<br>• Attack scenarios<br>  ◦ Examples of attack scenarios<br>  ◦ Attacks on cryptographic algorithms and their implementations<br>• Code injection attacks<br>  ◦ Different type of code injection attacks<br>  ◦ Countermeasures<br>• Invasive physical attacks<br>  ◦ Microprobing<br>  ◦ Prevention and detection of single event effects<br>  ◦ Reverse engineering<br>  ◦ IP Protection<br>  ◦ Watermarking<br>• Non-invasive logical attacks<br>  ◦ Phishing<br>  ◦ Forged authenticity<br>  ◦ Countermeasures<br>• Non-invasive physical attacks<br>  ◦ Eavesdroping<br>  ◦ Side-channel attacks<br>• Case study: Security in automotive applications |
| *Skills* | • The students show the influence of attacks and the corresponding countermeasures on the dependability of embedded systems<br>• The students describe the different countermeasures of attacks<br>• The students summarize different security facilities and measures for embedded systems<br>• The students show the overhead (area, time) of security facilities<br>• The students classify different types of attack on embedded systems |
| **Personal Competence** | |
| *Social Competence* | • The students develop concepts in groups with subsequent implementations |

| | |
|---|---|
| *Autonomy* | • The students acquire new knowledge from specific literature and to associate this knowledge with other classes. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory |

| **Course L1804: Security in Embedded Hardware** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | NN |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | Course coverage:<br>• Attack scenarios<br>  ◦ Examples of attack scenarios<br>  ◦ Attacks on cryptographic algorithms and their implementations<br>• Code injection attacks<br>  ◦ Different type of code injection attacks<br>  ◦ Countermeasures<br>• Invasive physical attacks<br>  ◦ Microprobing<br>  ◦ Prevention and detection of single event effects<br>  ◦ Reverse engineering<br>  ◦ IP Protection<br>  ◦ Watermarking<br>• Non-invasive logical attacks<br>  ◦ Phishing<br>  ◦ Forged authenticity<br>  ◦ Countermeasures<br>• Non-invasive physical attacks<br>  ◦ Eavesdroping<br>  ◦ Side-channel attacks<br>• Case study: Security in automotive applications |
| **Literature** | • Catherine H. Gebotys Security in Embedded Devices. Springer 2010.<br>• Benoit Badrignans et al. Security Trends for FPGAs. Springer 2011.<br>• Daniel Ziener Techniques for Increasing Security and Reliability of IP Cores Embedded in FPGA and ASIC Designs. Dr. Hut 2010. |

| Course L1805: Security in Embedded Hardware | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | NN |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0837: Communication Networks II - Simulation and Modeling

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Simulation and Modelling of Communication Networks (L0887) | Project-/problem-based Learning | 5 | 6 |

| | |
|---|---|
| **Module Responsible** | Prof. Andreas Timm-Giel |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Knowledge of computer and communication networks<br>• Basic programming skills |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to explain the necessary stochastics, the discrete event simulation technology and modelling of networks for performance evaluation. |
| *Skills* | Students are able to apply the method of simulation for performance evaluation to different, also not practiced, problems of communication networks. The students can analyse the obtained results and explain the effects observed in the network. They are able to question their own results. |
| **Personal Competence** | |
| *Social Competence* | Students are able to acquire expert knowledge in groups, present the results, and discuss solution approaches and results. They are able to work out solutions for new problems in small teams. |
| *Autonomy* | Students are able to transfer independently and in discussion with others the acquired method and expert knowledge to new problems. They can identify missing knowledge and acquire this knowledge independently. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 45-60 minutes colloquium with two students, therefore about 30 minutes per student. |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory |

| Course L0887: Simulation and Modelling of Communication Networks | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 5 |
| **CP** | 6 |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Lecturer** | Prof. Andreas Timm-Giel |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | In the course necessary basic stochastics and the discrete event simulation are introduced. Also simulation models for communication networks, for example, traffic models, mobility models and radio channel models are presented in the lecture. Students work with a simulation tool, where they can directly try out the acquired skills, algorithms and models. At the end of the course increasingly complex networks and protocols are considered and their performance is determined by simulation. |
| **Literature** | • Skript des Instituts für Kommunikationsnetze<br>Further literature is announced at the beginning of the lecture. |

# Module M0924: Software for Embedded Systems

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Software for Embdedded Systems (L1069) | Lecture | 2 | 3 |
| Software for Embdedded Systems (L1070) | Recitation Section (small) | 3 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Volker Turau |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Good knowledge and experience in programming language C<br>• Basis knowledge in software engineering<br>• Basic understanding of assembly language |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students know the basic principles and procedures of software engineering for embedded systems. They are able to describe the usage and pros of event based programming using interrupts. They know the components and functions of a concrete microcontroller. The participants explain requirements of real time systems. They know at least three scheduling algorithms for real time operating systems including their pros and cons. |
| *Skills* | Students build interrupt-based programs for a concrete microcontroller. They build and use a preemptive scheduler. They use peripheral components (timer, ADC, EEPROM) to realize complex tasks for embedded systems. To interface with external components they utilize serial protocols. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory<br>Mechatronics: Technical Complementary Course: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Mechatronics: Specialisation System Design: Elective Compulsory |

| Course L1069: Software for Embdedded Systems | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Volker Turau |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | • General-Purpose Processors<br>• Programming the Atmel AVR<br>• Interrupts<br>• C for Embedded Systems<br>• Standard Single Purpose Processors: Peripherals<br>• Finite-State Machines<br>• Memory<br>• Operating Systems for Embedded Systems<br>• Real-Time Embedded Systems<br>• Boot loader and Power Management |
| **Literature** | 1. Embedded System Design, F. Vahid and T. Givargis, John Wiley<br>2. Programming Embedded Systems: With C and Gnu Development Tools, M. Barr and A. Massa, O'Reilly<br>3. C und C++ für Embedded Systems, F. Bollow, M. Homann, K. Köhn, MITP<br>4. The Art of Designing Embedded Systems, J. Ganssle, Newnses<br>5. Mikrocomputertechnik mit Controllern der Atmel AVR-RISC-Familie, G. Schmitt, Oldenbourg<br>6. Making Embedded Systems: Design Patterns for Great Software, E. White, O'Reilly |

| Course L1070: Software for Embdedded Systems | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 3 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 48, Study Time in Lecture 42 |
| **Lecturer** | Prof. Volker Turau |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M1301: Software Testing

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Software Testing (L1791) | Lecture | 2 | 3 |
| Software Testing (L1792) | Project-/problem-based Learning | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Sibylle Schupp |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Software Engineering<br>• Higher Programming Languages<br>• Object-Oriented Programming<br>• Algorithms and Data Structures<br>• Experience with (Small) Software Projects<br>• Statistics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students explain the different phases of testing, describe fundamental techniques of different types of testing, and paraphrase the basic principles of the corresponding test process. They give examples of software development scenarios and the corresponding test type and technique. They explain algorithms used for particular testing techniques and describe possible advantages and limitations. |
| *Skills* | Students identify the appropriate testing type and technique for a given problem. They adapt and execute respective algorithms to execute a concrete test technique properly. They interpret testing results and execute corresponding steps for proper re-test scenarios. They write and analyze test specifications. They apply bug finding techniques for non-trivial problems. |
| **Personal Competence** | |
| *Social Competence* | Students discuss relevant topics in class. They defend their solutions orally. They communicate in English. |
| *Autonomy* | Students can assess their level of knowledge continuously and adjust it appropriately, based on feedback and on self-guided studies. Within limits, they can set their own learning goals. Upon successful completion, students can identify and precisely formulate new problems in academic or applied research in the field of software testing. Within this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports. They can devise plans to arrive at new solutions or assess existing ones |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Subject theoretical and practical work |
| **Examination duration and scale** | Software |
| | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory |

| | |
|---|---|
| **Assignment for the Following Curricula** | Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory |

| **Course L1791: Software Testing** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sibylle Schupp |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Fundamentals of software testing<br>• Regression-testing techniques<br>• Search-based testing<br>• Combinatorial testing<br>• Product-line testing<br>• Debugging<br>• Model-based testing |
| **Literature** | • M. Pezze and M. Young, Software Testing and Analysis, John Wiley 2008.<br>• P. Ammann and J. Offutt, "Introduction to Software Testing", 2nd edition 2016.<br>• A. Zeller: "Why Programs Fail: A Guide to Systematic Debugging", 2nd edition 2012. |

| **Course L1792: Software Testing** | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sibylle Schupp |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Fundamentals of software testing<br>• Regression-testing techniques<br>• Search-based testing<br>• Combinatorial testing<br>• Product-line testing<br>• Debugging<br>• Model-based testing |
| **Literature** | • M. Pezze and M. Young, Software Testing and Analysis, John Wiley 2008.<br>• P. Ammann and J. Offutt, "Introduction to Software Testing", 2nd edition 2015.<br>• A. Zeller: "Why Programs Fail: A Guide to Systematic Debugging", 2nd edition 2012. |

# Module M0711: Numerical Mathematics II

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Numerical Mathematics II (L0568) | Lecture | 2 | 3 |
| Numerical Mathematics II (L0569) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Sabine Le Borne |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Numerical Mathematics I<br>• MATLAB knowledge |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to<br>• name advanced numerical methods for interpolation, integration, linear least squares problems, eigenvalue problems, nonlinear root finding problems and explain their core ideas,<br>• repeat convergence statements for the numerical methods,<br>• sketch convergence proofs,<br>• explain practical aspects of numerical methods concerning runtime and storage needs<br>explain aspects regarding the practical implementation of numerical methods with respect to computational and storage complexity.<br>• |
| *Skills* | Students are able to<br>• implement, apply and compare advanced numerical methods in MATLAB,<br>• justify the convergence behaviour of numerical methods with respect to the problem and solution algorithm and to transfer it to related problems,<br>• for a given problem, develop a suitable solution approach, if necessary through composition of several algorithms, to execute this approach and to critically evaluate the results |
| **Personal Competence** | |
| *Social Competence* | Students are able to<br>• work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms. |
| *Autonomy* | Students are capable<br>• to assess whether the supporting theoretical and practical excercises are better solved individually or in a team,<br>• to assess their individual progess and, if necessary, to ask questions and seek help. |

| | |
|---|---|
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 25 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory<br>Technomathematics: Specialisation I. Mathematics: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory |

| **Course L0568: Numerical Mathematics II** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sabine Le Borne, Dr. Patricio Farrell |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | 1. Error and stability: Notions and estimates<br>2. Interpolation: Rational and trigonometric interpolation<br>3. Quadrature: Gaussian quadrature, orthogonal polynomials<br>4. Linear systems: Perturbation theory of decompositions, structured matrices<br>5. Eigenvalue problems: LR-, QD-, QR-Algorithmus<br>6. Krylov space methods: Arnoldi-, Lanczos methods |
| **Literature** | • Stoer/Bulirsch: Numerische Mathematik 1, Springer<br>• Dahmen, Reusken: Numerik für Ingenieure und Naturwissenschaftler, Springer |

| **Course L0569: Numerical Mathematics II** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sabine Le Borne, Dr. Patricio Farrell |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M1395: Real-Time Systems

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Real-Time Systems (L1974) | Lecture | 3 | 4 |
| Real-Time Systems (L1975) | Recitation Section (small) | 1 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Heiko Falk |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | |
| *Skills* | |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory |

## Course L1974: Real-Time Systems

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 3 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 78, Study Time in Lecture 42 |
| **Lecturer** | Ph.D Selma Saidi, Ph.D Selma Saidi |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | |
| **Literature** | |

| Course L1975: Real-Time Systems | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Ph.D Selma Saidi, Ph.D Selma Saidi |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | |
| **Literature** | |

# Module M0942: Software Security

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Software Security (L1103) | Lecture | 2 | 3 |
| Software Security (L1104) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Dieter Gollmann |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Familiarity with C/C++, web programming |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can<br>• name the main causes for security vulnerabilities in software<br>• explain current methods for identifying and avoiding security vulnerabilities<br>• explain the fundamental concepts of code-based access control |
| *Skills* | Students are capable of<br>• performing a software vulnerability analysis<br>• developing secure code |
| **Personal Competence** | |
| *Social Competence* | None |
| *Autonomy* | Students are capable of acquiring knowledge independently from professional publications, technical standards, and other sources, and are capable of applying newly acquired knowledge to new problems. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 minutes |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Kernfächer Computer Science: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems: Elective Compulsory |

| Course L1103: Software Security | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Dieter Gollmann |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Reliabilty and Software Security<br>• Attacks exploiting character and integer representations<br>• Buffer overruns<br>• Vulnerabilities in memory managemet: double free attacks<br>• Race conditions<br>• SQL injection<br>• Cross-site scripting and cross-site request forgery<br>• Testing for security; taint analysis<br>• Type safe languages<br>• Development proceses for secure software<br>• Code-based access control |
| **Literature** | M. Howard, D. LeBlanc: Writing Secure Code, 2nd edition, Microsoft Press (2002)<br><br>G. Hoglund, G. McGraw: Exploiting Software, Addison-Wesley (2004)<br><br>L. Gong, G. Ellison, M. Dageforde: Inside Java 2 Platform Security, 2nd edition, Addison-Wesley (2003)<br><br>B. LaMacchia, S. Lange, M. Lyons, R. Martin, K. T. Price: .NET Framework Security, Addison-Wesley Professional (2002)<br><br>D. Gollmann: Computer Security, 3rd edition (2011) |

| Course L1104: Software Security | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Dieter Gollmann |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0910: Advanced System-on-Chip Design (Lab)

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Advanced System-on-Chip Design (L1061) | Project-/problem-based Learning | 3 | 6 |

| | |
|---|---|
| **Module Responsible** | Prof. Heiko Falk |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Successful completion of the practical FPGA lab of module "Computer Architecture" is a mandatory prerequisite. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | This module provides in-depth, hands-on experience on advanced concepts of computer architecture. Using the Hardware Description Language VHDL and using reconfigurable FPGA hardware boards, students learn how to design complex computer systems (so-called systems-on-chip, SoCs), that are commonly found in the domain of embedded systems, in actual hardware.<br><br>Starting with a simple processor architecture, the students learn to how realize instruction-processing of a computer processor according to the principle of pipelining. They implement different styles of cache-based memory hierarchies, examine strategies for dynamic scheduling of machine instructions and for branch prediction, and finally construct a complex MPSoC system (multi-processor system-on-chip) that consists of multiple processor cores that are connected via a shared bus. |
| *Skills* | Students will be able to analyze, how highly specific and individual computer systems can be constructed using a library of given standard components. They evaluate the interferences between the physical structure of a computer system and the software executed thereon. This way, they will be enabled to estimate the effects of design decision at the hardware level on the performance of the entire system, to evaluate the whole and complex system and to propose design options to improve a system. |
| **Personal Competence** | |
| *Social Competence* | Students are able to solve similar problems alone or in a group and to present the results accordingly. |
| *Autonomy* | Students are able to acquire new knowledge from specific literature, to transform this knowledge into actual implementations of complex hardware structures, and to associate this knowledge with contents of other classes. |
| **Workload in Hours** | Independent Study Time 138, Study Time in Lecture 42 |
| **Credit points** | 6 |
| **Examination** | Subject theoretical and practical work |
| **Examination duration and scale** | VHDL Codes and FPGA-based implementations |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory |

| Course L1061: Advanced System-on-Chip Design | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 3 |
| **CP** | 6 |
| **Workload in Hours** | Independent Study Time 138, Study Time in Lecture 42 |
| **Lecturer** | Prof. Heiko Falk |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | • Introduction into fundamental technologies (FPGAs, MIPS single-cycle machine)<br>• Pipelined instruction execution<br>• Cache-based memory hierarchies<br>• Busses and their arbitration<br>• Multi-Processor Systems-on-Chip<br>• Optional: Advanced pipelining concepts (dynamic scheduling, branch prediction) |
| **Literature** | • D. Patterson, J. Hennessy. Rechnerorganisation und -entwurf. Elsevier, 2005.<br>• A. Tanenbaum, J. Goodman. Computerarchitektur. Pearson, 2001.<br>• A. Clements. The Principles of Computer Hardware. 3. Auflage, Oxford University Press, 2000. |

# Module M0549: Scientific Computing and Accuracy

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Verification Methods (L0122) | Lecture | 2 | 3 |
| Verification Methods (L1208) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Siegfried Rump |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basic knowledge in numerics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students have deeper knowledge of numerical and semi-numerical methods with the goal to compute principally exact and accurate error bounds. For several fundamental problems they know algorithms with the verification of the correctness of the computed result. |
| *Skills* | The students can devise algorithms for several basic problems which compute rigorous error bounds for the solution and analyze the sensitivity with respect to variation of the input data as well. |
| **Personal Competence** | |
| *Social Competence* | The students have the skills to solve problems together in small groups and to present the achieved results in an appropriate manner. |
| *Autonomy* | The students are able to retrieve necessary informations from the given literature and to combine them with the topics of the lecture. Throughout the lecture they can check their abilities and knowledge on the basis of given exercises and test questions providing an aid to optimize their learning process. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory<br>Technomathematics: Specialisation II. Informatics: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: |

| | |
|---|---|
| | Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory |

| **Course L0122: Verification Methods** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Siegfried Rump |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | • Fast and accurate interval arithmetic<br>• Error-free transformations<br>• Verification methods for linear and nonlinear systems<br>• Verification methods for finite integrals<br>• Treatment of multiple zeros<br>• Automatic differentiation<br>• Implementation in Matlab/INTLAB<br>• Practical applications |
| **Literature** | Neumaier: Interval Methods for Systems of Equations. In: Encyclopedia of Mathematics and its Applications. Cambridge University Press, 1990<br>S.M. Rump. Verification methods: Rigorous results using floating-point arithmetic. Acta Numerica, 19:287-449, 2010. |

| **Course L1208: Verification Methods** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Siegfried Rump |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0839: Traffic Engineering

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Seminar Traffic Engineering (L0902) | Seminar | 2 | 2 |
| Traffic Engineering (L0900) | Lecture | 2 | 2 |
| Traffic Engineering Exercises (L0901) | Recitation Section (small) | 1 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Andreas Timm-Giel |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Fundamentals of communication or computer networks<br>• Stochastics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to describe methods for planning, optimisation and performance evaluation of communication networks. |
| *Skills* | Students are able to solve typical planning and optimisation tasks for communication networks. Furthermore they are able to evaluate the network performance using queuing theory.<br>Students are able to apply independently what they have learned to other and new problems. They can present their results in front of experts and discuss them. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | Students are able to acquire the necessary expert knowledge to understand the functionality and performance of new communication networks independently. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory |

| Course L0902: Seminar Traffic Engineering | |
|---|---|
| **Typ** | Seminar |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Andreas Timm-Giel |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Selected applications of methods for planning, optimization, and performance evaluation of communication networks, which have been introduced in the traffic engineering lecture are prepared by the students and presented in a seminar. |
| **Literature** | • U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Vieweg + Teubner<br>• further literature announced in the lecture |

| Course L0900: Traffic Engineering | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Andreas Timm-Giel |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Network Planning and Optimization<br>• Linear Programming (LP)<br>• Network planning with LP solvers<br>• Planning of communication networks<br>Queueing Theory for Communication Networks<br>• Stochastic processes<br>• Queueing systems<br>• Switches (circuit- and packet switching)<br>• Network of queues |
| **Literature** | Literatur:<br>U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer<br>Weitere Literatur wird in der Lehrveranstaltung bekanntgegeben<br>/<br>Literature:<br>U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer<br>further literature announced in the lecture |

| Course L0901: Traffic Engineering Exercises | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Andreas Timm-Giel |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Accompanying exercise for the traffic engineering course |
| **Literature** | Literatur:<br>U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer<br>Weitere Literatur wird in der Lehrveranstaltung bekanntgegeben / Literature:<br>U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer<br>further literature announced in the lecture |

# Module M0733: Software Analysis

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Software Analysis (L0631) | Lecture | 2 | 3 |
| Software Analysis (L0632) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Sibylle Schupp |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Basic knowledge of software-engineering activities<br>• Discrete algebraic structures<br>• Object-oriented programming, algorithms, and data structures<br>• Functional programming or Procedural programming |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students apply the major approaches to data-flow analysis, control-flow analysis, and type-based analysis, along with their classification schemes, and employ abstract interpretation. They explain the standard forms of internal representations and models, including their mathematical structure and properties, and evaluate their suitability for a particular analysis. They explain and categorize the major analysis algorithms. They distinguish precise solutions from approximative approaches, and show termination and soundness properties. |
| *Skills* | Presented with an analytical task for a software artifact, students select appropriate approaches from software analysis, and justify their choice. They design suitable representations by modifying standard representations. They develop customized analyses and devise them as safe overapproximations. They formulate analyses in a formal way and construct arguments for their correctness, behavior, and precision. |
| **Personal Competence** | |
| *Social Competence* | Students discuss relevant topics in class. They defend their solutions orally. They communicate in English. |
| *Autonomy* | Using accompanying on-line material for self study, students can assess their level of knowledge continuously and adjust it appropriately. Working on exercise problems, they receive additional feedback. Within limits, they can set their own learning goals. Upon successful completion, students can identify and precisely formulate new problems in academic or applied research in the field of software analysis. Within this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports. They can devise plans to arrive at new solutions or assess existing ones. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Subject theoretical and practical work |
| **Examination duration and scale** | software artifacts/mathematical write-ups; short presentation |
| | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems, Focus |

| | |
|---|---|
| **Assignment for the Following Curricula** | Software: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory<br>International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory |

| **Course L0631: Software Analysis** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sibylle Schupp |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Modeling: Control-Flow Modeling, Data Dependences, Intermediate Languages)<br>• Classical Bit-Vector Analyses (Reaching Definition, Very Busy Expressions, Liveness, Available Expressions, May/Must, Forward/Backward)<br>• Monotone Frameworks (Lattices, Transfer Functions, Ascending Chain Condition, Distributivity, Constant Propagation)<br>• Theory of Data-Flow Analysis (Tarski's Fixed Point Theorem, Data-Flow Equations, MFP Solution, MOP Solution, Worklist Algorithm)<br>• Non-Classical Data-Flow Analyses<br>• Abstract Interpretation (Galois Connections, Approximating Fixed Points, Construction Techniques)<br>• Type Systems (Type Derivation, Inference Trees, Algorithm W, Unification)<br>• Recent Developments of Analysis Techniques and Applications |
| **Literature** | • Flemming Nielsen, Hanne Nielsen, and Chris Hankin. Principles of Program Analysis. Springer, 2nd. ed. 2005.<br>• Uday Khedker, Amitabha Sanyal, and Bageshri Karkara. Data Flow Analysis: Theory and Practice. CRC Press, 2009.<br>• Benjamin Pierce, Types and Programming Languages, MIT Press.<br>• Selected research papers |

| **Course L0632: Software Analysis** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sibylle Schupp |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Specialization Intelligence Engineering

## Module M1270: Technical Complementary Course I for CSMS (according to Subject Specific Regulations)

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|

| | |
|---|---|
| **Module Responsible** | Prof. Karl-Heinz Zimmermann |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | None |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students acquire advanced knowledge in a technical subject available at TUHH. |
| *Skills* | The students acquire professional competence in a technical subject available at TUHH. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Depends on choice of courses |
| **Credit points** | 6 |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory |

# Module M0667: Algorithmic Algebra

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Algorithmic Algebra (L0422) | Lecture | 3 | 5 |
| Algorithmic Algebra (L0423) | Recitation Section (small) | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Dr. Prashant Batra |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Mathe I-III (Real analysis,computing in Vector spaces , principle of complete induction) Diskrete Mathematik I (gropus, rings, ideals, fields; euclidean algorithm) |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can discuss logical connections between the following concepts and explain them by means of examples: Smith normal form, Chinese remainder theorem, grid point sets, integer solution of inequality systems. |
| | Students are able to access independently further logical connections between the concepts with which they have become familiar and are able to verify them. |
| *Skills* | Students are able to develop a suitable solution approach to given problems, to pursue it and to evaluate the results critically, such as in solving multivariate equation systems and in grid point theory. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory |

## Course L0422: Algorithmic Algebra

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 3 |
| **CP** | 5 |
| **Workload in Hours** | Independent Study Time 108, Study Time in Lecture 42 |
| **Lecturer** | Dr. Prashant Batra |
| **Language** | DE |
| **Cycle** | WiSe |

| | |
|---|---|
| **Content** | Extended euclidean algorithm, solution of the Bezout-equation<br><br>Division with remainder (over rings)<br><br>fast arithmetic algorithms (conversion, fast multiplications)<br><br>discrete Fourier-transformation over rings<br><br>Computation with modular remainders, solving of remainder systems (chinese remainder theorem), solvability of integer linear systems over the integers<br><br>linearization of polynomial equations-- matrix approach<br><br>Sylvester-matrix, elimination<br><br>elimination in rings, elimination of many variables<br><br>Buchberger algorithm, Gröbner basis<br><br>Minkowskis Lattice Point theorem and integer-valued optimization<br><br>LLL-algorithm for construction of 'short' lattice vectors in polynomial time |
| **Literature** | von zur Gathen, Joachim; Gerhard, Jürgen<br>Modern computer algebra. 3rd ed. (English) Zbl 1277.68002<br>Cambridge: Cambridge University Press (ISBN 978-1-107-03903-2/hbk; 978-1-139-85606-5/ebook).<br><br>Yap, Chee Keng<br>Fundamental problems of algorithmic algebra. (English) Zbl 0999.68261<br>Oxford: Oxford University Press. xvi, 511 p. $ 87.00 (2000).<br><br>Free download for students from author's website: http://cs.nyu.edu/yap/book/berlin/<br><br>Cox, David; Little, John; O'Shea, Donal<br>Ideals, varieties, and algorithms. An introduction to computational algebraic geometry and commutative algebra. 3rd ed. (English) Zbl 1118.13001<br>Undergraduate Texts in Mathematics. New York, NY: Springer (ISBN 978-0-387-35650-1/hbk; 978-0-387-35651-8/ebook). xv, 551 p.<br><br>eBook: http://dx.doi.org/10.1007/978-0-387-35651-8<br><br>Concrete abstract algebra : from numbers to Gröbner bases / Niels **Lauritzen**<br>**Verfasser:** **Lauritzen,** Niels<br>**Ausgabe:** Reprinted with corr.<br>**Erschienen:** Cambridge [u.a.] : Cambridge Univ. Press, 2006<br>**Umfang:** XIV, 240 S. : graph. Darst.<br>**Anmerkung:** Includes bibliographical references and index<br>**ISBN:** 0-521-82679-9, 978-0-521-82679-2 (hbk.) : GBP 55.00<br>0-521-53410-0, 978-0-521-53410-9 (pbk.) : USD 39.99<br><br>Koepf, Wolfram<br>Computer algebra. An algorithmic oriented introduction. (Computeralgebra. Eine algorithmisch orientierte Einführung.) (German) Zbl 1161.68881<br>Berlin: Springer (ISBN 3-540-29894-0/pbk). xiii, 515 p.<br><br>springer eBook: http://dx.doi.org/10.1007/3-540-29895-9 |

| | |
|---|---|
| | Kaplan, Michael<br>Computer algebra. (Computeralgebra.) (German) Zbl 1093.68148<br>Berlin: Springer (ISBN 3-540-21379-1/pbk). xii, 391 p.<br><br>springer eBook:<br><br>http://dx.doi.org/10.1007/b137968 |

| **Course L0423: Algorithmic Algebra** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Dr. Prashant Batra |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0881: Mathematical Image Processing

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Mathematical Image Processing (L0991) | Lecture | 3 | 4 |
| Mathematical Image Processing (L0992) | Recitation Section (small) | 1 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Marko Lindner |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Analysis: partial derivatives, gradient, directional derivative<br>• Linear Algebra: eigenvalues, least squares solution of a linear system |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to<br>• characterize and compare diffusion equations<br>• explain elementary methods of image processing<br>• explain methods of image segmentation and registration<br>• sketch and interrelate basic concepts of functional analysis |
| *Skills* | Students are able to<br>• implement and apply elementary methods of image processing<br>• explain and apply modern methods of image processing |
| **Personal Competence** | |
| *Social Competence* | Students are able to work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge) and to explain theoretical foundations. |
| *Autonomy* | • Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them.<br>• Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 20 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Mechatronics: Technical Complementary Course: Elective Compulsory<br>Technomathematics: Specialisation I. Mathematics: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory |

| | |
|---|---|
| | Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| **Course L0991: Mathematical Image Processing** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 3 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 78, Study Time in Lecture 42 |
| **Lecturer** | Prof. Marko Lindner |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | • basic methods of image processing<br>• smoothing filters<br>• the diffusion / heat equation<br>• variational formulations in image processing<br>• edge detection<br>• image segmentation<br>• image registration |
| **Literature** | Bredies/Lorenz: Mathematische Bildverarbeitung |

| **Course L0992: Mathematical Image Processing** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Marko Lindner |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M1336: Soft Computing

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Soft Computing (L1869) | Lecture | 4 | 6 |

| | |
|---|---|
| **Module Responsible** | Prof. Karl-Heinz Zimmermann |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | |
| *Skills* | |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 25 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory<br>Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory |

## Course L1869: Soft Computing

| | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 4 |
| **CP** | 6 |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Lecturer** | Prof. Karl-Heinz Zimmermann |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | |
| **Literature** | |

# Module M0550: Digital Image Analysis

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Digital Image Analysis (L0126) | Lecture | 4 | 6 |

| | |
|---|---|
| **Module Responsible** | Prof. Rolf-Rainer Grigat |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | System theory of one-dimensional signals (convolution and correlation, sampling theory, interpolation and decimation, Fourier transform, linear time-invariant systems), linear algebra (Eigenvalue decomposition, SVD), basic stochastics and statistics (expectation values, influence of sample size, correlation and covariance, normal distribution and its parameters), basics of Matlab, basics in optics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can<br>• Describe imaging processes<br>• Depict the physics of sensorics<br>• Explain linear and non-linear filtering of signals<br>• Establish interdisciplinary connections in the subject area and arrange them in their context<br>• Interpret effects of the most important classes of imaging sensors and displays using mathematical methods and physical models. |
| *Skills* | Students are able to<br>• Use highly sophisticated methods and procedures of the subject area<br>• Identify problems and develop and implement creative solutions.<br>Students can solve simple arithmetical problems relating to the specification and design of image processing and image analysis systems.<br>Students are able to assess different solution approaches in multidimensional decision-making areas.<br>Students can undertake a prototypical analysis of processes in Matlab. |
| **Personal Competence** | |
| *Social Competence* | k.A. |
| *Autonomy* | Students can solve image analysis tasks independently using the relevant literature. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |

| | |
|---|---|
| **Examination duration and scale** | 60 Minutes, Content of Lecture and materials in StudIP |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory<br>Electrical Engineering: Specialisation Medical Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory<br>International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory |

| **Course L0126: Digital Image Analysis** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 4 |
| **CP** | 6 |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Lecturer** | Prof. Rolf-Rainer Grigat |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Image representation, definition of images and volume data sets, illumination, radiometry, multispectral imaging, reflectivities, shape from shading<br>• Perception of luminance and color, color spaces and transforms, color matching functions, human visual system, color appearance models<br>• imaging sensors (CMOS, CCD, HDR, X-ray, IR), sensor characterization(EMVA1288), lenses and optics<br>• spatio-temporal sampling (interpolation, decimation, aliasing, leakage, moiré, flicker, apertures)<br>• features (filters, edge detection, morphology, invariance, statistical features, texture)<br>• optical flow ( variational methods, quadratic optimization, Euler-Lagrange equations)<br>• segmentation (distance, region growing, cluster analysis, active contours, level sets, energy minimization and graph cuts)<br>• registration (distance and similarity, variational calculus, iterative closest points) |
| **Literature** | Bredies/Lorenz, Mathematische Bildverarbeitung, Vieweg, 2011<br>Wedel/Cremers, Stereo Scene Flow for 3D Motion Analysis, Springer 2011<br>Handels, Medizinische Bildverarbeitung, Vieweg, 2000<br>Pratt, Digital Image Processing, Wiley, 2001<br>Jain, Fundamentals of Digital Image Processing, Prentice Hall, 1989 |

# Module M0563: Robotics

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Robotics: Modelling and Control (L0168) | Lecture | 3 | 3 |
| Robotics: Modelling and Control (L1305) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Uwe Weltin |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Fundamentals of electrical engineering<br>Broad knowledge of mechanics<br>Fundamentals of control theory |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to describe fundamental properties of robots and solution approaches for multiple problems in robotics. |
| *Skills* | Students are able to derive and solve equations of motion for various manipulators.<br>Students can generate trajectories in various coordinate systems.<br>Students can design linear and partially nonlinear controllers for robotic manipulators. |
| **Personal Competence** | |
| *Social Competence* | Students are able to work goal-oriented in small mixed groups. |
| *Autonomy* | Students are able to recognize and improve knowledge deficits independently.<br>With instructor assistance, students are able to evaluate their own knowledge level and define a further course of study. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>International Production Management: Specialisation Production Technology: Elective Compulsory<br>International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory<br>International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory<br>Mechanical Engineering and Management: Core qualification: Compulsory<br>Mechatronics: Core qualification: Compulsory<br>Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Production: Elective Compulsory |

| | |
|---|---|
| | Product Development, Materials and Production: Specialisation Materials: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory |

| **Course L0168: Robotics: Modelling and Control** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 3 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 48, Study Time in Lecture 42 |
| **Lecturer** | Prof. Uwe Weltin |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | Fundamental kinematics of rigid body systems<br><br>Newton-Euler equations for manipulators<br><br>Trajectory generation<br><br>Linear and nonlinear control of robots |
| **Literature** | Craig, John J.: Introduction to Robotics Mechanics and Control, Third Edition, Prentice Hall. ISBN 0201-54361-3<br><br>Spong, Mark W.; Hutchinson, Seth; Vidyasagar, M. : Robot Modeling and Control. WILEY. ISBN 0-471-64990-2 |

| **Course L1305: Robotics: Modelling and Control** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Uwe Weltin |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0677: Digital Signal Processing and Digital Filters

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Digital Signal Processing and Digital Filters (L0446) | Lecture | 3 | 4 |
| Digital Signal Processing and Digital Filters (L0447) | Recitation Section (large) | 1 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Gerhard Bauch |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Mathematics 1-3<br>• Signals and Systems<br>• Fundamentals of signal and system theory as well as random processes.<br>• Fundamentals of spectral transforms (Fourier series, Fourier transform, Laplace transform) |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students know and understand basic algorithms of digital signal processing. They are familiar with the spectral transforms of discrete-time signals and are able to describe and analyse signals and systems in time and image domain. They know basic structures of digital filters and can identify and assess important properties including stability. They are aware of the effects caused by quantization of filter coefficients and signals. They are familiar with the basics of adaptive filters. They can perform traditional and parametric methods of spectrum estimation, also taking a limited observation window into account. |
| *Skills* | The students are able to apply methods of digital signal processing to new problems. They can choose and parameterize suitable filter striuctures. In particular, the can design adaptive filters according to the minimum mean squared error (MMSE) criterion and develop an efficient implementation, e.g. based on the LMS or RLS algorithm. Furthermore, the students are able to apply methods of spectrum estimation and to take the effects of a limited observation window into account. |
| **Personal Competence** | |
| *Social Competence* | The students can jointly solve specific problems. |
| *Autonomy* | The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory<br>Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory<br>Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory |

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|---|---|
| | Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory |

| **Course L0446: Digital Signal Processing and Digital Filters** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 3 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 78, Study Time in Lecture 42 |
| **Lecturer** | Prof. Gerhard Bauch |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Transforms of discrete-time signals:<br>  ◦ Discrete-time Fourier Transform (DTFT)<br>  ◦ Discrete Fourier-Transform (DFT), Fast Fourier Transform (FFT)<br>  ◦ Z-Transform<br>• Correspondence of continuous-time and discrete-time signals, sampling, sampling theorem<br>• Fast convolution, Overlap-Add-Method, Overlap-Save-Method<br>• Fundamental structures and basic types of digital filters<br>• Characterization of digital filters using pole-zero plots, important properties of digital filters<br>• Quantization effects<br>• Design of linear-phase filters<br>• Fundamentals of stochastic signal processing and adaptive filters<br>  ◦ MMSE criterion<br>  ◦ Wiener Filter<br>  ◦ LMS- and RLS-algorithm<br>• Traditional and parametric methods of spectrum estimation |
| **Literature** | K.-D. Kammeyer, K. Kroschel: Digitale Signalverarbeitung. Vieweg Teubner.<br>V. Oppenheim, R. W. Schafer, J. R. Buck: Zeitdiskrete Signalverarbeitung. Pearson StudiumA. V.<br>W. Hess: Digitale Filter. Teubner.<br>Oppenheim, R. W. Schafer: Digital signal processing. Prentice Hall.<br>S. Haykin: Adaptive flter theory.<br>L. B. Jackson: Digital filters and signal processing. Kluwer.<br>T.W. Parks, C.S. Burrus: Digital filter design. Wiley. |

| Course L0447: Digital Signal Processing and Digital Filters | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Gerhard Bauch |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0846: Control Systems Theory and Design

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Control Systems Theory and Design (L0656) | Lecture | 2 | 4 |
| Control Systems Theory and Design (L0657) | Recitation Section (small) | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Herbert Werner |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Introduction to Control Systems |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | • Students can explain how linear dynamic systems are represented as state space models; they can interpret the system response to initial states or external excitation as trajectories in state space<br>• They can explain the system properties controllability and observability, and their relationship to state feedback and state estimation, respectively<br>• They can explain the significance of a minimal realisation<br>• They can explain observer-based state feedback and how it can be used to achieve tracking and disturbance rejection<br>• They can extend all of the above to multi-input multi-output systems<br>• They can explain the z-transform and its relationship with the Laplace Transform<br>• They can explain state space models and transfer function models of discrete-time systems<br>• They can explain the experimental identification of ARX models of dynamic systems, and how the identification problem can be solved by solving a normal equation<br>• They can explain how a state space model can be constructed from a discrete-time impulse response |
| *Skills* | • Students can transform transfer function models into state space models and vice versa<br>• They can assess controllability and observability and construct minimal realisations<br>• They can design LQG controllers for multivariable plants<br>• They can carry out a controller design both in continuous-time and discrete-time domain, and decide which is appropriate for a given sampling rate<br>• They can identify transfer function models and state space models of dynamic systems from experimental data<br>• They can carry out all these tasks using standard software tools (Matlab Control Toolbox, System Identification Toolbox, Simulink) |
| **Personal Competence** | |
| *Social Competence* | Students can work in small groups on specific problems to arrive at joint solutions. |
| *Autonomy* | Students can obtain information from provided sources (lecture notes, software documentation, experiment guides) and use it when solving given problems.<br>They can assess their knowledge in weekly on-line tests and thereby control their learning progress. |

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| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 120 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Core qualification: Compulsory<br>Energy Systems: Core qualification: Elective Compulsory<br>Aircraft Systems Engineering: Specialisation Aircraft Systems: Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory<br>International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory<br>Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory<br>Mechatronics: Core qualification: Compulsory<br>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory<br>Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory<br>Biomedical Engineering: Specialisation Medical Technology and Control Theory: Compulsory<br>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory<br>Product Development, Materials and Production: Core qualification: Elective Compulsory<br>Theoretical Mechanical Engineering: Core qualification: Compulsory |

| Course L0656: Control Systems Theory and Design | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 92, Study Time in Lecture 28 |
| **Lecturer** | Prof. Herbert Werner |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | State space methods (single-input single-output)<br><br>• State space models and transfer functions, state feedback<br>• Coordinate basis, similarity transformations<br>• Solutions of state equations, matrix exponentials, Caley-Hamilton Theorem<br>• Controllability and pole placement<br>• State estimation, observability, Kalman decomposition<br>• Observer-based state feedback control, reference tracking<br>• Transmission zeros<br>• Optimal pole placement, symmetric root locus<br>Multi-input multi-output systems<br>• Transfer function matrices, state space models of multivariable systems, Gilbert realization<br>• Poles and zeros of multivariable systems, minimal realization<br>• Closed-loop stability<br>• Pole placement for multivariable systems, LQR design, Kalman filter<br><br>Digital Control<br>• Discrete-time systems: difference equations and z-transform<br>• Discrete-time state space models, sampled data systems, poles and zeros<br>• Frequency response of sampled data systems, choice of sampling rate<br><br>System identification and model order reduction<br>• Least squares estimation, ARX models, persistent excitation<br>• Identification of state space models, subspace identification<br>• Balanced realization and model order reduction<br><br>Case study<br>• Modelling and multivariable control of a process evaporator using Matlab and Simulink<br>Software tools<br>• Matlab/Simulink |
| **Literature** | • Werner, H., Lecture Notes „Control Systems Theory and Design“<br>• T. Kailath "Linear Systems", Prentice Hall, 1980<br>• K.J. Astrom, B. Wittenmark "Computer Controlled Systems" Prentice Hall, 1997<br>• L. Ljung "System Identification - Theory for the User", Prentice Hall, 1999 |

| Course L0657: Control Systems Theory and Design | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Herbert Werner |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0586: Efficient Algorithms

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Efficient Algorithms (L0120) | Lecture | 2 | 3 |
| Efficient Algorithms (L1207) | Recitation Section (small) | 2 | 3 |

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|---|---|
| **Module Responsible** | Prof. Siegfried Rump |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Programming in Matlab and/or C<br>Basic knowledge in discrete mathematics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are able to explain the basic theory and methods of network algorithms and in particular their data structures. They are able to analyze the computational behavior and computing time of linear programming algorithms as well network algorithms. Moreover the students can distinguish between efficiently solvable and NP-hard problems. |
| *Skills* | The students are able to analyze complex tasks and can determine possibilities to transform them into networking algorithms. In particular they can efficiently implement basic algorithms and data structures of LP- and network algorithms and identify possible weaknesses. They are able to distinguish between different efficient data structures and are able to use them appropriately. |
| **Personal Competence** | |
| *Social Competence* | The students have the skills to solve problems together in small groups and to present the achieved results in an appropriate manner. |
| *Autonomy* | The students are able to retrieve necessary informations from the given literature and to combine them with the topics of the lecture. Throughout the lecture they can check their abilities and knowledge on the basis of given exercises and test questions providing an aid to optimize their learning process. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 30 min |
| | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory |

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|---|---|
| **Assignment for the Following Curricula** | Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory |

| **Course L0120: Efficient Algorithms** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Siegfried Rump |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | - Linear Programming<br>- Data structures<br>- Leftist heaps<br>- Minimum spanning tree<br>- Shortest path<br>- Maximum flow<br>- NP-hard problems via max-cut |
| **Literature** | R. E. Tarjan: Data Structures and Network Algorithms. CBMS 44, Society for Industrial and Applied Mathematics, Philadelphia, PA, 1983.<br>Wesley, 2011 http://algs4.cs.princeton.edu/home/<br>V. Chvátal, ``Linear Programming", Freeman, New York, 1983. |

| **Course L1207: Efficient Algorithms** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Siegfried Rump |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0633: Industrial Process Automation

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Industrial Process Automation (L0344) | Lecture | 2 | 3 |
| Industrial Process Automation (L0345) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Alexander Schlaefer |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | mathematics and optimization methods<br>principles of automata<br>principles of algorithms and data structures<br>programming skills |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students can evaluate and assess disctrete event systems. They can evaluate properties of processes and explain methods for process analysis. The students can compare methods for process modelling and select an appropriate method for actual problems. They can discuss scheduling methods in the context of actual problems and give a detailed explanation of advantages and disadvantages of different programming methods. |
| *Skills* | The students are able to develop and model processes and evaluate them accordingly. This involves taking into account optimal scheduling, understanding algorithmic complexity and implementation using PLCs. |
| **Personal Competence** | |
| *Social Competence* | The students work in teams to solve problems. |
| *Autonomy* | The students can reflect their knowledge and document the results of their work. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 minutes |
| **Assignment for the** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory<br>Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory<br>Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory |

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|---|---|
| **Following Curricula** | International Production Management: Specialisation Production Technology: Elective Compulsory<br>International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory<br>Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

| **Course L0344: Industrial Process Automation** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Alexander Schlaefer |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | - foundations of problem solving and system modeling, discrete event systems<br>- properties of processes, modeling using automata and Petri-nets<br>- design considerations for processes (mutex, deadlock avoidance, liveness)<br>- optimal scheduling for processes<br>- optimal decisions when planning manufacturing systems, decisions under uncertainty<br>- software design and software architectures for automation, PLCs |
| **Literature** | J. Lunze: „Automatisierungstechnik“, Oldenbourg Verlag, 2012<br>Reisig: Petrinetze: Modellierungstechnik, Analysemethoden, Fallstudien; Vieweg+Teubner 2010<br>Hrúz, Zhou: Modeling and Control of Discrete-event Dynamic Systems; Springer 2007<br>Li, Zhou: Deadlock Resolution in Automated Manufacturing Systems, Springer 2009<br>Pinedo: Planning and Scheduling in Manufacturing and Services, Springer 2009 |

| **Course L0345: Industrial Process Automation** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Alexander Schlaefer |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0549: Scientific Computing and Accuracy

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Verification Methods (L0122) | Lecture | 2 | 3 |
| Verification Methods (L1208) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Siegfried Rump |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Basic knowledge in numerics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students have deeper knowledge of numerical and semi-numerical methods with the goal to compute principally exact and accurate error bounds. For several fundamental problems they know algorithms with the verification of the correctness of the computed result. |
| *Skills* | The students can devise algorithms for several basic problems which compute rigorous error bounds for the solution and analyze the sensitivity with respect to variation of the input data as well. |
| **Personal Competence** | |
| *Social Competence* | The students have the skills to solve problems together in small groups and to present the achieved results in an appropriate manner. |
| *Autonomy* | The students are able to retrieve necessary informations from the given literature and to combine them with the topics of the lecture. Throughout the lecture they can check their abilities and knowledge on the basis of given exercises and test questions providing an aid to optimize their learning process. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory<br>Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory<br>Technomathematics: Specialisation II. Informatics: Elective Compulsory<br>Process Engineering: Specialisation Process Engineering: Elective Compulsory |

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|---|---|
| | Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory |

| Course L0122: Verification Methods | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Siegfried Rump |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | • Fast and accurate interval arithmetic<br>• Error-free transformations<br>• Verification methods for linear and nonlinear systems<br>• Verification methods for finite integrals<br>• Treatment of multiple zeros<br>• Automatic differentiation<br>• Implementation in Matlab/INTLAB<br>• Practical applications |
| **Literature** | Neumaier: Interval Methods for Systems of Equations. In: Encyclopedia of Mathematics and its Applications. Cambridge University Press, 1990<br>S.M. Rump. Verification methods: Rigorous results using floating-point arithmetic. Acta Numerica, 19:287-449, 2010. |

| Course L1208: Verification Methods | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Siegfried Rump |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0623: Intelligent Systems in Medicine

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Intelligent Systems in Medicine (L0331) | Lecture | 2 | 3 |
| Intelligent Systems in Medicine (L0334) | Project Seminar | 2 | 2 |
| Intelligent Systems in Medicine (L0333) | Recitation Section (small) | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Prof. Alexander Schlaefer |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • principles of math (algebra, analysis/calculus)<br>• principles of stochastics<br>• principles of programming, Java/C++ and R/Matlab<br>• advanced programming skills |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are able to analyze and solve clinical treatment planning and decision support problems using methods for search, optimization, and planning. They are able to explain methods for classification and their respective advantages and disadvantages in clinical contexts. The students can compare different methods for representing medical knowledge. They can evaluate methods in the context of clinical data and explain challenges due to the clinical nature of the data and its acquisition and due to privacy and safety requirements. |
| *Skills* | The students can give reasons for selecting and adapting methods for classification, regression, and prediction. They can assess the methods based on actual patient data and evaluate the implemented methods. |
| **Personal Competence** | |
| *Social Competence* | The students discuss the results of other groups, provide helpful feedback and can incoorporate feedback into their work. |
| *Autonomy* | The students can reflect their knowledge and document the results of their work. They can present the results in an appropriate manner. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 minutes |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Medical Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory<br>Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory<br>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory<br>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective |

| | |
|---|---|
| | Compulsory<br>Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory |

| Course L0331: Intelligent Systems in Medicine | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Alexander Schlaefer |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | - methods for search, optimization, planning, classification, regression and prediction in a clinical context<br>- representation of medical knowledge<br>- understanding challenges due to clinical and patient related data and data acquisition<br>The students will work in groups to apply the methods introduced during the lecture using problem based learning. |
| **Literature** | Russel & Norvig: Artificial Intelligence: a Modern Approach, 2012<br>Berner: Clinical Decision Support Systems: Theory and Practice, 2007<br>Greenes: Clinical Decision Support: The Road Ahead, 2007<br>Further literature will be given in the lecture |

| Course L0334: Intelligent Systems in Medicine | |
|---|---|
| **Typ** | Project Seminar |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Alexander Schlaefer |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0333: Intelligent Systems in Medicine | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Alexander Schlaefer |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0926: Distributed Algorithms

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Distributed Algorithms (L1071) | Lecture | 2 | 3 |
| Distributed Algorithms (L1072) | Recitation Section (large) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Volker Turau |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Algorithms and data structures<br>• Distributed systems<br>• Discrete mathematics<br>• Graph theory |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students know the main abstractions of distributed algorithms (synchronous/asynchronous model, message passing and shared memory model). They are able to describe complexity measures for distributed algorithms (round , message and memory complexity). They explain well known distributed algorithms for important problems such as leader election, mutual exclusion, graph coloring, spanning trees. They know the fundamental techniques used for randomized algorithms. |
| *Skills* | Students design their own distributed algorithms and analyze their complexity. They make use of known standard algorithms. They compute the complexity of randomized algorithms. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 45 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory |

| Course L1071: Distributed Algorithms | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Volker Turau |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | • Leader Election<br>• Colorings & Independent Sets<br>• Tree Algorithms<br>• Minimal Spanning Trees<br>• Randomized Distributed Algorithms<br>• Mutual Exclusion |
| **Literature** | 1. David Peleg: Distributed Computing - A Locality-Sensitive Approach. SIAM Monograph, 2000<br>2. Gerard Tel: Introduction to Distributed Algorithms, Cambridge University Press, 2nd edition, 2000<br>3. Nancy Lynch: Distributed Algorithms. Morgan Kaufmann, 1996<br>4. Volker Turau: Algorithmische Graphentheorie. Oldenbourg Wissenschaftsverlag, 3. Auflage, 2004. |

| Course L1072: Distributed Algorithms | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Volker Turau |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0676: Digital Communications

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Digital Communications (L0444) | Lecture | 2 | 3 |
| Digital Communications (L0445) | Recitation Section (large) | 1 | 2 |
| Laboratory Digital Communications (L0646) | Practical Course | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Prof. Gerhard Bauch |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Mathematics 1-3<br>• Signals and Systems<br>• Fundamentals of Communications and Random Processes |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students are able to understand, compare and design modern digital information transmission schemes. They are familiar with the properties of linear and non-linear digital modulation methods. They can describe distortions caused by transmission channels and design and evaluate detectors including channel estimation and equalization. They know the principles of single carrier transmission and multi-carrier transmission as well as the fundamentals of basic multiple access schemes. |
| *Skills* | The students are able to design and analyse a digital information transmission scheme including multiple access. They are able to choose a digital modulation scheme taking into account transmission rate, required bandwidth, error probability, and further signal properties. They can design an appropriate detector including channel estimation and equalization taking into account performance and complexity properties of suboptimum solutions. They are able to set parameters of a single carrier or multi carrier transmission scheme and trade the properties of both approaches against each other. |
| **Personal Competence** | |
| *Social Competence* | The students can jointly solve specific problems. |
| *Autonomy* | The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Core qualification: Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems: Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory |

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|---|---|
| | International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory<br>International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory |

| **Course L0444: Digital Communications** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Gerhard Bauch |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | • Digital modulation methods<br>• Coherent and non-coherent detection<br>• Channel estimation and equalization<br>• Single-Carrier- and multi carrier transmission schemes, multiple access schemes (TDMA, FDMA, CDMA, OFDM) |
| **Literature** | K. Kammeyer: Nachrichtenübertragung, Teubner<br>P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner.<br>J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill.<br>S. Haykin: Communication Systems. Wiley<br>R.G. Gallager: Principles of Digital Communication. Cambridge<br>A. Goldsmith: Wireless Communication. Cambridge.<br>D. Tse, P. Viswanath: Fundamentals of Wireless Communication. Cambridge. |

| **Course L0445: Digital Communications** | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Gerhard Bauch |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0646: Laboratory Digital Communications | |
|---|---|
| **Typ** | Practical Course |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Gerhard Bauch |
| **Language** | DE/EN |
| **Cycle** | WiSe |
| **Content** | - DSL transmission<br>- Random processes<br>- Digital data transmission |
| **Literature** | K. Kammeyer: Nachrichtenübertragung, Teubner<br>P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner.<br>J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill.<br>S. Haykin: Communication Systems. Wiley<br>R.G. Gallager: Principles of Digital Communication. Cambridge<br>A. Goldsmith: Wireless Communication. Cambridge.<br>D. Tse, P. Viswanath: Fundamentals of Wireless Communication. Cambridge. |

# Module M0629: Intelligent Autonomous Agents and Cognitive Robotics

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Intelligent Autonomous Agents and Cognitive Robotics (L0341) | Lecture | 2 | 4 |
| Intelligent Autonomous Agents and Cognitive Robotics (L0512) | Recitation Section (small) | 2 | 2 |

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|---|---|
| **Module Responsible** | Rainer Marrone |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Vectors, matrices, Calculus |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can explain the agent abstraction, define intelligence in terms of rational behavior, and give details about agent design (goals, utilities, environments). They can describe the main features of environments. The notion of adversarial agent cooperation can be discussed in terms of decision problems and algorithms for solving these problems. For dealing with uncertainty in real-world scenarios, students can summarize how Bayesian networks can be employed as a knowledge representation and reasoning formalism in static and dynamic settings. In addition, students can define decision making procedures in simple and sequential settings, with and with complete access to the state of the environment. In this context, students can describe techniques for solving (partially observable) Markov decision problems, and they can recall techniques for measuring the value of information. Students can identify techniques for simultaneous localization and mapping, and can explain planning techniques for achieving desired states. Students can explain coordination problems and decision making in a multi-agent setting in term of different types of equilibria, social choice functions, voting protocol, and mechanism design techniques. |
| *Skills* | Students can select an appropriate agent architecture for concrete agent application scenarios. For simplified agent application students can derive decision trees and apply basic optimization techniques. For those applications they can also create Bayesian networks/dynamic Bayesian networks and apply bayesian reasoning for simple queries. Students can also name and apply different sampling techniques for simplified agent scenarios. For simple and complex decision making students can compute the best action or policies for concrete settings. In multi-agent situations students will apply techniques for finding different equilibria states,e.g., Nash equilibria. For multi-agent decision making students will apply different voting protocols and compare and explain the results. |
| **Personal Competence** | |
| *Social Competence* | Students are able to discuss their solutions to problems with others. They communicate in English |
| *Autonomy* | Students are able of checking their understanding of complex concepts by solving varaints of concrete problems |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 minutes |

| | |
|---|---|
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>International Production Management: Specialisation Production Technology: Elective Compulsory<br>International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory<br>Mechatronics: Technical Complementary Course: Elective Compulsory<br>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory<br>Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory<br>Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory<br>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory |

| Course L0341: Intelligent Autonomous Agents and Cognitive Robotics | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 92, Study Time in Lecture 28 |
| **Lecturer** | Rainer Marrone |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Definition of agents, rational behavior, goals, utilities, environment types<br>• Adversarial agent cooperation:<br>Agents with complete access to the state(s) of the environment, games, Minimax algorithm, alpha-beta pruning, elements of chance<br>• Uncertainty:<br>Motivation: agents with no direct access to the state(s) of the environment, probabilities, conditional probabilities, product rule, Bayes rule, full joint probability distribution, marginalization, summing out, answering queries, complexity, independence assumptions, naive Bayes, conditional independence assumptions<br>• Bayesian networks:<br>Syntax and semantics of Bayesian networks, answering queries revised (inference by enumeration), typical-case complexity, pragmatics: reasoning from effect (that can be perceived by an agent) to cause (that cannot be directly perceived).<br>• Probabilistic reasoning over time:<br>Environmental state may change even without the agent performing actions, dynamic Bayesian networks, Markov assumption, transition model, sensor model, inference problems: filtering, prediction, smoothing, most-likely explanation, special cases: hidden Markov models, Kalman filters, Exact inferences and approximations<br>• Decision making under uncertainty:<br>Simple decisions: utility theory, multivariate utility functions, dominance, decision networks, value of informatio<br>Complex decisions: sequential decision problems, value iteration, policy iteration, MDPs<br>Decision-theoretic agents: POMDPs, reduction to multidimensional continuous MDPs, dynamic decision networks<br>• Simultaneous Localization and Mapping<br>• Planning<br>• Game theory (Golden Balls: Split or Share)<br>Decisions with multiple agents, Nash equilibrium, Bayes-Nash equilibrium<br>• Social Choice<br>Voting protocols, preferences, paradoxes, Arrow's Theorem,<br>• Mechanism Design<br>Fundamentals, dominant strategy implementation, Revelation Principle, Gibbard-Satterthwaite Impossibility Theorem, Direct mechanisms, incentive compatibility, strategy-proofness, Vickrey-Groves-Clarke mechanisms, expected externality mechanisms, participation constraints, individual rationality, budget balancedness, bilateral trade, Myerson-Satterthwaite Theorem |
| **Literature** | 1. Artificial Intelligence: A Modern Approach (Third Edition), Stuart Russell, Peter Norvig, Prentice Hall, 2010, Chapters 2-5, 10-11, 13-17<br>2. Probabilistic Robotics, Thrun, S., Burgard, W., Fox, D. MIT Press 2005<br>3. Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations, Yoav Shoham, Kevin Leyton-Brown, Cambridge University Press, 2009 |

| Course L0512: Intelligent Autonomous Agents and Cognitive Robotics | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Rainer Marrone |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M1271: Technical Complementary Course II for CSMS (according to Subject Specific Regulations)

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|

| | |
|---|---|
| **Module Responsible** | Prof. Karl-Heinz Zimmermann |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | None |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Die Studierenden können die wesentlichen Inhalte des technischen Faches im Rahmen eines Vortrages oder einer Diskussion wiedergeben. |
| *Skills* | The students acquire professional competence in a technical subject available at TUHH. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Depends on choice of courses |
| **Credit points** | 6 |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computer Science: Specialisation Intelligence Engineering: Elective Compulsory |

# Module M1302: Applied Humanoid Robotics

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Humanoid Robotics (L1794) | Project-/problem-based Learning | 6 | 6 |

| | |
|---|---|
| **Module Responsible** | Prof. Herbert Werner |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Object oriented programming; algorithms and data structures<br>• Introduction to control systems<br>• Control systems theory and design<br>• Mechanics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | • Students can explain humanoid robots.<br>• Students can explain the basic concepts, relationships and methods of forward- and inverse kinematics<br>• Students learn to apply basic control concepts for different tasks in humanoid robotics. |
| *Skills* | • Students can implement models for humanoid robotic systems in Matlab and C++, and use these models for robot motion or other tasks.<br>• They are capable of using models in Matlab for simulation and testing these models if necessary with C++ code on the real robot system.<br>• They are capable of selecting methods for solving abstract problems, for which no standard methods are available, and apply it successfully. |
| **Personal Competence** | |
| *Social Competence* | • Students can develop joint solutions in mixed teams and present these.<br>• They can provide appropriate feedback to others, and constructively handle feedback on their own results |
| *Autonomy* | • Students are able to obtain required information from provided literature sources, and to put in into the context of the lecture.<br>• They can independently define tasks and apply the appropriate means to solve them. |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Credit points** | 6 |
| **Examination** | Written elaboration |
| **Examination duration and scale** | 5-10 pages |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory |

| | |
|---|---|
| | Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory |

| **Course L1794: Humanoid Robotics** | |
|---|---|
| **Typ** | Project-/problem-based Learning |
| **Hrs/wk** | 6 |
| **CP** | 6 |
| **Workload in Hours** | Independent Study Time 96, Study Time in Lecture 84 |
| **Lecturer** | Prof. Herbert Werner |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | • Fundamentals of kinematics<br>• Static and dynamic stability of humanoid robotic systems<br>• Combination of different software environments (Matlab, C++, etc.)<br>• Introduction to the necessary software frameworks<br>• Team project<br>• Presentation and Demonstration of intermediate and final results |
| **Literature** | • B. Siciliano, O. Khatib. "Handbook of Robotics. Part A: Robotics Foundations", Springer (2008) |

# Module M0551: Pattern Recognition and Data Compression

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Pattern Recognition and Data Compression (L0128) | Lecture | 4 | 6 |

| | |
|---|---|
| **Module Responsible** | Prof. Rolf-Rainer Grigat |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Linear algebra (including PCA, unitary transforms), stochastics and statistics, binary arithmetics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can name the basic concepts of pattern recognition and data compression.<br>Students are able to discuss logical connections between the concepts covered in the course and to explain them by means of examples. |
| *Skills* | Students can apply statistical methods to classification problems in pattern recognition and to prediction in data compression. On a sound theoretical and methodical basis they can analyze characteristic value assignments and classifications and describe data compression and video signal coding. They are able to use highly sophisticated methods and processes of the subject area. Students are capable of assessing different solution approaches in multidimensional decision-making areas. |
| **Personal Competence** | |
| *Social Competence* | k.A. |
| *Autonomy* | Students are capable of identifying problems independently and of solving them scientifically, using the methods they have learnt. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 60 Minutes, Content of Lecture and materials in StudIP |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory |

| | |
|---|---|
| | International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory<br>International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory |

| **Course L0128: Pattern Recognition and Data Compression** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 4 |
| **CP** | 6 |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Lecturer** | Prof. Rolf-Rainer Grigat |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | Structure of a pattern recognition system, statistical decision theory, classification based on statistical models, polynomial regression, dimension reduction, multilayer perceptron regression, radial basis functions, support vector machines, unsupervised learning and clustering, algorithm-independent machine learning, mixture models and EM, adaptive basis function models and boosting, Markov random fields<br><br>Information, entropy, redundancy, mutual information, Markov processes, basic coding schemes (code length, run length coding, prefix-free codes), entropy coding (Huffman, arithmetic coding), dictionary coding (LZ77/Deflate/LZMA2, LZ78/LZW), prediction, DPCM, CALIC, quantization (scalar and vector quantization), transform coding, prediction, decorrelation (DPCM, DCT, hybrid DCT, JPEG, JPEG-LS), motion estimation, subband coding, wavelets, HEVC (H.265,MPEG-H) |
| **Literature** | Schürmann: Pattern Classification, Wiley 1996<br>Murphy, Machine Learning, MIT Press, 2012<br>Barber, Bayesian Reasoning and Machine Learning, Cambridge, 2012<br>Duda, Hart, Stork: Pattern Classification, Wiley, 2001<br>Bishop: Pattern Recognition and Machine Learning, Springer 2006<br><br>Salomon, Data Compression, the Complete Reference, Springer, 2000<br>Sayood, Introduction to Data Compression, Morgan Kaufmann, 2006<br>Ohm, Multimedia Communication Technology, Springer, 2004<br>Solari, Digital video and audio compression, McGraw-Hill, 1997<br>Tekalp, Digital Video Processing, Prentice Hall, 1995 |

# Module M0840: Optimal and Robust Control

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Optimal and Robust Control (L0658) | Lecture | 2 | 3 |
| Optimal and Robust Control (L0659) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Herbert Werner |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Classical control (frequency response, root locus)<br>• State space methods<br>• Linear algebra, singular value decomposition |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | • Students can explain the significance of the matrix Riccati equation for the solution of LQ problems.<br>• They can explain the duality between optimal state feedback and optimal state estimation.<br>• They can explain how the H2 and H-infinity norms are used to represent stability and performance constraints.<br>• They can explain how an LQG design problem can be formulated as special case of an H2 design problem.<br>• They can explain how model uncertainty can be represented in a way that lends itself to robust controller design<br>• They can explain how - based on the small gain theorem - a robust controller can guarantee stability and performance for an uncertain plant.<br>• They understand how analysis and synthesis conditions on feedback loops can be represented as linear matrix inequalities. |
| *Skills* | • Students are capable of designing and tuning LQG controllers for multivariable plant models.<br>• They are capable of representing a H2 or H-infinity design problem in the form of a generalized plant, and of using standard software tools for solving it.<br>• They are capable of translating time and frequency domain specifications for control loops into constraints on closed-loop sensitivity functions, and of carrying out a mixed-sensitivity design.<br>• They are capable of constructing an LFT uncertainty model for an uncertain system, and of designing a mixed-objective robust controller.<br>• They are capable of formulating analysis and synthesis conditions as linear matrix inequalities (LMI), and of using standard LMI-solvers for solving them.<br>• They can carry out all of the above using standard software tools (Matlab robust control toolbox). |
| **Personal Competence** | |
| *Social Competence* | Students can work in small groups on specific problems to arrive at joint solutions. |
| *Autonomy* | Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems. |

| | |
|---|---|
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory<br>Energy Systems: Core qualification: Elective Compulsory<br>Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Mechatronics: Specialisation System Design: Elective Compulsory<br>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory<br>Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory<br>Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory<br>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Production: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Materials: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Core qualification: Elective Compulsory |

| Course L0658: Optimal and Robust Control | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Herbert Werner |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Optimal regulator problem with finite time horizon, Riccati differential equation<br>• Time-varying and steady state solutions, algebraic Riccati equation, Hamiltonian system<br>• Kalman's identity, phase margin of LQR controllers, spectral factorization<br>• Optimal state estimation, Kalman filter, LQG control<br>• Generalized plant, review of LQG control<br>• Signal and system norms, computing H2 and H∞ norms<br>• Singular value plots, input and output directions<br>• Mixed sensitivity design, H∞ loop shaping, choice of weighting filters<br><br>• Case study: design example flight control<br>• Linear matrix inequalities, design specifications as LMI constraints (H2, H∞ and pole region)<br>• Controller synthesis by solving LMI problems, multi-objective design<br>• Robust control of uncertain systems, small gain theorem, representation of parameter uncertainty |
| **Literature** | • Werner, H., Lecture Notes: "Optimale und Robuste Regelung"<br>• Boyd, S., L. El Ghaoui, E. Feron and V. Balakrishnan "Linear Matrix Inequalities in Systems and Control", SIAM, Philadelphia, PA, 1994<br>• Skogestad, S. and I. Postlewhaite "Multivariable Feedback Control", John Wiley, Chichester, England, 1996<br>• Strang, G. "Linear Algebra and its Applications", Harcourt Brace Jovanovic, Orlando, FA, 1988<br>• Zhou, K. and J. Doyle "Essentials of Robust Control", Prentice Hall International, Upper Saddle River, NJ, 1998 |

| Course L0659: Optimal and Robust Control | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Herbert Werner |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0630: Robotics and Navigation in Medicine

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Robotics and Navigation in Medicine (L0335) | Lecture | 2 | 3 |
| Robotics and Navigation in Medicine (L0338) | Project Seminar | 2 | 2 |
| Robotics and Navigation in Medicine (L0336) | Recitation Section (small) | 1 | 1 |

| | |
|---|---|
| **Module Responsible** | Prof. Alexander Schlaefer |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • principles of math (algebra, analysis/calculus)<br>• principles of programming, e.g., in Java or C++<br>• solid R or Matlab skills |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students can explain kinematics and tracking systems in clinical contexts and illustrate systems and their components in details. Systems can be evaluated with respect to collision detection and safety and regulations. Students can assess typical systems regarding design and limitations. |
| *Skills* | The students are able to design and evaluate navigation systems and robotic systems for medical applications. |
| **Personal Competence** | |
| *Social Competence* | The students discuss the results of other groups, provide helpful feedback and can incoorporate feedback into their work. |
| *Autonomy* | The students can reflect their knowledge and document the results of their work. They can present the results in an appropriate manner. |
| **Workload in Hours** | Independent Study Time 110, Study Time in Lecture 70 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 minutes |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Medical Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory<br>Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory<br>Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory<br>Biomedical Engineering: Specialisation Management and Business Administration: Elective |

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|---|---|
| | Compulsory<br>Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Production: Elective Compulsory<br>Product Development, Materials and Production: Specialisation Materials: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory |

| **Course L0335: Robotics and Navigation in Medicine** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Alexander Schlaefer |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | - kinematics<br>- calibration<br>- tracking systems<br>- navigation and image guidance<br>- motion compensation<br>The seminar extends and complements the contents of the lecture with respect to recent research results. |
| **Literature** | Spong et al.: Robot Modeling and Control, 2005<br>Troccaz: Medical Robotics, 2012<br>Further literature will be given in the lecture. |

| **Course L0338: Robotics and Navigation in Medicine** | |
|---|---|
| **Typ** | Project Seminar |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Prof. Alexander Schlaefer |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

| Course L0336: Robotics and Navigation in Medicine | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 1 |
| **CP** | 1 |
| **Workload in Hours** | Independent Study Time 16, Study Time in Lecture 14 |
| **Lecturer** | Prof. Alexander Schlaefer |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0673: Information Theory and Coding

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Information Theory and Coding (L0436) | Lecture | 3 | 4 |
| Information Theory and Coding (L0438) | Recitation Section (large) | 1 | 2 |

| | |
|---|---|
| **Module Responsible** | Prof. Gerhard Bauch |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Mathematics 1-3<br>• Probability theory and random processes<br>• Basic knowledge of communications engineering (e.g. from lecture "Fundamentals of Communications and Random Processes") |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The students know the basic definitions for quantification of information in the sense of information theory. They know Shannon's source coding theorem and channel coding theorem and are able to determine theoretical limits of data compression and error-free data transmission over noisy channels. They understand the principles of source coding as well as error-detecting and error-correcting channel coding. They are familiar with the principles of decoding, in particular with modern methods of iterative decoding. They know fundamental coding schemes, their properties and decoding algorithms. |
| *Skills* | The students are able to determine the limits of data compression as well as of data transmission through noisy channels and based on those limits to design basic parameters of a transmission scheme. They can estimate the parameters of an error-detecting or error-correcting channel coding scheme for achieving certain performance targets. They are able to compare the properties of basic channel coding and decoding schemes regarding error correction capabilities, decoding delay, decoding complexity and to decide for a suitable method. They are capable of implementing basic coding and decoding schemes in software. |
| **Personal Competence** | |
| *Social Competence* | The students can jointly solve specific problems. |
| *Autonomy* | The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Information and Communication Systems: Core qualification: Compulsory<br>International Management and Engineering: Specialisation II. Electrical Engineering: Elective |

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|---|---|
| | Compulsory<br>Mechatronics: Technical Complementary Course: Elective Compulsory |

| **Course L0436: Information Theory and Coding** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 3 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 78, Study Time in Lecture 42 |
| **Lecturer** | Prof. Gerhard Bauch |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | • Fundamentals of information theory<br>  ◦ Self information, entropy, mutual information<br>  ◦ Source coding theorem, channel coding theorem<br>  ◦ Channel capacity of various channels<br>• Fundamental source coding algorithms:<br>  ◦ Huffman Code, Lempel Ziv Algorithm<br>• Fundamentals of channel coding<br>  ◦ Basic parameters of channel coding and respective bounds<br>  ◦ Decoding principles: Maximum-A-Posteriori Decoding, Maximum-Likelihood Decoding, Hard-Decision-Decoding and Soft-Decision-Decoding<br>  ◦ Error probability<br>• Block codes<br>• Low Density Parity Check (LDPC) Codes and iterative Ddecoding<br>• Convolutional codes and Viterbi-Decoding<br>• Turbo Codes and iterative decoding<br>• Coded Modulation |
| **Literature** | Bossert, M.: Kanalcodierung. Oldenbourg.<br>Friedrichs, B.: Kanalcodierung. Springer.<br>Lin, S., Costello, D.: Error Control Coding. Prentice Hall.<br>Roth, R.: Introduction to Coding Theory.<br>Johnson, S.: Iterative Error Correction. Cambridge.<br>Richardson, T., Urbanke, R.: Modern Coding Theory. Cambridge University Press.<br>Gallager, R. G.: Information theory and reliable communication. Whiley-VCH<br>Cover, T., Thomas, J.: Elements of information theory. Wiley. |

| Course L0438: Information Theory and Coding | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Gerhard Bauch |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M1310: Methods and Applications of Differential Geometry

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Methods and Applications of Differential Geometry (L1808) | Lecture | 4 | 6 |

| | |
|---|---|
| **Module Responsible** | Prof. Karl-Heinz Zimmermann |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Linear Algebra, Multivariate Calculus |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | The lectures start by reviewing basics from linear algebra and analysis under the aspect of abstraction from coordinates and proceed to methods of differential geometry with applications to computer graphics, robotics, and physical field equations. As part of a computer science curriculum, they discuss relations between the mathematical and the computer data types, and possible computer implementations of mathematical constructions. Keywords:<br><br>Data types, algorithms, numbers and number codes, discretisation of coninuous structures, systems of coordinates; vector spaces, tensors, quaternions, exterior algebra, Clifford algebras, Lie algebras; coordinate-free vector analysis, vector fields, Lie deivative, diffferential equations, variational calculus, differential forms and operators; surfaces in space, curvature, covariant derivative, geodesics; manifolds, fibre bundles, transformation groups, Riemannian metrics, symplectic structures; groups of symmetries, invariants, special functions |
| *Skills* | |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 25 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory |

| Course L1808: Methods and Applications of Differential Geometry | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 4 |
| **CP** | 6 |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Lecturer** | Prof. Georg Friedrich Mayer-Lindenberg |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | The lectures start by reviewing basics from linear algebra and analysis under the aspect of abstraction from coordinates and proceed to methods of differential geometry with applications to computer graphics, robotics, and physical field equations. As part of a computer science curriculum, they discuss relations between the mathematical and the computer data types, and possible computer implementations of mathematical constructions. Keywords:<br><br>Data types, algorithms, numbers and number codes, discretisation of coninuous structures, systems of coordinates; vector spaces, tensors, quaternions, exterior algebra, Clifford algebras, Lie algebras; coordinate-free vector analysis, vector fields, Lie deivative, diffferential equations, variational calculus, differential forms and operators; surfaces in space, curvature, covariant derivative, geodesics; manifolds, fibre bundles, transformation groups, Riemannian metrics, symplectic structures; groups of symmetries, invariants, special functions |
| **Literature** | Agricola, Friedrich, Vektoranalysis, Vieweg/Teubner 2010<br><br>A.C. Da Silva, Lectures on Symplectic Geometry, Springer L.N. Math. 1764<br><br>J. Snygg, Differential Geometry using Clifford's Algebra, Birkhäuser 2010<br><br>T. Frankel The Geometry of Physics Cambridge U. P. 2012<br><br>M.Desbrun et al. Discrete exterior calculus, arXiv:math/0508341v2<br><br>J.Marsden et al. Discrete Mechanics and Variational Integrators, Acta numerica. 2001 |

# Module M0711: Numerical Mathematics II

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Numerical Mathematics II (L0568) | Lecture | 2 | 3 |
| Numerical Mathematics II (L0569) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Sabine Le Borne |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Numerical Mathematics I<br>• MATLAB knowledge |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students are able to<br>• name advanced numerical methods for interpolation, integration, linear least squares problems, eigenvalue problems, nonlinear root finding problems and explain their core ideas,<br>• repeat convergence statements for the numerical methods,<br>• sketch convergence proofs,<br>• explain practical aspects of numerical methods concerning runtime and storage needs<br>explain aspects regarding the practical implementation of numerical methods with respect to computational and storage complexity.<br>• |
| *Skills* | Students are able to<br>• implement, apply and compare advanced numerical methods in MATLAB,<br>• justify the convergence behaviour of numerical methods with respect to the problem and solution algorithm and to transfer it to related problems,<br>• for a given problem, develop a suitable solution approach, if necessary through composition of several algorithms, to execute this approach and to critically evaluate the results |
| **Personal Competence** | |
| *Social Competence* | Students are able to<br>• work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms. |
| *Autonomy* | Students are capable<br>• to assess whether the supporting theoretical and practical excercises are better solved individually or in a team,<br>• to assess their individual progess and, if necessary, to ask questions and seek help. |

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|---|---|
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 25 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory<br>Technomathematics: Specialisation I. Mathematics: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory |

| **Course L0568: Numerical Mathematics II** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sabine Le Borne, Dr. Patricio Farrell |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | 1. Error and stability: Notions and estimates<br>2. Interpolation: Rational and trigonometric interpolation<br>3. Quadrature: Gaussian quadrature, orthogonal polynomials<br>4. Linear systems: Perturbation theory of decompositions, structured matrices<br>5. Eigenvalue problems: LR-, QD-, QR-Algorithmus<br>6. Krylov space methods: Arnoldi-, Lanczos methods |
| **Literature** | • Stoer/Bulirsch: Numerische Mathematik 1, Springer<br>• Dahmen, Reusken: Numerik für Ingenieure und Naturwissenschaftler, Springer |

| **Course L0569: Numerical Mathematics II** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Sabine Le Borne, Dr. Patricio Farrell |
| **Language** | DE/EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0627: Machine Learning and Data Mining

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Machine Learning and Data Mining (L0340) | Lecture | 2 | 4 |
| Machine Learning and Data Mining (L0510) | Recitation Section (small) | 2 | 2 |

| | |
|---|---|
| **Module Responsible** | NN |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Calculus<br>• Stochastics |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can explain the difference between instance-based and model-based learning approaches, and they can enumerate basic machine learning technique for each of the two basic approaches, either on the basis of static data, or on the basis of incrementally incoming data . For dealing with uncertainty, students can describe suitable representation formalisms, and they explain how axioms, features, parameters, or structures used in these formalisms can be learned automatically with different algorithms. Students are also able to sketch different clustering techniques. They depict how the performance of learned classifiers can be improved by ensemble learning, and they can summarize how this influences computational learning theory. Algorithms for reinforcement learning can also be explained by students. |
| *Skills* | Student derive decision trees and, in turn, propositional rule sets from simple and static data tables and are able to name and explain basic optimization techniques. They present and apply the basic idea of first-order inductive leaning. Students apply the BME, MAP, ML, and EM algorithms for learning parameters of Bayesian networks and compare the different algorithms. They also know how to carry out Gaussian mixture learning. They can contrast kNN classifiers, neural networks, and support vector machines, and name their basic application areas and algorithmic properties. Students can describe basic clustering techniques and explain the basic components of those techniques. Students compare related machine learning techniques, e.g., k-means clustering and nearest neighbor classification. They can distinguish various ensemble learning techniques and compare the different goals of those techniques. |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 minutes |
| | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory |

| | |
|---|---|
| **Assignment for the Following Curricula** | International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory |

| **Course L0340: Machine Learning and Data Mining** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 92, Study Time in Lecture 28 |
| **Lecturer** | Rainer Marrone |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | • Decision trees<br>• First-order inductive learning<br>• Incremental learning: Version spaces<br>• Uncertainty<br>• Bayesian networks<br>• Learning parameters of Bayesian networks<br>BME, MAP, ML, EM algorithm<br>• Learning structures of Bayesian networks<br>• Gaussian Mixture Models<br>• kNN classifier, neural network classifier, support vector machine (SVM) classifier<br>• Clustering<br>Distance measures, k-means clustering, nearest neighbor clustering<br>• Kernel Density Estimation<br>• Ensemble Learning<br>• Reinforcement Learning<br>• Computational Learning Theory |
| **Literature** | 1. Artificial Intelligence: A Modern Approach (Third Edition), Stuart Russel, Peter Norvig, Prentice Hall, 2010, Chapters 13, 14, 18-21<br>2. Machine Learning: A Probabilistic Perspective, Kevin Murphy, MIT Press 2012 |

| **Course L0510: Machine Learning and Data Mining** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 32, Study Time in Lecture 28 |
| **Lecturer** | Rainer Marrone |
| **Language** | EN |
| **Cycle** | SoSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0832: Advanced Topics in Control

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Advanced Topics in Control (L0661) | Lecture | 2 | 3 |
| Advanced Topics in Control (L0662) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Herbert Werner |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | H-infinity optimal control, mixed-sensitivity design, linear matrix inequalities |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |

**Professional Competence**

*Knowledge*

- Students can explain the advantages and shortcomings of the classical gain scheduling approach
- They can explain the representation of nonlinear systems in the form of quasi-LPV systems
- They can explain how stability and performance conditions for LPV systems can be formulated as LMI conditions
- They can explain how gridding techniques can be used to solve analysis and synthesis problems for LPV systems
- They are familiar with polytopic and LFT representations of LPV systems and some of the basic synthesis techniques associated with each of these model structures

- Students can explain how graph theoretic concepts are used to represent the communication topology of multiagent systems
- They can explain the convergence properties of first order consensus protocols
- They can explain analysis and synthesis conditions for formation control loops involving either LTI or LPV agent models

- Students can explain the state space representation of spatially invariant distributed systems that are discretized according to an actuator/sensor array
- They can explain (in outline) the extension of the bounded real lemma to such distributed systems and the associated synthesis conditions for distributed controllers

*Skills*

- Students are capable of constructing LPV models of nonlinear plants and carry out a mixed-sensitivity design of gain-scheduled controllers; they can do this using polytopic, LFT or general LPV models
- They are able to use standard software tools (Matlab robust control toolbox) for these tasks

- Students are able to design distributed formation controllers for groups of agents with either LTI or LPV dynamics, using Matlab tools provided

- Students are able to design distributed controllers for spatially interconnected systems, using the Matlab MD-toolbox

| | |
|---|---|
| **Personal Competence** | |
| *Social Competence* | Students can work in small groups and arrive at joint results. |
| *Autonomy* | Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Oral exam |
| **Examination duration and scale** | 30 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory<br>Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory<br>Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory<br>Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory<br>Mechatronics: Specialisation System Design: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory<br>Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory<br>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory<br>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory<br>Theoretical Mechanical Engineering: Core qualification: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory |

| Course L0661: Advanced Topics in Control | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Herbert Werner |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Linear Parameter-Varying (LPV) Gain Scheduling<br><br>- Linearizing gain scheduling, hidden coupling<br>- Jacobian linearization vs. quasi-LPV models<br>- Stability and induced L2 norm of LPV systems<br>- Synthesis of LPV controllers based on the two-sided projection lemma<br>- Simplifications: controller synthesis for polytopic and LFT models<br>- Experimental identification of LPV models<br>- Controller synthesis based on input/output models<br>- Applications: LPV torque vectoring for electric vehicles, LPV control of a robotic manipulator<br><br>• Control of Multi-Agent Systems<br><br>- Communication graphs<br>- Spectral properties of the graph Laplacian<br>- First and second order consensus protocols<br>- Formation control, stability and performance<br>- LPV models for agents subject to nonholonomic constraints<br>- Application: formation control for a team of quadrotor helicopters<br><br>• Control of Spatially Interconnected Systems<br><br>- Multidimensional signals, l2 and L2 signal norm<br>- Multidimensional systems in Roesser state space form<br>- Extension of real-bounded lemma to spatially interconnected systems<br>- LMI-based synthesis of distributed controllers<br>- Spatial LPV control of spatially varying systems<br>- Applications: control of temperature profiles, vibration damping for an actuated beam |
| **Literature** | • Werner, H., Lecture Notes "Advanced Topics in Control"<br>• Selection of relevant research papers made available as pdf documents via StudIP |

| Course L0662: Advanced Topics in Control | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Herbert Werner |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M1249: Numerical Methods for Medical Imaging

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Numerical Methods for Medical Imaging (L1694) | Lecture | 2 | 3 |
| Numerical Methods for Medical Imaging (L1695) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Tobias Knopp |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | |
| *Skills* | |
| **Personal Competence** | |
| *Social Competence* | |
| *Autonomy* | |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 90 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory<br>Electrical Engineering: Specialisation Medical Technology: Elective Compulsory<br>Electrical Engineering: Specialisation Medical Technology: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory |

| Course L1694: Numerical Methods for Medical Imaging | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Tobias Knopp |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | |
| **Literature** | **Bildgebende Verfahren in der Medizin**; O. Dössel; Springer, Berlin, 2000<br><br>**Bildgebende Systeme für die medizinische Diagnostik**; H. Morneburg (Hrsg.); Publicis MCD, München, 1995<br><br>**Introduction to the Mathematics of Medical Imaging**; C. L.Epstein; Siam, Philadelphia, 2008<br><br>**Medical Image Processing, Reconstruction and Restoration**; J. Jan; Taylor and Francis, Boca Raton, 2006<br><br>**Principles of Magnetic Resonance Imaging**; Z.-P. Liang and P. C. Lauterbur; IEEE Press, New York, 1999 |

| Course L1695: Numerical Methods for Medical Imaging | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Tobias Knopp |
| **Language** | DE |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0552: 3D Computer Vision

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| 3D Computer Vision (L0129) | Lecture | 2 | 3 |
| 3D Computer Vision (L0130) | Recitation Section (small) | 2 | 3 |

| | |
|---|---|
| **Module Responsible** | Prof. Rolf-Rainer Grigat |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | • Knowlege of the modules Digital Image Analysis and Pattern Recognition and Data Compression are used in the practical task<br>• Linear Algebra (including PCA, SVD), nonlinear optimization (Levenberg-Marquardt), basics of stochastics and basics of Matlab are required and cannot be explained in detail during the lecture. |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Students can explain and describe the field of projective geometry. |
| *Skills* | Students are capable of<br>• Implementing an exemplary 3D or volumetric analysis task<br>• Using highly sophisticated methods and procedures of the subject area<br>• Identifying problems and<br>• Developing and implementing creative solution suggestions.<br><br>With assistance from the teacher students are able to link the contents of the three subject areas (modules)<br>• Digital Image Analysis<br>• Pattern Recognition and Data Compression<br>and<br>• 3D Computer Vision<br><br>in practical assignments. |
| **Personal Competence** | |
| *Social Competence* | Students can collaborate in a small team on the practical realization and testing of a system to reconstruct a three-dimensional scene or to evaluate volume data sets. |
| *Autonomy* | Students are able to solve simple tasks independently with reference to the contents of the lectures and the exercise sets.<br><br>Students are able to solve detailed problems independently with the aid of the tutorial's programming task. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 60 Minutes, Content of Lecture and materials in StudIP |
| | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory |

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| **Assignment for the Following Curricula** | Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory<br>Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory<br>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory<br>Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory<br>Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory<br>Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory |

| **Course L0129: 3D Computer Vision** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Rolf-Rainer Grigat |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Projective Geometry and Transformations in 2D und 3D in homogeneous coordinates<br>• Projection matrix, calibration<br>• Epipolar Geometry, fundamental and essential matrices, weak calibration, 5 point algorithm<br>• Homographies 2D and 3D<br>• Trifocal Tensor<br>• Correspondence search |
| **Literature** | • **Skriptum Grigat/Wenzel**<br>• Hartley, Zisserman: Multiple View Geometry in Computer Vision. Cambridge 2003. |

| **Course L0130: 3D Computer Vision** | |
|---|---|
| **Typ** | Recitation Section (small) |
| **Hrs/wk** | 2 |
| **CP** | 3 |
| **Workload in Hours** | Independent Study Time 62, Study Time in Lecture 28 |
| **Lecturer** | Prof. Rolf-Rainer Grigat |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Module M0738: Digital Audio Signal Processing

## Courses

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|
| Digital Audio Signal Processing (L0650) | Lecture | 3 | 4 |
| Digital Audio Signal Processing (L0651) | Recitation Section (large) | 1 | 2 |

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|---|---|
| **Module Responsible** | Prof. Udo Zölzer |
| **Admission Requirements** | None |
| **Recommended Previous Knowledge** | Signals and Systems |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | Die Studierenden können die grundlegenden Verfahren und Methoden der digitalen Audiosignalverarbeitung erklären. Sie können die wesentlichen physikalischen Effekte bei der Sprach- und Audiosignalverarbeitung erläutern und in Kategorien einordnen. Sie können einen Überblick der numerischen Methoden und messtechnischen Charakterisierung von Algorithmen zur Audiosignalverarbeitung geben. Sie können die erarbeiteten Algorithmen auf weitere Anwendungen im Bereich der Informationstechnik und Informatik abstrahieren. |
| *Skills* | The students will be able to apply methods and techniques from audio signal processing in the fields of mobile and internet communication. They can rely on elementary algorithms of audio signal processing in form of Matlab code and interactive JAVA applets. They can study parameter modifications and evaluate the influence on human perception and technical applications in a variety of applications beyond audio signal processing. Students can perform measurements in time and frequency domain in order to give objective and subjective quality measures with respect to the methods and applications. |
| **Personal Competence** | |
| *Social Competence* | The students can work in small groups to study special tasks and problems and will be enforced to present their results with adequate methods during the exercise. |
| *Autonomy* | The students will be able to retrieve information out of the relevant literature in the field and putt hem into the context of the lecture. They can relate their gathered knowledge and relate them to other lectures (signals and systems, digital communication systems, image and video processing, and pattern recognition). They will be prepared to understand and communicate problems and effects in the field audio signal processing. |
| **Workload in Hours** | Independent Study Time 124, Study Time in Lecture 56 |
| **Credit points** | 6 |
| **Examination** | Written exam |
| **Examination duration and scale** | 45 min |
| **Assignment for the Following Curricula** | Computer Science: Specialisation Intelligence Engineering: Elective Compulsory<br>Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory<br>Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory<br>Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory<br>Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory |

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| | Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory |

| **Course L0650: Digital Audio Signal Processing** | |
|---|---|
| **Typ** | Lecture |
| **Hrs/wk** | 3 |
| **CP** | 4 |
| **Workload in Hours** | Independent Study Time 78, Study Time in Lecture 42 |
| **Lecturer** | Prof. Udo Zölzer |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | • Introduction (Studio Technology, Digital Transmission Systems, Storage Media, Audio Components at Home)<br>• Quantization (Signal Quantization, Dither, Noise Shaping, Number Representation)<br>• AD/DA Conversion (Methods, AD Converters, DA Converters, Audio Processing Systems, Digital Signal Processors, Digital Audio Interfaces, Single-Processor Systems, Multiprocessor Systems)<br>• Equalizers (Recursive Audio Filters, Nonrecursive Audio Filters, Multi-Complementary Filter Bank)<br>• Room Simulation (Early Reflections, Subsequent Reverberation, Approximation of Room Impulse Responses)<br>• Dynamic Range Control (Static Curve, Dynamic Behavior, Implementation, Realization Aspects)<br>• Sampling Rate Conversion (Synchronous Conversion, Asynchronous Conversion, Interpolation Methods)<br>• Data Compression (Lossless Data Compression, Lossy Data Compression, Psychoacoustics, ISO-MPEG1 Audio Coding) |
| **Literature** | - U. Zölzer, Digitale Audiosignalverarbeitung, 3. Aufl., B.G. Teubner, 2005.<br>- U. Zölzer, Digitale Audio Signal Processing, 2nd Edition, J. Wiley & Sons, 2005.<br>- U. Zölzer (Ed), Digital Audio Effects, 2nd Edition, J. Wiley & Sons, 2011. |

| Course L0651: Digital Audio Signal Processing | |
|---|---|
| **Typ** | Recitation Section (large) |
| **Hrs/wk** | 1 |
| **CP** | 2 |
| **Workload in Hours** | Independent Study Time 46, Study Time in Lecture 14 |
| **Lecturer** | Prof. Udo Zölzer |
| **Language** | EN |
| **Cycle** | WiSe |
| **Content** | See interlocking course |
| **Literature** | See interlocking course |

# Thesis

## Module M-002: Master Thesis

**Courses**

| Title | Typ | Hrs/wk | CP |
|---|---|---|---|

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|---|---|
| **Module Responsible** | Professoren der TUHH |
| **Admission Requirements** | • According to General Regulations §21 (1):<br><br>At least 60 credit points have to be achieved in study programme. The examinations board decides on exceptions. |
| **Recommended Previous Knowledge** | |
| **Educational Objectives** | After taking part successfully, students have reached the following learning results |
| **Professional Competence** | |
| *Knowledge* | • The students can use specialized knowledge (facts, theories, and methods) of their subject competently on specialized issues.<br>• The students can explain in depth the relevant approaches and terminologies in one or more areas of their subject, describing current developments and taking up a critical position on them.<br>• The students can place a research task in their subject area in its context and describe and critically assess the state of research. |
| *Skills* | The students are able:<br><br>• To select, apply and, if necessary, develop further methods that are suitable for solving the specialized problem in question.<br>• To apply knowledge they have acquired and methods they have learnt in the course of their studies to complex and/or incompletely defined problems in a solution-oriented way.<br>• To develop new scientific findings in their subject area and subject them to a critical assessment. |
| **Personal Competence** | |
| *Social Competence* | Students can<br><br>• Both in writing and orally outline a scientific issue for an expert audience accurately, understandably and in a structured way.<br>• Deal with issues competently in an expert discussion and answer them in a manner that is appropriate to the addressees while upholding their own assessments and viewpoints convincingly. |
| *Autonomy* | Students are able:<br><br>• To structure a project of their own in work packages and to work them off accordingly.<br>• To work their way in depth into a largely unknown subject and to access the information required for them to do so. |

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|---|---|
| | • To apply the techniques of scientific work comprehensively in research of their own. |
| **Workload in Hours** | Independent Study Time 900, Study Time in Lecture 0 |
| **Credit points** | 30 |
| **Examination** | Thesis |
| **Examination duration and scale** | According to General Regulations |
| **Assignment for the Following Curricula** | Civil Engineering: Thesis: Compulsory<br>Bioprocess Engineering: Thesis: Compulsory<br>Chemical and Bioprocess Engineering: Thesis: Compulsory<br>Computer Science: Thesis: Compulsory<br>Electrical Engineering: Thesis: Compulsory<br>Energy and Environmental Engineering: Thesis: Compulsory<br>Energy Systems: Thesis: Compulsory<br>Environmental Engineering: Thesis: Compulsory<br>Aircraft Systems Engineering: Thesis: Compulsory<br>Global Innovation Management: Thesis: Compulsory<br>Computational Science and Engineering: Thesis: Compulsory<br>Computational Science and Engineering: Thesis: Compulsory<br>Information and Communication Systems: Thesis: Compulsory<br>International Production Management: Thesis: Compulsory<br>International Management and Engineering: Thesis: Compulsory<br>Joint European Master in Environmental Studies - Cities and Sustainability: Thesis: Compulsory<br>Logistics, Infrastructure and Mobility: Thesis: Compulsory<br>Materials Science: Thesis: Compulsory<br>Mathematical Modelling in Engineering: Theory, Numerics, Applications: Thesis: Compulsory<br>Mechanical Engineering and Management: Thesis: Compulsory<br>Mechatronics: Thesis: Compulsory<br>Biomedical Engineering: Thesis: Compulsory<br>Microelectronics and Microsystems: Thesis: Compulsory<br>Product Development, Materials and Production: Thesis: Compulsory<br>Renewable Energies: Thesis: Compulsory<br>Naval Architecture and Ocean Engineering: Thesis: Compulsory<br>Ship and Offshore Technology: Thesis: Compulsory<br>Theoretical Mechanical Engineering: Thesis: Compulsory<br>Process Engineering: Thesis: Compulsory<br>Water and Environmental Engineering: Thesis: Compulsory |