TUHH

Technische Universität Hamburg-Harburg

Module Manual

Master of Science

Computer Science

Cohort: Winter Term 2015

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Table of Contents

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. • Students are able to explain basic theories, categories, and models in selected special areas of business management. • Students are able to interrelate technical and management knowledge.
Skills	• Students are able to apply basic methods in selected areas of business management. • Students are able to explain and give reasons for decision proposals on practical issues in areas of business management.
Personal Competence	
Social Competence	
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

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 Non-technical Elective Study Area** 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. **The Learning Architecture** consists of a cross-disciplinarily study offering. The centrally designed teaching offering ensures that courses in the "non-technical department" follow the specific profiling of TUHH degree courses. 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". 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. **Teaching and Learning Arrangements** 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. **Fields of Teaching** are based on research findings from the academic disciplines cultural studies, social studies, arts, historical studies, communication 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. 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. **The Competence Level** 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. 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. **Specialized Competence (Knowledge)** Students can • explain specialized areas in context of the relevant non-technical disciplines, • outline basic theories, categories, terminology, models, concepts or artistic techniques in the disciplines represented in the learning area, • different specialist disciplines relate to their own discipline and differentiate it as well as make connections, • 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, • Can communicate in a foreign language in a manner appropriate to the subject.
Skills	**Professional Competence (Skills)** In selected sub-areas students can • apply basic and specific methods of the said scientific disciplines, • aquestion a specific technical phenomena, models, theories from the viewpoint of another, aforementioned specialist discipline, • to handle simple and advanced questions in aforementioned scientific disciplines in a sucsessful manner, • 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)** Students will be able • to learn to collaborate in different manner, • to present and analyze problems in the abovementioned fields in a partner or group situation in a manner appropriate to the addressees,

	• 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), • to explain nontechnical items to auditorium with technical background knowledge.
Autonomy	**Personal Competences (Self-reliance)** Students are able in selected areas • to reflect on their own profession and professionalism in the context of real-life fields of application • to organize themselves and their own learning processes • to reflect and decide questions in front of a broad education background • to communicate a nontechnical item in a competent way in writen form or verbaly • 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 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	
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.
Skills	Students are able to access independently further logical connections between the concepts with which they have become familiar and are able to verify them. 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	
Assignment for the Following Curricula	Computer Science: Core qualification: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: 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 Division with remainder (over rings) fast arithmetic algorithms (conversion, fast multiplications) discrete Fourier-transformation over rings Computation with modular remainders, solving of remainder systems (chinese remainder theorem), solvability of integer linear systems over the integers linearization of polynomial equations-- matrix approach Sylvester-matrix, elimination elimination in rings, elimination of many variables Buchberger algorithm, Gröbner basis Minkowskis Lattice Point theorem and integer-valued optimization LLL-algorithm for construction of 'short' lattice vectors in polynomial time
Literature	von zur Gathen, Joachim; Gerhard, Jürgen Modern computer algebra. 3rd ed. (English) Zbl 1277.68002 Cambridge: Cambridge University Press (ISBN 978-1-107-03903-2/hbk; 978-1-139-85606-5/ebook). Yap, Chee Keng Fundamental problems of algorithmic algebra. (English) Zbl 0999.68261 Oxford: Oxford University Press. xvi, 511 p. $ 87.00 (2000). Free download for students from author's website: http://cs.nyu.edu/yap/book/berlin/ Cox, David; Little, John; O'Shea, Donal

	Ideals, varieties, and algorithms. An introduction to computational algebraic geometry and commutative algebra. 3rd ed. (English) Zbl 1118.13001 Undergraduate Texts in Mathematics. New York, NY: Springer (ISBN 978-0-387-35650-1/hbk; 978-0-387-35651-8/ebook). xv, 551 p. eBook: http://dx.doi.org/10.1007/978-0-387-35651-8 **Verfasser:** Concrete abstract algebra : from numbers to Gröbner bases / Niels **Lauritzen** **Lauritzen, Niels** **Ausgabe:** Reprinted with corr. **Erschienen:** Cambridge [u.a.] : Cambridge Univ. Press, 2006 **Umfang:** XIV, 240 S. : graph. Darst. **Anmerkung:** Includes bibliographical references and index **ISBN:** 0-521-82679-9, 978-0-521-82679-2 (hbk.) : GBP 55.00 0-521-53410-0, 978-0-521-53410-9 (pbk.) : USD 39.99 Koepf, Wolfram Computer algebra. An algorithmic oriented introduction. (Computeralgebra. Eine algorithmisch orientierte Einführung.) (German) Zbl 1161.68881 Berlin: Springer (ISBN 3-540-29894-0/pbk). xiii, 515 p. springer eBook: http://dx.doi.org/10.1007/3-540-29895-9 Kaplan, Michael Computer algebra. (Computeralgebra.) (German) Zbl 1093.68148 Berlin: Springer (ISBN 3-540-21379-1/pbk). xii, 391 p. springer eBook: 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 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 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	Oral exam
Examination duration and scale	30 minutes
Assignment for the Following Curricula	Computer Science: Core qualification: Elective Compulsory Computational Science and Engineering: Core qualification: Elective Compulsory 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 - Data structures - Leftist heaps - Minimum spanning tree - Shortest path - Maximum flow - 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. Wesley, 2011 http://algs4.cs.princeton.edu/home/ 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 M0683: Algebraic Statistics for Computational Biology

Courses

Title	Typ	Hrs/wk	CP
Algebraic Statistics for Computational Biology (L0457)	Recitation Section (small)	2	3
Algebraic Statistics for Computational Biology (L0456)	Lecture	2	3

Module Responsible	Prof. Karl-Heinz Zimmermann
Admission Requirements	None.
Recommended Previous Knowledge	Mathematical Calculus, Linear Algebra, and Higher Abstract Algebra.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know the alignment of sequences, the hidden Markov model, and phylogenetic tree models including the respective algorithms. Moreover, they know the EM algorithm, general algebraic statistical models and developping invariants for them, Gröbner bases in polynomial rings, elimination theory for systems of polynomial equations, and the use of computer algebra systems to solve problems in the context of this class.
Skills	The students are able to formalize, compute, and analyze alignments of sequences, hidden Markov models, and phylogenetic tree models. Moreover, they can compute Gröbner bases in polynomial rings, use elimination theory to tackle systems of polynomial equations, and provide invariants for algebraic statistical models.
Personal Competence	
Social Competence	Students are able to solve specific problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from newer literature and to associate this knowledge with other fields.
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 Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Core qualification: Elective Compulsory Computational Science and Engineering: Core qualification: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory

Course L0457: Algebraic Statistics for Computational Biology

Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Karl-Heinz Zimmermann
Language	DE/EN
Cycle	WiSe
Content	
Literature	

Course L0456: Algebraic Statistics for Computational Biology

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Karl-Heinz Zimmermann
Language	DE/EN
Cycle	WiSe
Content	
Literature	

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. Blanca Ayuso Dios
Admission Requirements	None
Recommended Previous Knowledge	• Lecture contents of prerequisite lectures • MATLAB knowledge
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • name advanced numerical methods for interpolation, integration, linear least squares problems, eigenvalue problems, nonlinear root finding problems and explain their core ideas, • repeat convergence statements for the numerical methods, • sketch convergence proofs, • explain aspects regarding the practical implementation of numerical methods with respect to computational and storage complexity. •
Skills	Students are able to • implement, apply and compare advanced numerical methods in MATLAB, • justify the convergence behaviour of numerical methods with respect to the problem and solution algorithm and to transfer it to related problems, • 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 • 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 • to assess whether the supporting theoretical and practical excercises are better solved individually or in a team, • 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	30 min
Assignment for the Following Curricula	Computer Science: Core qualification: Elective Compulsory Computational Science and Engineering: Core qualification: Elective Compulsory Technomathematics: Specialisation Mathematics: Elective Compulsory 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. Blanca Ayuso Dios
Language	DE/EN
Cycle	WiSe
Content	1. Error and stability: Notions and estimates 2. Interpolation: Rational and trigonometric interpolation 3. Quadrature: Gaussian quadrature, orthogonal polynomials 4. Linear systems: Perturbation theory of decompositions, structured matrices 5. Eigenvalue problems: LR-, QD-, QR-Algorithmus 6. Krylov space methods: Arnoldi-, Lanczos methods
Literature	• Stoer/Bulirsch: Numerische Mathematik 1, Springer • 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. Blanca Ayuso Dios
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0582: Nonlinear Optimization

Courses

Title	Typ	Hrs/wk	CP
Nonlinear Optimization (L0228)	Lecture	3	4
Nonlinear Optimization (L0229)	Recitation Section (small)	1	2

Module Responsible	Dr. Christian Jansson
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in mathematics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students have knowledge of the basic principles of numerical nonlinear optimization. In particular, they know the fundamental criteria for optimality as well as optimization algorithms for finite dimensional and infinite dimensional problems.
Skills	The students have experience in working with software packages in the area of optimization. The are able to model practical problems in optimization in a flexible manner, and they can judge approximately computed solutions according to the problem.
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 use and to retrieve necessary informations from the given literature. They are able to check their knowledge with the exercises. In this way they can control their learning.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Oral exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Computer Science: Core qualification: Elective Compulsory Computational Science and Engineering: Core qualification: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory

Course L0228: Nonlinear Optimization	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Dr. Christian Jansson
Language	DE
Cycle	SoSe
Content	Introduction Examples MATLAB and the Optimization Toolbox Mathematical Review • Optimal Solutions • Taylor´s Theorem • Positive Semidefinite Matrices • Convex Sets • Convex Functions • Characterization of Differentiable Convex Functions Optimality Conditions • Unconstrained problems • Constrained Problems, Theorem of Kuhn-Tucker Optimal Control • Introduction • Pontryagin´s Principle • Riccati´s Differential Equation Algorithms for Unconstrained Optimisation Problems • Basic Descent Methods, Method of Steepest Descent • Newton"s Method • Modified Newton"s Methods • Trust Region Methods • Levenberg-Marquardt Method • Quasi-Newton Methods: Rank 1-Correction, DFP- and BFGS Method • Numerical Experiments • Software Algorithms for Constrained Optimization Problems and Convex Problems • Interior-Point Methods • Newton"s Methods for Solving the Kuhn-Tucker Conditions • Sequential Quadratic Programming • Software package Matlab's Optimization Toolbox • Linear Matrix Inequalities and Semidefinite Programming • Duality • Applications (Robust Optimization, Relaxation for Combinatorial Optimization, Polynomial Problems, Truss Problems) • Branch and Bound Methods • Verified Results for Semidefinite Programming and the Software Package VSDP •
Literature	• ◦ M.S. Bazaraa, H.D. Sheraly, C.M. Shetty: Nonlinear Programming, John Wiley, 1993 ◦ S. Boyd, L. Vandenberghe: Convex Optimization, Cambridge University Press, 2004 ◦ N.I.M. Gould, S. Leyffer: An Introduction to algorithms for nonlinear optimization, Springer, 2003 • A. Nemirovski: Lectures on Modern Convex Optimization, SIAM, 2001 • C. Floudas, P.M. Pardalos (eds.): Encyclopedia of Optimization, Springer, 2001

Course L0229: Nonlinear Optimization	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Dr. Christian Jansson
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0685: Algebraic Methods in Information and Communication Technology

Courses

Title	Typ	Hrs/wk	CP
Algebraic Methods in Information and Communication Technology (L0461)	Lecture	2	3
Algebraic Methods in Information and Communication Technology (L0462)	Recitation Section (small)	2	3

Module Responsible	Prof. Karl-Heinz Zimmermann
Admission Requirements	None.
Recommended Previous Knowledge	Mathematical Calculus, Linear Algebra, and foundations of Higher Abstract Algebra.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students will get familiar with the following topics: algebraic combinatorics; ideals, local rings, standard bases and systems of polynomial equations; modules, syzygies, and free resolutions; algebraic invariant theory. These are the core topics. Further topics are elliptic curves, homological algebra, knot theory, and sheaves.
Skills	The students are able to provide computations in the fields given above.
Personal Competence	
Social Competence	Students are able to solve specific problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from newer literature and to associate this knowledge with other fields.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Oral exam
Examination duration and scale	Einzelprüfung, 30 min
Assignment for the Following Curricula	Computer Science: Core qualification: Elective Compulsory Computational Science and Engineering: Core qualification: Elective Compulsory

Course L0461: Algebraic Methods in Information and Communication Technology

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Karl-Heinz Zimmermann
Language	DE/EN
Cycle	SoSe
Content	
Literature	

Course L0462: Algebraic Methods in Information and Communication Technology

Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Karl-Heinz Zimmermann
Language	DE/EN
Cycle	SoSe
Content	
Literature	

Module M0804: Research Project and Seminar

Courses

Title	Typ	Hrs/wk	CP
Project Work (L1761)	Projection Course	10	16
Seminar (L0817)	Seminar	2	2

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 372, Study Time in Lecture 168
Credit points	18
Examination	according to Subject Specific Regulations
Examination duration and scale	Presentation on a current research topic (25-30 min and 5 min discussion). The research work is a project work according to the statutes of the ASPO and FSPO.
Assignment for the Following Curricula	Computer Science: Core qualification: Compulsory Computational Science and Engineering: Core qualification: Compulsory Information and Communication Systems: Core qualification: Compulsory

Course L1761: Project Work

Typ	Projection Course
Hrs/wk	10
CP	16
Workload in Hours	Independent Study Time 340, 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. / Current literature on research topics of the chosen specialization.

Course L0817: Seminar

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, 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 • Active participation in discussions
Literature	Wird vom Veranstalter bekanntgegeben.

Specialization Computer and Software Engineering

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)	Problem-based Learning	2	2
Communication Networks Excercise (L0898)	Problem-based Learning	1	2

Module Responsible	Prof. Andreas Timm-Giel
Admission Requirements	None
Recommended Previous Knowledge	• Fundamental stochastics • 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	Colloquium
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 Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory 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	Dr. Maciej Mühleisen
Language	EN
Cycle	WiSe
Content	
Literature	• Skript des Instituts für Kommunikationsnetze • Tannenbaum, Computernetzwerke, Pearson-Studium Further literature is announced at the beginning of the lecture.

Course L0899: Selected Topics of Communication Networks	
Typ	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	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 M0753: Software Verification

Courses

Title	Typ	Hrs/wk	CP
Software Verification (L0629)	Lecture	2	3
Software Verification (L0630)	Recitation Section (small)	2	2
Software Verification (L1622)	Recitation Section (large)	2	1

Module Responsible	Prof. Sibylle Schupp
Admission Requirements	None
Recommended Previous Knowledge	• 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 96, Study Time in Lecture 84
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 Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems: Compulsory 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
	• Deductive verification
	  ◦ Specification
	  ◦ Proof obligations
	  ◦ Program properties
	  ◦ Automated vs. interactive theorem proving
	• Model checking
	  ◦ Foundations
	  ◦ Property languages
	  ◦ Tool support
	• Recent developments of verification techniques and applications

Literature	• C. Baier and J-P. Katoen, Principles of Model Checking, MIT Press 2007. • M. Huth and M. Bryan, Logic in Computer Science. Modelling and Reasoning about Systems, 2nd Edition, 2004. • Selected Research Papers

Course L0630: Software Verification	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1622: Software Verification	
Typ	Recitation Section (large)
Hrs/wk	2
CP	1
Workload in Hours	Independent Study Time 2, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	WiSe
Content	
Literature	

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	
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	
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 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 • Colorings & Independent Sets • Tree Algorithms • Minimal Spanning Trees • Randomized Distributed Algorithms • Mutual Exclusion
Literature	1. David Peleg: Distributed Computing - A Locality-Sensitive Approach. SIAM Monograph, 2000 2. Gerard Tel: Introduction to Distributed Algorithms, Cambridge University Press, 2nd edition, 2000 3. Nancy Lynch: Distributed Algorithms. Morgan Kaufmann, 1996 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 M0556: Computer Graphics and Animation

Courses

Title	Typ	Hrs/wk	CP
Computer Graphics and Animation (L0145)	Lecture	2	3
Computer Graphics and Animation (L0768)	Project Seminar	2	3

Module Responsible	Prof. Helmut Weberpals
Admission Requirements	
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 • solid skills in modelling and shading, • solid skills in computer animation techniques, and • 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	Project
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory

Course L0145: Computer Graphics and Animation	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Helmut Weberpals
Language	EN
Cycle	SoSe
Content	Computer graphics and animation are leading to an unprecedented visual revolution. The course deals with its technological foundations: • Object-oriented Computer Graphics • Projections and Transformations • Polygonal and Parametric Modelling • Illuminating, Shading, Rendering • Computer Animation Techniques • Kinematics and Dynamics Effects 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: 3D Computer Graphics. Harlow: Pearson (3rd ed., repr., 2009). Dariush Derakhshani: Introducing Autodesk Maya 2014. New York, NY : Wiley (2013).

Course L0768: Computer Graphics and Animation	
Typ	Project Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Helmut Weberpals
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0653: High-Performance Computing

Courses

Title	Typ	Hrs/wk	CP
Fundamentals of High-Performance Computing (L0242)	Lecture	2	3
Fundamentals of High-Performance Computing (L1416)	Problem-based Learning	2	3

Module Responsible	Prof. Thomas Rung
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in usage of modern IT environment
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to outline the fundamentals of numerical algorithms for high-performance computers by reference to modern hardware examples. Students can explain the relation between hard- and software aspects for the design of algorithms.
Skills	Student can perform a critical assesment of the computational efficiency of simulation approaches.
Personal Competence	
Social Competence	Students are able to develop and code algorithms in a team.
Autonomy	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Written exam
Examination duration and scale	1.5h
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory

Course L0242: Fundamentals of High-Performance Computing

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Thomas Rung
Language	DE/EN
Cycle	SoSe
Content	Fundamentals of modern hardware architectur, critical hard- & software aspects for efficient processing of exemplary algorithms, concepts for shared- and distributed-memory systems, implementations for accelerator hardware (GPGPUs)
Literature	

Course L1416: Fundamentals of High-Performance Computing

Typ	Problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Thomas Rung
Language	DE/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	Probability theory and random processes Basic knowledge of communications engineering is desirable (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 Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Engineering: Elective Compulsory Information and Communication Systems: Core qualification: Compulsory 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
	  ◦ Self information, entropy, mutual information
	  ◦ Source coding theorem, channel coding theorem
	  ◦ Channel capacity of various channels
	• Fundamental source coding algorithms:
	  ◦ Huffman Code, Lempel Ziv Algorithm
	• Fundamentals of channel coding
	  ◦ Basic parameters of channel coding and respective bounds
	  ◦ Decoding principles: Maximum-A-Posteriori Decoding, Maximum-Likelihood Decoding, Hard-Decision-Decoding and Soft-Decision-Decoding
	  ◦ Error probability
	• Block codes
	• Low Density Parity Check (LDPC) Codes and iterative Ddecoding
	• Convolutional codes and Viterbi-Decoding
	• Turbo Codes and iterative decoding
	• Coded Modulation

Literature	Bossert, M.: Kanalcodierung. Oldenbourg. Friedrichs, B.: Kanalcodierung. Springer. Lin, S., Costello, D.: Error Control Coding. Prentice Hall. Roth, R.: Introduction to Coding Theory. Johnson, S.: Iterative Error Correction. Cambridge. Richardson, T., Urbanke, R.: Modern Coding Theory. Cambridge University Press. Gallager, R. G.: Information theory and reliable communication. Whiley-VCH 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 M1318: Wireless Sensor Networks

Courses

Title	Typ	Hrs/wk	CP
Selected Topics of Wireless Sensor Networks (L1819)	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 Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory

Course L1819: Selected Topics of Wireless Sensor Networks

Typ	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: • Energy-efficient / low-power Medium Access • Energy-efficient / low-power Routing (Data Collection and Data Dissemination) • Energy Harvesting • Intermittently Powered Sensor Nodes • Energy-Aware Load Adaptation and Scheduling • 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 M1323: Cryptography

Courses

Title	Typ	Hrs/wk	CP
Cryptography (L1825)	Recitation Section (small)	2	3
Cryptography (L1826)	Lecture	2	3

Module Responsible	Prof. Chris Brzuska
Admission Requirements	None
Recommended Previous Knowledge	Prerequisites: 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* *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	
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 Information and Communication Systems: Specialisation Secure and Dependable IT Systems: Elective Compulsory

Course L1825: 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: - Foundations of Cryptography: Volume 1, Basic Tools, Oded Goldreich, Cambridge University Press 2007, ISBN-10: 0521035368, ISBN-13: 978-0521035361 - Foundations of Cryptography: Volume 2, Basic Applications, Oded Goldreich, Cambridge University Press 2009, ISBN-10: 052111991X, ISBN-13: 978-0521119917

Course L1826: 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: 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: - One-way functions - Pseudorandomness - Pseudorandom generators - Pseudorandom functions - symmetric encryption - asymmetric encryption - message authentication codes - signature schemes - secure channels - recent attacks on real-life protocols such as TLS, IPsec,...
Literature	Literatur: - Foundations of Cryptography: Volume 1, Basic Tools, Oded Goldreich, Cambridge University Press 2007, ISBN-10: 0521035368, ISBN-13: 978-0521035361 - Foundations of Cryptography: Volume 2, Basic Applications, Oded Goldreich, Cambridge University Press 2009, ISBN-10: 052111991X, ISBN-13: 978-0521119917

Module M1324: Software Testing

Courses

Title	Typ	Hrs/wk	CP
Software Testing (L1827)	Problem-based Learning	2	3
Software Testing (L1828)	Lecture	2	3

Module Responsible	Prof. Sibylle Schupp
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 Computer and Software Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory

Course L1827: Software Testing

Typ	Problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Sandro Schulze
Language	EN
Cycle	SoSe
Content	
Literature	

Course L1828: Software Testing

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Sandro Schulze
Language	EN
Cycle	SoSe
Content	
Literature	

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
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	Written exam
Examination duration and scale	90 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 Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory 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	SoSe
Content	• Modeling: Control-Flow Modeling, Data Dependences, Intermediate Languages) • Classical Bit-Vector Analyses (Reaching Definition, Very Busy Expressions, Liveness, Available Expressions, May/Must, Forward/Backward) • Monotone Frameworks (Lattices, Transfer Functions, Ascending Chain Condition, Distributivity, Constant Propagation) • Theory of Data-Flow Analysis (Tarski's Fixed Point Theorem, Data-Flow Equations, MFP Solution, MOP Solution, Worklist Algorithm) • Non-Classical Data-Flow Analyses • Abstract Interpretation (Galois Connections, Approximating Fixed Points, Construction Techniques) • Type Systems (Type Derivation, Inference Trees, Algorithm W, Unification) • Recent Developments of Analysis Techniques and Applications
Literature	• Flemming Nielsen, Hanne Nielsen, and Chris Hankin. Principles of Program Analysis. Springer, 2nd. ed. 2005. • Uday Khedker, Amitabha Sanyal, and Bageshri Karkara. Data Flow Analysis: Theory and Practice. CRC Press, 2009. • 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	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)	Problem-based Learning	5	6

Module Responsible	Prof. Andreas Timm-Giel
Admission Requirements	
Recommended Previous Knowledge	• Knowledge of computer and communication networks • 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	Colloquium
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 Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory

Course L0887: Simulation and Modelling of Communication Networks

Typ	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 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	
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 Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory Mechatronics: Technical Complementary Course: 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 • Programming the Atmel AVR • Interrupts • C for Embedded Systems • Standard Single Purpose Processors: Peripherals • Finite-State Machines • Memory • Operating Systems for Embedded Systems • Real-Time Embedded Systems • Boot loader and Power Management
Literature	1. Embedded System Design, F. Vahid and T. Givargis, John Wiley 2. Programming Embedded Systems: With C and Gnu Development Tools, M. Barr and A. Massa, O'Reilly 3. C und C++ für Embedded Systems, F. Bollow, M. Homann, K. Köhn, MITP 4. The Art of Designing Embedded Systems, J. Ganssle, Newnses 5. Mikrocomputertechnik mit Controllern der Atmel AVR-RISC-Familie, G. Schmitt, Oldenbourg 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 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 • explain the fundamental security services that can be implemented with the methods of modern cryptography, • describe current standardized network security protocols and mechanisms, • follow current methods for the formal analysis of security protocols.
Skills	Students are capable of • performing an analysis of network security solutions. • identifying suitable security solutions for given requirements. • recognizing the limitations of existing standard solutions, • 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 Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory 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 • Security services and cryptographic mechanisms • Key establishment: Diffie-Hellman, Kerberos • IPsec protocols, mobile IPv6 • SSL/TLS • GSM/UMTS/LTE security protocols • WLAN security • Firewalls and Intrusion Detection Systems • Formal analysis of security protocols
Literature	W. Stallings: Cryptography and Network Security: Principles and Practice, 6th edition (2013) A. Menezes, P. van Oorschot, S. Vanstone: Handbook of Applied Cryptography, CRC Press (1997) D. Gollmann: Computer Security, 3rd edition, Wiley (2011) 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 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" 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 • to illustrate the structure and organization of such compilers, • to distinguish and explain intermediate representations of various abstraction levels, and • to assess optimizations and their underlying problems in all compiler phases. The high demands on compilers for embedded systems make effective code optimizations mandatory. The students learn in particular, • which kinds of optimizations are applicable at the source code level, • how the translation from source code to assembly code is performed, • which kinds of optimizations are applicable at the assembly code level, • how register allocation is performed, and • how memory hierarchies can be exploited effectively. 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. 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 minutes, contents of course
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: 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	
Literature	• Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2nd Edition, Springer, 2012. • Steven S. Muchnick. Advanced Compiler Design and Implementation. Morgan Kaufmann, 1997. • 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 M0910: Advanced System-on-Chip Design (Lab)

Courses

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

Module Responsible	Prof. Heiko Falk
Admission Requirements	None.
Recommended Previous Knowledge	Module "Computer Architecture", in particular having passed the practical labs of "Computer Architecture"
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. 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	Project
Examination duration and scale	
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 L1061: Advanced System-on-Chip Design

Typ	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) • Pipelined instruction execution • Cache-based memory hierarchies • Busses and their arbitration • Multi-Processor Systems-on-Chip • Optional: Advanced pipelining concepts (dynamic scheduling, branch prediction)
Literature	• D. Patterson, J. Hennessy. Rechnerorganisation und -entwurf. Elsevier, 2005. • A. Tanenbaum, J. Goodman. Computerarchitektur. Pearson, 2001. • A. Clements. The Principles of Computer Hardware. 3. Auflage, Oxford University Press, 2000.

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 • name the main causes for security vulnerabilities in software • explain current methods for identifying and avoiding security vulnerabilities • explain the fundamental concepts of code-based access control
Skills	Students are capable of • performing a software vulnerability analysis • 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 Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory 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 • Attacks exploiting character and integer representations • Buffer overruns • Vulnerabilities in memory managemet: double free attacks • Race conditions • SQL injection • Cross-site scripting and cross-site request forgery • Testing for security; taint analysis • Type safe languages • Development proceses for secure software • Code-based access control
Literature	M. Howard, D. LeBlanc: Writing Secure Code, 2nd edition, Microsoft Press (2002) G. Hoglund, G. McGraw: Exploiting Software, Addison-Wesley (2004) L. Gong, G. Ellison, M. Dageforde: Inside Java 2 Platform Security, 2nd edition, Addison-Wesley (2003) B. LaMacchia, S. Lange, M. Lyons, R. Martin, K. T. Price: .NET Framework Security, Addison-Wesley Professional (2002) 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 M0913: CMOS Nanoelectronics with Practice

Courses

Title	Typ	Hrs/wk	CP
CMOS Nanoelectronics (L0764)	Lecture	2	3
CMOS Nanoelectronics (L1063)	Laboratory Course	2	2
CMOS Nanoelectronics (L1059)	Recitation Section (small)	1	1

Module Responsible	Prof. Wolfgang Krautschneider
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of MOS devices and electronic circuits
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the functionality of very small MOS transistors and explain the problems occurring due to scaling-down the minimum feature size. • Students are able to explain the basic steps of processing of very small MOS devices. • Students can exemplify the functionality of volatile and non-volatile memories und give their specifications. • Students can describe the limitations of advanced MOS technologies. • Students can explain measurement methods for MOS quality control.
Skills	• Students can quantify the current-voltage-behavior of very small MOS transistors and list possible applications. • Students can describe larger electronic systems by their functional blocks. • Students can name the existing options for the specific applications and select the most appropriate ones.
Personal Competence	
Social Competence	• Students can team up with one or several partners who may have different professional backgrounds • Students are able to work by their own or in small groups for solving problems and answer scientific questions.
Autonomy	• Students are able to assess their knowledge in a realistic manner. • The students are able to draw scenarios for estimation of the impact of advanced mobile electronics on the future lifestyle of the society.
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 Electrical Engineering: Core qualification: Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Microelectronics and Microsystems: Core qualification: Elective Compulsory

Course L0764: CMOS Nanoelectronics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Wolfgang Krautschneider
Language	EN
Cycle	WiSe
Content	• Ideal and non-ideal MOS devices • Threshold voltage, Parasitic charges, Work function difference • I-V behavior • Scaling-down rules • Details of very small MOS transistors • Basic CMOS process flow • Memory Technology, SRAM, DRAM, embedded DRAM • Gain memory cells • Non-volatile memories, Flash memory circuits • Methods for Quality Control, C(V)-technique, Charge pumping, Uniform injection • Systems with extremely small CMOS transistors
Literature	• S. Deleonibus, Electronic Device Architectures for the Nano-CMOS Era, Pan Stanford Publishing, 2009. • Y. Taur and T.H. Ning, Fundamentals of Modern VLSI Devices, Cambridge University Press, 2nd edition. • R.F. Pierret, Advanced Semiconductor Fundamentals, Prentice Hall, 2003. • F. Schwierz, H. Wong, J. J. Liou, Nanometer CMOS, Pan Stanford Publishing, 2010. • H.-G. Wagemann und T. Schönauer, Silizium-Planartechnologie, Grundprozesse, Physik und Bauelemente Teubner-Verlag, 2003, ISBN 3519004674

Course L1063: CMOS Nanoelectronics	
Typ	Laboratory Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Wolfgang Krautschneider
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1059: CMOS Nanoelectronics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Wolfgang Krautschneider
Language	EN
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 • 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. 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 Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: 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 • 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 • Linear Programming (LP) • Network planning with LP solvers • Planning of communication networks Queueing Theory for Communication Networks • Stochastic processes • Queueing systems • Switches (circuit- and packet switching) • Network of queues
Literature	Literatur: U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer Weitere Literatur wird in der Lehrveranstaltung bekanntgegeben / Literature: U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer 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: U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer Weitere Literatur wird in der Lehrveranstaltung bekanntgegeben / Literature: U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer further literature announced in the lecture

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 minutes
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory 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 • Error-free transformations • Verification methods for linear and nonlinear systems • Verification methods for finite integrals • Treatment of multiple zeros • Automatic differentiation • Implementation in Matlab/INTLAB • Practical applications
Literature	Neumaier: Interval Methods for Systems of Equations. In: Encyclopedia of Mathematics and its Applications. Cambridge University Press, 1990 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 M1318: Wireless Sensor Networks

Courses

Title	Typ	Hrs/wk	CP
Selected Topics of Wireless Sensor Networks (L1819)	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 Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory

Course L1819: Selected Topics of Wireless Sensor Networks

Typ	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: • Energy-efficient / low-power Medium Access • Energy-efficient / low-power Routing (Data Collection and Data Dissemination) • Energy Harvesting • Intermittently Powered Sensor Nodes • Energy-Aware Load Adaptation and Scheduling • 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 M1301: Software Testing

Courses

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

Module Responsible	Prof. Sibylle Schupp
Admission Requirements	None
Recommended Previous Knowledge	• Software Engineering • Higher Programming Languages • Algorithms and Data Structures • 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 learnin 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, t 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 ones
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 Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory 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	Dr. Sandro Schulze
Language	EN
Cycle	SoSe
Content	• Fundamentals of software testing • Regression-testing techniques • Search-based testing • Combinatorial testing • Product-line testing • Debugging • Model-based testing
Literature	• M. Pezze and M. Young, Software Testing and Analysis, John Wiley 2008. • P. Ammann and J. Offutt, "Introduction to Software Testing", 2nd edition 2015. • A. Zeller: "Why Programs Fail: A Guide to Systematic Debugging", 2nd edition 2012.

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

Specialization Intelligence Engineering

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	
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 • Describe imaging processes • Depict the physics of sensorics • Explain linear and non-linear filtering of signals • Establish interdisciplinary connections in the subject area and arrange them in their context • Interpret effects of the most important classes of imaging sensors and displays using mathematical methods and physical models.
Skills	Students are able to • Use highly sophisticated methods and procedures of the subject area • Identify problems and develop and implement creative solutions. Students can solve simple arithmetical problems relating to the specification and design of image processing and image analysis systems. Students are able to assess different solution approaches in multidimensional decision-making areas. Students can undertake a prototypical analysis of processes in Matlab.
Personal Competence	
Social Competence	
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 Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory 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 • Perception of luminance and color, color spaces and transforms, color matching functions, human visual system, color appearance models • imaging sensors (CMOS, CCD, HDR, X-ray, IR), sensor characterization(EMVA1288), lenses and optics • spatio-temporal sampling (interpolation, decimation, aliasing, leakage, moiré, flicker, apertures) • features (filters, edge detection, morphology, invariance, statistical features, texture) • optical flow (variational methods, quadratic optimization, Euler-Lagrange equations) • segmentation (distance, region growing, cluster analysis, active contours, level sets, energy minimization and graph cuts) • registration (distance and similarity, variational calculus, iterative closest points)
Literature	Bredies/Lorenz, Mathematische Bildverarbeitung, Vieweg, 2011 Wedel/Cremers, Stereo Scene Flow for 3D Motion Analysis, Springer 2011 Handels, Medizinische Bildverarbeitung, Vieweg, 2000 Pratt, Digital Image Processing, Wiley, 2001 Jain, Fundamentals of Digital Image Processing, Prentice Hall, 1989

Module M0554: Quantitative Methods - Statistics and Operations Research

Courses

Title	Typ	Hrs/wk	CP
Quantitative Methods - Statistics and Operations Research (L0127)	Problem-based Learning	3	4
Quantitative Methods - Statistics and Operations Research (L0250)	Lecture	2	2

Module Responsible	Prof. Kathrin Fischer
Admission Requirements	None.
Recommended Previous Knowledge	Knowledge of Mathematics on the Bachelor Level. Relevant previous knowledge is tested by an online module
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know • different methods from the field of descriptive statistics and can explain them and their importance for Business Analysis; • different discrete and continuous distribution functions and can explain their meaning and their areas of application • the laws of probability theory as, e.g. the Bayes rule, and can explain them; • different methods of oinferential statistics - e.g. confidence intervals, hypothesis testing and regression analysis - and can explain their theoretical background; • the history and relevance of Operations Research; • linear programming methods for solving planning problems and can explain them; • selected methods of transportation and network optimization amd can explain them; • integer programming models and methods, e.g. for location planning; • appropriate software for solving these problems.
Skills	Students are able to • collect empirical data by appropriate methods, to aggregate, classify and analyze the data and to draw conclusions from them also in complex and realistic situations; • recognize different distribution functions and to apply them in the solution of Business problems; • apply laws of probability, as e.g. the Bayes rule, to construct solutions for Business problems; • select appropriate methods of inferential statistics, apply them to Business problems and evaluate the results of their analysis; • construct appropriate quantitative - linear or integer - models for Business planning situations; • apply methods from linear and integer programming and interpret and evaluate the results; • apply methods from transport and network planning and interpret and evaluate the results; • solve the problems with appropriate software, carry out sensitivity analyses and evaluate the results; • develop a critical judgement of the different methods and their applicability; • use models and methods from Statistics and OR to analyse problems from the areas of business and engineering and to evaluate the results; • apply their theoretical knowledge of the different methods to practical problems.
Personal Competence	
Social Competence	Students are able to • engage in scientific discussions on topics from the fields of Statistics and OR; • present the results of their work to specialists; • work successfully and respectfully in a team.
Autonomy	Students are able to • carry out complex data analyses independently, individually or in a team; • solve complex Business planning problems independently or in a team, selecting and using appropriate software; • gather knowledge in the area independently and to apply their knowledge also in new and unknown situations; • critically evaluate the results of their work and the consequences.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Examination	Written exam
Examination duration and scale	3 hours
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Global Innovation Management: Core qualification: Elective Compulsory International Management and Engineering: Core qualification: Compulsory

Course L0127: Quantitative Methods - Statistics and Operations Research	
Typ	Problem-based Learning
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Kathrin Fischer
Language	EN
Cycle	WiSe
Content	**Statistics** • Descriptive Statistics: Graphical representations, calculation of relevant measures of central tendency etc., also by using a computer; application of methods for large data sets, analysis and comparison of results, critical discussion and evaluation of methods; • Probability theory: important laws, dependent probabilities, Bayes Rule; application to practical problems; • Use and application of probability distributions , as e.g. Binomial and Normal distribution to Management and Engineering problems; • Methods of inferential statistics: confidence intervals: theoretical background and applications; hypothesis testing: theoretical background and application to business problems; regression analysis: theoretical background and application. **Operations Research** • Linear Programming: Modelling business decision situations, solving problems by Simplex method and by using software, theoretical background of Simplex procedure, Dual Simplex procedure and blocked variables, special cases (degeneracy etc.); sensitivity analysis • Transportation planning: Modellung transportation and transshipment problems in global networks; Solving transportation problems using software • Network Optimization problems: modelling production and transportation networks, solving planning problems in networks • Integer Programming: Models using integer variables, e.g. in location decisions, branch and bound procedure
Literature	Ausgewählte Bücher: D.R. Anderson / D.J. Sweeney / T.A. Williams / Martin: Quantitative Methods for Business. 11th Edition, Thomson, South Western 2008. Bluman, Alan G.: Elementary Statistics – A brief version. Third Edition, McGrawHill 2006. Bowerman, Bruce L. and O'Connell, Richard T.: Business Statistics in Practice, 4th edition, McGraw-Hill 2007. Domschke, W., Drexl, A.: Einführung in Operations Research, 7. Auflage, Springer, Berlin et al. 2007. Domschke, W. / A. Drexl / R. Klein / A. Scholl / S. Voß: Übungen und Fallbeispiele zum Operations Research, 6. Auflage, Springer, Berlin et al. 2007 Hillier, F.S., Lieberman, G.J.: Introduction to Operations Research. 8th Edition, McGraw-Hill, 2005. Schira, J.: Statistische Methoden der VWL und BWL – Theorie und Praxis. 2. Auflage, Pearson Verlag 2005. Zudem: Skript und Unterlagen, die zur Vorlesung herausgegeben werden.

Course L0250: Quantitative Methods - Statistics and Operations Research	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Kathrin Fischer
Language	EN
Cycle	WiSe
Content	**Statistics** • Descriptive Statistics: Graphical representations, calculation of relevant measures of central tendency etc., also by using a computer; application of methods for large data sets, analysis and comparison of results, critical discussion and evaluation of methods; • Probability theory: important laws, dependent probabilities, Bayes Rule; application to practical problems; • Use and application of probability distributions , as e.g. Binomial and Normal distribution to Management and Engineering problems; • Methods of inferential statistics: confidence intervals: theoretical background and applications; hypothesis testing: theoretical background and application to business problems; regression analysis: theoretical background and application. **Operations Research** • Linear Programming: Modelling business decision situations, solving problems by Simplex method and by using software, theoretical background of Simplex procedure, Dual Simplex procedure and blocked variables, special cases (degeneracy etc.); sensitivity analysis • Transportation planning: Modellung transportation and transshipment problems in global networks; Solving transportation problems using software • Network Optimization problems: modelling production and transportation networks, solving planning problems in networks • Integer Programming: Models using integer variables, e.g. in location decisions, branch and bound procedure
Literature	Ausgewählte Bücher: D.R. Anderson / D.J. Sweeney / T.A. Williams / Martin: Quantitative Methods for Business. 11th Edition, Thomson, South Western 2008. Bluman, Alan G.: Elementary Statistics – A brief version. Third Edition, McGrawHill 2006. Bowerman, Bruce L. and O'Connell, Richard T.: Business Statistics in Practice, 4th edition, McGraw-Hill 2007. Domschke, W., Drexl, A.: Einführung in Operations Research, 7. Auflage, Springer, Berlin et al. 2007. Domschke, W. / A. Drexl / R. Klein / A. Scholl / S. Voß: Übungen und Fallbeispiele zum Operations Research, 6. Auflage, Springer, Berlin et al. 2007 Hillier, F.S., Lieberman, G.J.: Introduction to Operations Research. 8th Edition, McGraw-Hill, 2005. Schira, J.: Statistische Methoden der VWL und BWL – Theorie und Praxis. 2. Auflage, Pearson Verlag 2005. Zudem: Skript und Unterlagen, die zur Vorlesung herausgegeben werden.

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 • They can explain the system properties controllability and observability, and their relationship to state feedback and state estimation, respectively • They can explain the significance of a minimal realisation • They can explain observer-based state feedback and how it can be used to achieve tracking and disturbance rejection • They can extend all of the above to multi-input multi-output systems • They can explain the z-transform and its relationship with the Laplace Transform • They can explain state space models and transfer function models of discrete-time systems • 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 • 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 • They can assess controllability and observability and construct minimal realisations • They can design LQG controllers for multivariable plants • 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 • They can identify transfer function models and state space models of dynamic systems from experimental data • 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. They can assess their knowledge in weekly on-line tests and thereby control their learning progress.
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 Electrical Engineering: Core qualification: Compulsory Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems Engineering: Compulsory Computational Science and Engineering: Specialisation Systems Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechatronics: Core qualification: Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory 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) • State space models and transfer functions, state feedback • Coordinate basis, similarity transformations • Solutions of state equations, matrix exponentials, Caley-Hamilton Theorem • Controllability and pole placement • State estimation, observability, Kalman decomposition • Observer-based state feedback control, reference tracking • Transmission zeros • Optimal pole placement, symmetric root locus Multi-input multi-output systems • Transfer function matrices, state space models of multivariable systems, Gilbert realization • Poles and zeros of multivariable systems, minimal realization • Closed-loop stability • Pole placement for multivariable systems, LQR design, Kalman filter Digital Control • Discrete-time systems: difference equations and z-transform • Discrete-time state space models, sampled data systems, poles and zeros • Frequency response of sampled data systems, choice of sampling rate System identification and model order reduction • Least squares estimation, ARX models, persistent excitation • Identification of state space models, subspace identification • Balanced realization and model order reduction Case study • Modelling and multivariable control of a process evaporator using Matlab and Simulink Software tools • Matlab/Simulink
Literature	• Werner, H., Lecture Notes „Control Systems Theory and Design“ • T. Kailath "Linear Systems", Prentice Hall, 1980 • K.J. Astrom, B. Wittenmark "Computer Controlled Systems" Prentice Hall, 1997 • 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 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

Module Responsible	Rainer Marrone
Admission Requirements	
Recommended Previous Knowledge	Vectors, matrices, Calculus, propositional Logic, Stochastics (in particular practical representation formalisms such as Bayesian networks, dynamic Bayesian networks, hidden Markov models, Kalman filters)
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	
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
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering: Elective Compulsory International Production Management: Specialisation Production Technology: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory 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 • Adversarial agent cooperation: Agents with complete access to the state(s) of the environment, games, Minimax algorithm, alpha-beta pruning, elements of chance • Uncertainty: 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 • Bayesian networks: 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). • Probabilistic reasoning over time: 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 • Decision making under uncertainty: Simple decisions: utility theory, multivariate utility functions, dominance, decision networks, value of informatio Complex decisions: sequential decision problems, value iteration, policy iteration, MDPs Decision-theoretic agents: POMDPs, reduction to multidimensional continuous MDPs, dynamic decision networks • Simultaneous Localization and Mapping • Planning • Game theory (Golden Balls: Split or Share) Decisions with multiple agents, Nash equilibrium, Bayes-Nash equilibrium • Social Choice Voting protocols, preferences, paradoxes, Arrow's Theorem, • Mechanism Design 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 2. Probabilistic Robotics, Thrun, S., Burgard, W., Fox, D. MIT Press 2005 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 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 • 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 • characterize and compare diffusion equations • explain elementary methods of image processing • explain methods of image segmentation and registration • sketch and interrelate basic concepts of functional analysis
Skills	Students are able to • implement and apply elementary methods of image processing • 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. • 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	30
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Technomathematics: Specialisation Mathematics: Elective Compulsory 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 concepts of functional analysis • introduction to partial differential equations • basic methods of image processing • image segmentation • 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 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	
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. 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	
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 Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: 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 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 Murphy, Machine Learning, MIT Press, 2012 Barber, Bayesian Reasoning and Machine Learning, Cambridge, 2012 Duda, Hart, Stork: Pattern Classification, Wiley, 2001 Bishop: Pattern Recognition and Machine Learning, Springer 2006 Salomon, Data Compression, the Complete Reference, Springer, 2000 Sayood, Introduction to Data Compression, Morgan Kaufmann, 2006 Ohm, Multimedia Communication Technology, Springer, 2004 Solari, Digital video and audio compression, McGraw-Hill, 1997 Tekalp, Digital Video Processing, Prentice Hall, 1995

Module M0558: Operations Research

Courses

Title	Typ	Hrs/wk	CP
Operations Research (L0155)	Lecture	2	3
Operations Research - Seminar (L0156)	Seminar	2	3

Module Responsible	Prof. Kathrin Fischer
Admission Requirements	None
Recommended Previous Knowledge	Knowledge from the module "Quantitative Methods": Linear Programming, Network Optimization and basics of Integer Programming.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students have an in-depth knowledge of the following areas: They are able to • explain complex quantitative models for applications, e.g. production models with integrated inventory holding over time, portfolio models, revenue management models • Discuss advanced topics in linear programming, e.g, duality theory and its application, special structures as upper/lower bounds for variables; revised simplex method etc. • Study problems with multiple objectives and under uncertainty, i.e. the adaption of linear programming models to realistic applications • Discuss advanced topics in integer programming: complex problems, e.g. from vehicle routing, and logical constraints; advanced solutions procedures as branch and bound, cutting-plane procedures etc. • Examine dynamic and non-linear programming problems and applications in Management
Skills	Students have in-depth abilities in the following areas: They are able to • formulate complex quantitative models for applications, e.g. production models with integrated inventory holding over time, portfolio models, revenue management models • Apply duality theory in linear programming and analyze special structures as upper/lower bounds for variables; use the revised simplex method etc. • Analyze problems with multiple objectives and under uncertainty, i.e. the adaption of linear programming models to realistic applications • Set up advanced models in integer programming and solve them, e.g. problems from vehicle routing, or logical constraints • Analyze dynamic and non-linear programming problems and applications in Management
Personal Competence	
Social Competence	Students are able to • work successfully in a team, organize the team, and solve complex tasks in a team in a given time frame • give structured feedback, following feedback rules, and also accept deeback from their fellow students • lead discussions on problems from the field of OR • present the results of their work to specialists.
Autonomy	Students are able to • independently acquire relevant scientific knowledge from the literature • independently carry out a (pre-defined) complex research task • aggregate their knowledge and results and present it to others • apply their knowledge and experience also to new problems and unknown situations.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Examination	Homework
Examination duration and scale	To be announced in Lecture
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory Logistics, Infrastructure and Mobility: Core qualification: Elective Compulsory

Course L0155: Operations Research	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Kathrin Fischer
Language	DE
Cycle	SoSe
Content	• Complex quantitative models for applications, e.g. production models with integrated inventory holding over time, portfolio models, revenue management models • Advanced topics in linear programming, e.g, duality theory and its application, special structures as upper/lower bounds for variables; revised simplex method etc. • Problems with multiple objectives and under uncertainty: adaption of linear programming models to realistic applications • Advanced topics in integer programming: Modelling complex problems, e.g. from vehicle routing, and logical constraints; advanced solutions procedures as branch and bound, cutting-plane procedures etc. • Dynamic and non-linear programming and its applications in Management • Applications of models and methods in the area of supply chain management and logistics, e.g. in location planning etc.
Literature	Bücher: Albright, C., Winston, W.: Management Science Modeling. Revised Third Edition, South-Western 2009. Eiselt, H.A., Sandblom, C.-L.: Linear Programming and its Applications, Springer 2007. Eiselt, H.A., Sandblom, C.-L.: Integer Programming and Network Models, Springer 2000. Eiselt, H.A., Sandblom, C.-L.: Decision Analysis, Location Models, and Scheduling Problems, Springer 2004. Suhl, L., Mellouli, T.: Optimierungssysteme. Springer, Berlin et al., 2. Auflage, 2009. Williams, H.P.: Model Building in Mathematical Programming. 5th edition, Wiley & Sons, 2013. Winston, W., Venkataramanan, M.: Mathematical Programming. Operations Research, Volume 1, 4th Edition, Thomson, London et al. 2003. Sowie ein Skript, das zur Vorlesung herausgegeben wird.

Course L0156: Operations Research - Seminar	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Kathrin Fischer
Language	DE
Cycle	SoSe
Content	Special topics from different areas of the lecture are discussed in the seminar. Students are required to use current publications from highly esteemed journals in their assignment and to write an essay on a relevant OR topic. Moreover, they have to prepare and give a talk on that topic. The seminar is research-oriented and focuses on relevant research topics from the field.
Literature	Fachartikel (Journal Papers), die zu Beginn des Seminars bekanntgegeben werden.

Module M0587: Numerical and Seminumerical Programming

Courses

Title	Typ	Hrs/wk	CP
Numerical and Seminumerical Programming (L0124)	Lecture	2	3
Numerical and Seminumerical Programming (L1210)	Recitation Section (small)	2	3

Module Responsible	Prof. Siegfried Rump
Admission Requirements	Bachelor IIW or Mathematics
Recommended Previous Knowledge	Lecture numerics and computer algebra Basic knowledge in numerics and discrete mathematics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students have deeper knowledge of numerical, heuristical and exact methods. For several fundamental problems they know approximative and exact solution possibilities. They can distinguish between exact and heuristical approximative Solutions.
Skills	The students are able to analyze in depth complex problems in mathematics and computer science. In particular they can analyze the sensitivity of the solution and can calculate verified error bounds for a solution. For NP-hard problems they can derive efficient and heuristic algorithms.
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	
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory

Course L0124: Numerical and Seminumerical Programming

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	SoSe
Content	• Verification methods for linear and nonlinear systems • Sensitivity analysis • Ill-conditioned problems • Interactive packages: Maple, Mathematica, Matlab • Heuristic algorithms: threshold accepting, simulated annealing • Matrix memory • Neural networks
Literature	Golub, G.H. and Van Loan, Ch.: Matrix Computations, John Hopkins University Press, 3rd edition, 1996 Higham, N.J.: Accuracy and stability of numerical algorithms, SIAM Publications, Philadelphia, 2nd edition, 2002 S.M. Rump. Verification methods: Rigorous results using floating-point arithmetic. Acta Numerica, 19:287–449, 2010.

Course L1210: Numerical and Seminumerical Programming

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	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) programming skills, R/Matlab
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 Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory 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 - calibration - tracking systems - navigation and image guidance - motion compensation 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 Troccaz: Medical Robotics, 2012 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 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	
Recommended Previous Knowledge	• Calculus • 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
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: 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	NN
Language	EN
Cycle	SoSe
Content	• Decision trees • First-order inductive learning • Incremental learning: Version spaces • Uncertainty • Bayesian networks • Learning parameters of Bayesian networks BME, MAP, ML, EM algorithm • Learning structures of Bayesian networks • Gaussian Mixture Models • kNN classifier, neural network classifier, support vector machine (SVM) classifier • Clustering Distance measures, k-means clustering, nearest neighbor clustering • Kernel Density Estimation • Ensemble Learning • Reinforcement Learning • Computational Learning Theory
Literature	1. Artificial Intelligence: A Modern Approach (Third Edition), Stuart Russel, Peter Norvig, Prentice Hall, 2010, Chapters 13, 14, 18-21 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	NN
Language	EN
Cycle	SoSe
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 • 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 • Implementing an exemplary 3D or volumetric analysis task • Using highly sophisticated methods and procedures of the subject area • Identifying problems and • Developing and implementing creative solution suggestions. With assistance from the teacher students are able to link the contents of the three subject areas (modules) • Digital Image Analysis • Pattern Recognition and Data Compression and • 3D Computer Vision 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. 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
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: 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 • Projection matrix, calibration • Epipolar Geometry, fundamental and essential matrices, weak calibration, 5 point algorithm • Homographies 2D and 3D • Trifocal Tensor • Correspondence search
Literature	• **Skriptum Grigat/Wenzel** • 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 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 Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: 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 **Bildgebende Systeme für die medizinische Diagnostik**; H. Morneburg (Hrsg.); Publicis MCD, München, 1995 **Introduction to the Mathematics of Medical Imaging**; C. L.Epstein; Siam, Philadelphia, 2008 **Medical Image Processing, Reconstruction and Restoration**; J. Jan; Taylor and Francis, Boca Raton, 2006 **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 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) • principles of stochastics • principles of programming, Java/C++ and R/Matlab • 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 Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory 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 - representation of medical knowledge - understanding challenges due to clinical and patient related data and data acquisition 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 Berner: Clinical Decision Support Systems: Theory and Practice, 2007 Greenes: Clinical Decision Support: The Road Ahead, 2007 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 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 principles of automata principles of algorithms and data structures 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 Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Production Management: Specialisation Production Technology: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory 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 - properties of processes, modeling using automata and Petri-nets - design considerations for processes (mutex, deadlock avoidance, liveness) - optimal scheduling for processes - optimal decisions when planning manufacturing systems, decisions under uncertainty - software design and software architectures for automation, PLCs
Literature	J. Lunze: „Automatisierungstechnik“, Oldenbourg Verlag, 2012 Reisig: Petrinetze: Modellierungstechnik, Analysemethoden, Fallstudien; Vieweg+Teubner 2010 Hrúz, Zhou: Modeling and Control of Discrete-event Dynamic Systems; Springer 2007 Li, Zhou: Deadlock Resolution in Automated Manufacturing Systems, Springer 2009 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 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

Module Responsible	Prof. Udo Zölzer
Admission Requirements	None
Recommended Previous Knowledge	
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 Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory 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) • Quantization (Signal Quantization, Dither, Noise Shaping, Number Representation) • AD/DA Conversion (Methods, AD Converters, DA Converters, Audio Processing Systems, Digital Signal Processors, Digital Audio Interfaces, Single-Processor Systems, Multiprocessor Systems) • Equalizers (Recursive Audio Filters, Nonrecursive Audio Filters, Multi-Complementary Filter Bank) • Room Simulation (Early Reflections, Subsequent Reverberation, Approximation of Room Impulse Responses) • Dynamic Range Control (Static Curve, Dynamic Behavior, Implementation, Realization Aspects) • Sampling Rate Conversion (Synchronous Conversion, Asynchronous Conversion, Interpolation Methods) • Data Compression (Lossless Data Compression, Lossy Data Compression, Psychoacoustics, ISO-MPEG1 Audio Coding)
Literature	- U. Zölzer, Digitale Audiosignalverarbeitung, 3. Aufl., B.G. Teubner, 2005. - U. Zölzer, Digitale Audio Signal Processing, 2nd Edition, J. Wiley & Sons, 2005. - 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	
Literature	

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 minutes
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Technomathematics: Specialisation II. Informatics: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory 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 • Error-free transformations • Verification methods for linear and nonlinear systems • Verification methods for finite integrals • Treatment of multiple zeros • Automatic differentiation • Implementation in Matlab/INTLAB • Practical applications
Literature	Neumaier: Interval Methods for Systems of Equations. In: Encyclopedia of Mathematics and its Applications. Cambridge University Press, 1990 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 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	Optimal and Robust Control
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 Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory 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 - Linearizing gain scheduling, hidden coupling - Jacobian linearization vs. quasi-LPV models - Stability and induced L2 norm of LPV systems - Synthesis of LPV controllers based on the two-sided projection lemma - Simplifications: controller synthesis for polytopic and LFT models - Experimental identification of LPV models - Controller synthesis based on input/output models - Applications: LPV torque vectoring for electric vehicles, LPV control of a robotic manipulator • Control of Multi-Agent Systems - Communication graphs - Spectral properties of the graph Laplacian - First and second order consensus protocols - Formation control, stability and performance - LPV models for agents subject to nonholonomic constraints - Application: formation control for a team of quadrotor helicopters • Control of Spatially Interconnected Systems - Multidimensional signals, l2 and L2 signal norm - Multidimensional systems in Roesser state space form - Extension of real-bounded lemma to spatially interconnected systems - LMI-based synthesis of distributed controllers - Spatial LPV control of spatially varying systems - Applications: control of temperature profiles, vibration damping for an actuated beam
Literature	• Werner, H., Lecture Notes "Advanced Topics in Control" • 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

Thesis

Module M-002: Master Thesis

Courses

Title	Typ	Hrs/wk	CP

Module Responsible	Professoren der TUHH
Admission Requirements	• According to General Regulations §24 (1): At least 126 ECTS 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. • 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. • 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: • To select, apply and, if necessary, develop further methods that are suitable for solving the specialized problem in question. • 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. • To develop new scientific findings in their subject area and subject them to a critical assessment.
Personal Competence	
Social Competence	Students can • Both in writing and orally outline a scientific issue for an expert audience accurately, understandably and in a structured way. • 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: • To structure a project of their own in work packages and to work them off accordingly. • To work their way in depth into a largely unknown subject and to access the information required for them to do so. • 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	according to Subject Specific Regulations
Examination duration and scale	see FSPO
Assignment for the Following Curricula	Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy and Environmental Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Global Innovation Management: Thesis: Compulsory Computational Science and Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Production Management: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Joint European Master in Environmental Studies - Cities and Sustainability: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Materials Science: Thesis: Compulsory Mechanical Engineering and Management: Thesis: Compulsory Mechatronics: Thesis: Compulsory Biomedical Engineering: Thesis: Compulsory Microelectronics and Microsystems: Thesis: Compulsory Product Development, Materials and Production: Thesis: Compulsory Renewable Energies: Thesis: Compulsory Naval Architecture and Ocean Engineering: Thesis: Compulsory Ship and Offshore Technology: Thesis: Compulsory Theoretical Mechanical Engineering: Thesis: Compulsory Process Engineering: Thesis: Compulsory Water and Environmental Engineering: Thesis: Compulsory