TUHH
Hamburg
University of
Technology

Module Manual

Master of Science (M.Sc.)

Mechatronics
Dual study program

Cohort: Winter Term 2022

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Program description

Content

The consecutive international master program "Mechatronics" extends the education in engineering, mathematics and natural science of the bachelor studies. It provides systematic, scientific and autonomous problem solving capabilities needed in industry and research.

The program covers the methods of computation, design and implementation of mechatronic systems.Students specialize in one out of two concentrations and develop the ability to work in the interfaces of the interconnected sub-disciplines. Based on personal interest, students are able to adapt their study programs within a broad catalogue of elective courses.

In addition to the foundational curriculum taught at TUHH, seminars on developing personal skills are integrated into the dual study programme, in the context of transfer between theory and practice. These seminars correspond to the modern professional requirements expected of an engineer, as well as promoting the link between the two places of learning.

The intensive dual courses at TUHH integrating practical experience consist of an academic-oriented and a practice-oriented element, which are completed at two places of learning. The academic-oriented element comprises study at TUHH. The practice-oriented element is coordinated with the study programme in terms of content and time, and consists of practical modules and phases spent in an affiliate company during periods when there are no lectures.

Career prospects

The consecutive international Master course "Mechatronics" prepares graduates for a wide range of job profiles in mechatronics engineering.

Graduates can work directly in their specialization area: System Design and Intelligent Systems and Robotics.

Additionally graduates have a multifaceted knowledge of methods for interdisciplinary topics.

Graduates may decide for direct entry into companies or to take up academic careers, e.g. Ph.D. studies, in universities or other research institutions. In companies they can take up jobs as specialists or subsequently qualify for demanding management tasks in the technical area (e.g. project, group, or team leader; R&D director).

The program is designed to be universal and allows graduates to work in a variety of different industrial sectors and with different projects.

In addition, students acquire basic professional and personal skills as part of the dual study programme that enable them to enter professional practice at an early stage and to go on to further study. Students also gain practical work experience through the integrated practical modules. Graduates of the dual course have broad foundational knowledge, fundamental skills for academic work and relevant personal competences.

Learning target

Graduates of the program are able to transfer the individually acquired specialized knowledge to new, unknown topics, to comprehend, to analyze and to scientifically solve complex problems of their discipline. They can find missing information and plan as well as execute theoretical and experimental studies. They are able to judge, evaluate and question scientific engineering results critically as well as making decisions based on this foundation and draw further conclusions. They are able to act methodically, to organize smaller projects, to select new technologies and scientific methods and to advance these further, if necessary.

Graduates can develop and document new ideas and solutions, independently or in teams. They are capable of presenting and discussing results to and with professionals. They can estimate their own strengths and weaknesses as well as possible consequences of their actions. They are capable of familiarizing themselves with complex tasks, defining new tasks and developing the necessary knowledge to solve them using systematically applied, appropriate means.

System Design

In the system design specialization, graduates learn how to work systematically and methodically on challenging design tasks.

They have broad knowledge of new development methods, are able to select appropriate solution strategies and use these autonomously to develop new products. They are qualified to use the approaches of integrated system development, such as simulation or modern testing procedures.

Intelligent Systems and Robotics

In the intelligent systems and robotics specialization, graduates learn how to work systematically and methodically on challenging tasks.

They have broad knowledge of automation and simulation and are able to select appropriate solution strategies and use these autonomously to develop intelligent systems.

By continually switching places of learnings throughout the dual study programme, it is possible for theory and practice to be interlinked. Students reflect theoretically on their individual professional practical experience, and apply the results of their reflection to new forms of practice. They also test theoretical elements of the course in a practical setting, and use their findings as a stimulus for theoretical debate.

Program structure

The course is designed modularly and is based on the university-wide standardized course structure with uniform module sizes (multiples of six credit points (CP)).

The program combines the disciplines of mechanical and electrical engineering and supports concentration in interdisciplinary fields of system design and system implementation.

All modules in the first semester are mandatory. This helps especially students from abroad to familiarize themselves with the university and culture.

Afterwards the students can broadly personalize their studies due to the high number and variety of elective courses.

In the common core skills, students take the following modules:

- Finite element analysis and Vibration theory (12 CP)
- Theory and design of control systems and Design and implementation of software systems
- Robotics and Mechatronic system
- Complementary courses business and management (catalogue) (6 CP)
- Nontechnical elective complementary courses (catalogue) (6 CP).

Students specialize by selecting one of the following areas, each covering 30 credit points:

- System design
- Intelligent systems and robotics.

Within each area of specialization 30 credits can be chosen form a module catalog containing modules with a size of six credits. Instead, open modules can be attend to the maximum extent of twelve credit points, in which smaller specialized courses can be combined, individually.

Students write a master thesis and one additional scientific project work.

- Project work (12 CP)
- Master thesis (30 CP)

The structural model of the dual study programme follows a module-differentiating approach. Given the practice-oriented element, the curriculum of the dual study programme is different compared to a standard Bachelor’s course. Five practical modules are completed at the dual students’ partner company as part of corresponding practical terms during lecture-free periods.

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	• Students are able to communicate in small interdisciplinary groups and to jointly develop solutions for complex problems
Autonomy	• Students are capable of acquiring necessary knowledge independently by means of research and preparation of material.
Workload in Hours	Depends on choice of courses
Credit points	6

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

Module M0563: Robotics

Courses

Title	Typ	Hrs/wk	CP
Robotics: Modelling and Control (L0168)	Integrated Lecture	4	4
Robotics: Modelling and Control (L1305)	Project-/problem-based Learning	2	2

Module Responsible	Dr. Martin Gomse
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of electrical engineering Broad knowledge of mechanics Fundamentals of control theory
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe fundamental properties of robots and solution approaches for multiple problems in robotics.
Skills	Students are able to derive and solve equations of motion for various manipulators. Students can generate trajectories in various coordinate systems. Students can design linear and partially nonlinear controllers for robotic manipulators.
Personal Competence	
Social Competence	Students are able to work goal-oriented in small mixed groups.
Autonomy	Students are able to recognize and improve knowledge deficits independently. With instructor assistance, students are able to evaluate their own knowledge level and define a further course of study.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	Compulsory: Yes; Bonus: None; Form: Subject theoretical and practical work; Description: Teilnahme an PBL-Einheiten sowie Erreichen des Gesamtziels und der jeweiligen Session-Ziele
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: 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 Robotics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory

Course L0168: Robotics: Modelling and Control

Typ	Integrated Lecture
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Dr. Martin Gomse
Language	EN
Cycle	WiSe
Content	Fundamental kinematics of rigid body systems Newton-Euler equations for manipulators Trajectory generation Linear and nonlinear control of robots
Literature	Craig, John J.: Introduction to Robotics Mechanics and Control, Third Edition, Prentice Hall. ISBN 0201-54361-3 Spong, Mark W.; Hutchinson, Seth; Vidyasagar, M. : Robot Modeling and Control. WILEY. ISBN 0-471-64990-2

Course L1305: Robotics: Modelling and Control	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Martin Gomse
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0808: Finite Elements Methods

Courses

Title	Typ	Hrs/wk	CP
Finite Element Methods (L0291)	Lecture	2	3
Finite Element Methods (L0804)	Recitation Section (large)	2	3

Module Responsible	Prof. Otto von Estorff
Admission Requirements	None
Recommended Previous Knowledge	Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics) Mathematics I, II, III (in particular differential equations)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students possess an in-depth knowledge regarding the derivation of the finite element method and are able to give an overview of the theoretical and methodical basis of the method.
Skills	The students are capable to handle engineering problems by formulating suitable finite elements, assembling the corresponding system matrices, and solving the resulting system of equations.
Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	The students are able to independently solve challenging computational problems and develop own finite element routines. Problems can be identified and the results are critically scrutinized.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** No / 20 % / Midterm
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory

Course L0291: Finite Element Methods	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	WiSe
Content	- General overview on modern engineering - Displacement method - Hybrid formulation - Isoparametric elements - Numerical integration - Solving systems of equations (statics, dynamics) - Eigenvalue problems - Non-linear systems - Applications - Programming of elements (Matlab, hands-on sessions) - Applications
Literature	Bathe, K.-J. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin

Course L0804: Finite Element Methods	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0846: Control Systems Theory and Design

Courses

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

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	Introduction to Control Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain how linear dynamic systems are represented as state space models; they can interpret the system response to initial states or external excitation as trajectories in state space • 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
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Electrical Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Computer Science in Engineering: Specialisation II. Engineering Science: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation 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 M1222: Design and Implementation of Software Systems

Courses

Title	Typ	Hrs/wk	CP
Design and Implementation of Software Systems (L1657)	Lecture	2	3
Design and Implementation of Software Systems (L1658)	Practical Course	2	3

Module Responsible	Prof. Bernd-Christian Renner
Admission Requirements	None
Recommended Previous Knowledge	- Imperativ programming languages (C, Pascal, Fortran or similar) - Simple data types (integer, double, char, boolean), arrays, if-then-else, for, while, procedure and function calls
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe mechatronic systems and define requirements.
Skills	Students are able to design and implement mechatronic systems. They are able to argue the combination of Hard- and Software and the interfaces.
Personal Competence	
Social Competence	Students are able to work goal-oriented in small mixed groups, learning and broadening teamwork abilities and define task within the team.
Autonomy	Students are able to solve individually exercises related to this lecture with instructional direction. Students are able to plan, execute and summarize a mechatronic experiment.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description**: No / 10 % / Attestation
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Mechatronics: Core Qualification: Compulsory

Course L1657: Design and Implementation of Software Systems

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Bernd-Christian Renner
Language	EN
Cycle	WiSe
Content	This course covers software design and implementation of mechatronic systems, tools for automation in Java. Content: • Introduction to software techniques • Procedural Programming • Object oriented software design • Java • Event based programming • Formal methods
Literature	• "The Pragmatic Programmer: From Journeyman to Master"Andrew Hunt, David Thomas, Ward Cunningham • "Core LEGO MINDSTORMS Programming: Unleash the Power of the Java Platform" Brian Bagnall Prentice Hall PTR, 1st edition (March, 2002) ISBN 0130093645 • "Objects First with Java: A Practical Introduction using BlueJ" David J. Barnes & Michael Kölling Prentice Hall/ Pearson Education; 2003, ISBN 0-13-044929-6

Course L1658: Design and Implementation of Software Systems

Typ	Practical Course
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Bernd-Christian Renner
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0751: Vibration Theory

Courses

Title	Typ	Hrs/wk	CP
Vibration Theory (L0701)	Integrated Lecture	4	6

Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	None
Recommended Previous Knowledge	• Calculus • Linear Algebra • Engineering Mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to denote terms and concepts of Vibration Theory and develop them further. • Students know methods of modeling and simulation for free, driven, self-excited and parameter driven vibrations. • Students know about concepts of linear and nonlinear vibration problems. • Students know basic tasks of vibration problems of discrete and continuous systems.
Skills	• Students are able to denote methods of Vibration Theory and develop them further. • Students are able to apply and expand methods of modeling and simulation for free, forced, self-excited and parameter driven vibrations. • Students are able to solve linear and nonlinear vibration problems.
Personal Competence	
Social Competence	• Students can analyze vibration problems, work on them, and reach working results also in teams or groups. • Students are able to document the results of vibration studies also in groups.
Autonomy	• Students are able to individually analyze and solve vibration problems. • Students are able to approach individually research tasks in Vibration Theory.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	2 Hours
Assignment for the Following Curricula	Energy Systems: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation 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: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L0701: Vibration Theory

Typ	Integrated Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Norbert Hoffmann
Language	DE/EN
Cycle	WiSe
Content	Linear and Nonlinear Single and Multiple Degree of Freedom Vibrations • Free vibration • Self-excited vibration • Parameter driven vibration • Forced vibration • Multi degree of freedom vibration • Continuum vibration • Irregular vibration
Literature	German - K. Magnus, K. Popp, W. Sextro: Schwingungen. Physikalische Grundlagen und mathematische Behandlung von Schwingungen. English - K. Magnus: Vibrations.

Module M1759: Linking theory and practice (dual study program, Master's degree)	
Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of practical modules as part of the dual Bachelor’s course • Module "interlinking theory and practice as part of the dual Master’s course"
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... ... can describe and classify selected classic and current theories, concepts and methods • related to project management and • change and transformation management ... and apply them to specific situations, processes and plans in a personal, professional context.
Skills	Dual students ... • ... anticipate typical difficulties, positive and negative effects, as well as success and failure factors in the engineering sector, evaluate them and consider promising strategies and courses of action. • ... develop specialised technical and conceptual skills to solve complex tasks and problems in their professional field of activity/work.
Personal Competence	
Social Competence	Dual students ... • ... can responsibly lead interdisciplinary teams within the framework of complex tasks and problems. • ... engage in sector-specific and cross-sectoral discussions with experts, stakeholders and staff, representing their approaches, points of view and work results.
Autonomy	Dual students ... • ... define, reflect and evaluate goals and measures for complex application-oriented projects and change processes. • ... shape their professional area of responsibility independently and sustainably. • ... take responsibility for their actions and for the results of their work.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Studienbegleitende und semesterübergreifende Dokumentation: Die Leistungspunkte für das Modul werden durch die Anfertigung eines digitalen Lern- und Entwicklungsberichtes (E-Portfolio) erworben. Dabei handelt es sich um eine fortlaufende Dokumentation und Reflexion der Lernerfahrungen und der Kompetenzentwicklung im Bereich der Personalen Kompetenz.

Course L2890: Responsible Project Management in Engineering (for Dual Study Program)	
Typ	Seminar
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Henning Haschke, Heiko Sieben
Language	DE
Cycle	WiSe/SoSe
Content	• Theories and methods of project management • Innovation management • Agile project management • Fundamentals of classic and agile methods • Hybrid use of classic and agile methods • Roles, perspectives and stakeholders throughout the project • Initiating and coordinating complex engineering projects • Principles of moderation, team management, team leadership, conflict management • Communication structures: in-house, cross-company • Public information policy • Promoting commitment and empowerment • Sharing experience with specialists and managers from the engineering sector • Documenting and reflecting on learning experiences
Literature	Seminarapparat

Course L2891: Responsible Change and Transformation Management in Engineering (for Dual Study Program)	
Typ	Seminar
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Henning Haschke, Heiko Sieben
Language	DE
Cycle	WiSe/SoSe
Content	• Basic concepts, opportunities and limits of organisational change • Models and methods of organisational design and development • Strategic orientation and change, and their short-, medium- and long-term consequences for individuals, organisations and society as a whole • Roles, perspectives and stakeholders in change processes • Initiating and coordinating change measures in engineering • Phase models of organisational change (Lewin, Kotter, etc.) • Change-oriented information policy and dealing with resistance and uncertainty • Promoting commitment and empowerment • Successfully handling change and transformation: personally, as an employee, as a manager (personal, professional, organisational) • Company-level and globally (systemic) • Sharing experience with specialists and managers from the engineering sector • Documenting and reflecting on learning experiences
Literature	Seminarapparat

Module M1756: Practical module 1 (dual study program, Master's degree)

Courses

Title	Typ	Hrs/wk	CP
Practical term 1 (dual study program, Master's degree) (L2887)		0	10

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of a compatible dual B.Sc. at TU Hamburg or comparable practical work experience and competences in the area of interlinking theory and practice • Course D from the module on interlinking theory and practice as part of the dual Master's course
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... combine their knowledge of facts, principles, theories and methods gained from previous study content with acquired practical knowledge - in particular their knowledge of practical professional procedures and approaches, in the current field of activity in engineering. • ... have a critical understanding of the practical applications of their engineering subject.
Skills	Dual students ... • ... apply technical theoretical knowledge to complex, interdisciplinary problems within the company, and evaluate the associated work processes and results, taking into account different possible courses of action. • ... implement the university's application recommendations with regard to their current tasks. • ... develop solutions as well as procedures and approaches in their field of activity and area of responsibility.
Personal Competence	
Social Competence	Dual students ... • ... work responsibly in project teams within their working area and proactively deal with problems within their team. • ... represent complex engineering viewpoints, facts, problems and solution approaches in discussions with internal and external stakeholders.
Autonomy	Dual students ... • ... define goals for their own learning and working processes as engineers. • ... reflect on learning and work processes in their area of responsibility. • ... reflect on the relevance of subject modules specialisations and specialisation for work as an engineer, and also implement the university's application recommendations and the associated challenges to positively transfer knowledge between theory and practice.
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Credit points	10
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Compulsory Environmental Engineering: Core Qualification: Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Information and Communication Systems: Core Qualification: Compulsory International Management and Engineering: Core Qualification: Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Compulsory Materials Science: Core Qualification: Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Core Qualification: Compulsory Microelectronics and Microsystems: Core Qualification: Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Renewable Energies: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory Water and Environmental Engineering: Core Qualification: Compulsory

Course L2887: Practical term 1 (dual study program, Master's degree)	
Typ	
Hrs/wk	0
CP	10
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe/SoSe
Content	**Company onboarding process** • Assigning a professional field of activity as an engineer (B.Sc.) and associated fields of work • Establishing responsibilities and authorisation of the dual student within the company as an engineer (B.Sc.) • Working independently in a team and on selected projects - across departments and, if applicable, across companies • Scheduling the current practical module with a clear correlation to work structures • Scheduling the examination phase/subsequent study semester **Operational knowledge and skills** • Company-specific: Responsibility as an engineer (B.Sc.) in their own area of work, coordinating team and project work, dealing with complex contexts and unsolved problems, developing and implementing innovative solutions • Subject specialisation (corresponding to the chosen course [M.Sc.]) in the field of activity • Systemic skills • Implementing the university’s application recommendations (theory-practice transfer) in corresponding work and task areas across the company **Sharing/reflecting on learning** • Creating an e-portfolio • Importance of course contents (M.Sc.) when working as an engineer • Importance of development and innovation when working as an engineer
Literature	• Studierendenhandbuch • Betriebliche Dokumente • Hochschulseitige Handlungsempfehlungen zum Theorie-Praxis-Transfer

Module M1757: Practical module 2 (dual study program, Master's degree)

Courses

Title	Typ	Hrs/wk	CP
Practical term 2 (dual study program, Master's degree) (L2888)		0	10

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of practical module 1 as part of the dual Master's course • course D from the module on interlinking theory and practice as part of the dual Master's course
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... combine their knowledge of facts, principles, theories and methods gained from previous study content with acquired practical knowledge - in particular their knowledge of practical professional procedures and approaches, in the current field of activity in engineering. • ... have a critical understanding of the practical applications of their engineering subject.
Skills	Dual students ... • ... apply technical theoretical knowledge to complex, interdisciplinary problems within the company, and evaluate the associated work processes and results, taking into account different possible courses of action. • ... implement the university's application recommendations with regard to their current tasks. • ... develop (new) solutions as well as procedures and approaches in their field of activity and area of responsibility - including in the case of frequently changing requirements (systemic skills).
Personal Competence	
Social Competence	Dual students ... • ... work responsibly in cross-departmental and interdisciplinary project teams and proactively deal with problems within their team. • ... represent complex engineering viewpoints, facts, problems and solution approaches in discussions with internal and external stakeholders and develop these further together.
Autonomy	Dual students ... • ... define goals for their own learning and working processes as engineers. • ... reflect on learning and work processes in their area of responsibility. • ... reflect on the relevance of subject modules specialisations and specialisation for work as an engineer, and also implement the university's application recommendations and the associated challenges to positively transfer knowledge between theory and practice.
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Credit points	10
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Compulsory Environmental Engineering: Core Qualification: Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Information and Communication Systems: Core Qualification: Compulsory International Management and Engineering: Core Qualification: Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Compulsory Materials Science: Core Qualification: Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Core Qualification: Compulsory Microelectronics and Microsystems: Core Qualification: Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Renewable Energies: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory Water and Environmental Engineering: Core Qualification: Compulsory

Course L2888: Practical term 2 (dual study program, Master's degree)	
Typ	
Hrs/wk	0
CP	10
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe/SoSe
Content	**Company onboarding process** • Assigning a professional field of activity as an engineer (B.Sc.) and associated fields of work • Establishing responsibilities and authorisation of the dual student within the company as an engineer (B.Sc.) • Taking personal responsibility within a team and on selected projects - across departments and, if applicable, across companies • Scheduling the current practical module with a clear correlation to work structures • Scheduling the examination phase/subsequent study semester **Operational knowledge and skills** • Company-specific: Responsibility as an engineer (B.Sc.) in their own area of work, coordinating team and project work, dealing with complex contexts and unsolved problems, developing and implementing innovative solutions • Subject specialisation (corresponding to the chosen course [M.Sc.]) in the field of activity • Systemic skills • Implementing the university’s application recommendations (theory-practice transfer) in corresponding work and task areas across the company **Sharing/reflecting on learning** • Updating their e-portfolio • Importance of course contents (M.Sc.) when working as an engineer • Importance of development and innovation when working as an engineer
Literature	• Studierendenhandbuch • Betriebliche Dokumente • Hochschulseitige Anwendungsempfehlungen zum Theorie-Praxis-Transfer

Module M0836: Communication Networks

Courses

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

Module Responsible	Prof. Andreas Timm-Giel
Admission Requirements	None
Recommended Previous Knowledge	• Fundamental stochastics • 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
Course achievement	None
Examination	Presentation
Examination duration and scale	1.5 hours colloquium with three students, therefore about 30 min per student. Topics of the colloquium are the posters from the previous poster session and the topics of the module.
Assignment for the Following Curricula	Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: 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 International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L0899: Selected Topics of Communication Networks

Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr.-Ing. Koojana Kuladinithi
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 L0897: Communication Networks	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr.-Ing. Koojana Kuladinithi
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 L0898: Communication Networks Excercise	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Dr.-Ing. Koojana Kuladinithi
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 M1211: Research Project Mechatronics

Courses

Title	Typ	Hrs/wk	CP

Module Responsible	Dozenten des Studiengangs
Admission Requirements	None
Recommended Previous Knowledge	Subjects of the program of studies.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to demonstrate their detailed knowledge in the field of mechatronics engineering. They can exemplify the state of technology and application and discuss critically in the context of actual problems and general conditions of science and society. The students can develop solving strategies and approaches for fundamental and practical problems in mechatronics engineering. They may apply theory based procedures and integrate safety-related, ecological, ethical, and economic view points of science and society. Scientific work techniques that are used can be described and critically reviewed.
Skills	The students are able to independently select methods for the project work and to justify this choice. They can explain how these methods relate to the field of work and how the context of application has to be adjusted. General findings and further developments may essentially be outlined.
Personal Competence	
Social Competence	The students are able to condense the relevance and the structure of the project work, the work steps and the sub-problems for the presentation and discussion in front of a bigger group. They can lead the discussion and give a feedback on the project to their colleagues.
Autonomy	The students are capable of independently planning and documenting the work steps and procedures while considering the given deadlines. This includes the ability to accurately procure the newest scientific information. Furthermore, they can obtain feedback from experts with regard to the progress of the work, and to accomplish results on the state of the art in science and technology.
Workload in Hours	Independent Study Time 360, Study Time in Lecture 0
Credit points	12
Course achievement	None
Examination	Study work
Examination duration and scale	lt. FSPO
Assignment for the Following Curricula	Mechatronics: Core Qualification: Compulsory

Module M1758: Practical module 3 (dual study program, Master's degree)

Courses

Title	Typ	Hrs/wk	CP
Practical term 3 (dual study program, Master's degree) (L2889)		0	10

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of practical module 2 as part of the dual Master’s course • course E from the module on interlinking theory and practice as part of the dual Master’s course
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... combine their comprehensive and specialised engineering knowledge acquired from previous study contents with the strategy-oriented practical knowledge gained from their current field of work and area of responsibility. • ... have a critical understanding of the practical applications of their engineering subject, as well as related fields when implementing innovations.
Skills	Dual students ... • ... apply specialised and conceptual skills to solve complex, sometimes interdisciplinary problems within the company, and evaluate the associated work processes and results, taking into account different possible courses of action. • ... implement the university’s application recommendations with regard to their current tasks. • ... develop new solutions as well as procedures and approaches to implement operational projects and assignments - even when facing frequently changing requirements and unpredictable changes (systemic skills). • ... can use academic methods to develop new ideas and procedures for operational problems and issues, and to assess these with regard to their usability.
Personal Competence	
Social Competence	Dual students ... • ... work responsibly in cross-departmental and interdisciplinary project teams and proactively deal with problems within their team. • ... can promote the professional development of others in a targeted manner. • ... represent complex and interdisciplinary engineering viewpoints, facts, problems and solution approaches in discussions with internal and external stakeholders and develop these further together.
Autonomy	Dual students ... • ... reflect on learning and work processes in their area of responsibility. • ... define goals for new application-oriented tasks, projects and innovation plans while reflecting on potential effects on the company and the public. • ... reflect on the relevance of areas of specialisation and research for work as an engineer, and also implement the university’s application recommendations and the associated challenges to positively transfer knowledge between theory and practice.
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Credit points	10
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Compulsory Environmental Engineering: Core Qualification: Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Information and Communication Systems: Core Qualification: Compulsory International Management and Engineering: Core Qualification: Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Compulsory Aeronautics: Core Qualification: Compulsory Materials Science and Engineering: Core Qualification: Compulsory Materials Science: Core Qualification: Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Core Qualification: Compulsory Microelectronics and Microsystems: Core Qualification: Compulsory

	Product Development, Materials and Production: Core Qualification: Compulsory Renewable Energies: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory Water and Environmental Engineering: Core Qualification: Compulsory

Course L2889: Practical term 3 (dual study program, Master's degree)	
Typ	
Hrs/wk	0
CP	10
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe/SoSe
Content	**Company onboarding process** • Assigning a future professional field of activity as an engineer (M.Sc.) and associated fields of work • Extending responsibilities and authorisation of the dual student within the company up to the intended first assignment after completing their studies • Working responsibly in a team; project responsibility within own area - as well as across divisions and companies if necessary • Scheduling the final practical module with a clear correlation to work structures • Internal agreement on a potential topic or innovation project for the Master's dissertation • Planning the Master's dissertation within the company in cooperation with TU Hamburg • Scheduling the examination phase/subsequent study semester **Operational knowledge and skills** • Company-specific: dealing with change, project and team development, responsibility as an engineer in their future field of work (M.Sc.), dealing with complex contexts, frequent and unpredictable changes, developing and implementing innovative solutions • Specialising in one field of work (final dissertation) • Systemic skills • Implementing the university's application recommendations (theory-practice transfer) in corresponding work and task areas across the company **Sharing/reflecting on learning** • E-portfolio • Relevance of study content and personal specialisation when working as an engineer • Relevance of research and innovation when working as an engineer
Literature	• Studierendenhandbuch • betriebliche Dokumente • Hochschulseitige Anwendungsempfehlungen zum Theorie-Praxis-Transfer

Module M1749: Energy Efficiency in Embedded Systems

Courses

Title	Typ	Hrs/wk	CP
Energy Efficiency in Embedded Systems (L2870)	Lecture	2	3
Energy Efficiency in Embedded Systems (L2872)	Project-/problem-based Learning	2	2
Energy Efficiency in Embedded Systems (L2871)	Recitation Section (large)	1	1

Module Responsible	Prof. Ulf Kulau
Admission Requirements	None
Recommended Previous Knowledge	• Computer Engineering (mandatory) • Programming Skills in C (mandatory) • Computer Architecture (recommended)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	**Motivation:** In the field of computer science we have only limited possibilities to influence the efficiency of the hardware directly, respectively we are dependent on the manufacturers (e.g. of microcontrollers). However, in order to exploit the full potential of the hardware we are given at the system level, we need a deeper understanding of the background, processes and mechanisms of power dissipation in embedded systems. Where does the power dissipation come from, what happens at the hardware level, what mechanisms can I use directly/indirectly, what is the tradeoff between flexibility and efficiency,.... are only a few questions, which will be elaborated and discussed in this event. **Contents of teaching:** • Motivation and power dissipation on semiconductor level • Power dissipation of digital circuits, inparticular CMOS • Power Management in Hard- and Software (Sleep Modes, DVS, FS, Undervolting) • Energy efficient system design (applications) • Energy Harvesting and Transiently Powered Computing (TPC)
Skills	Upon completion of this module, students will have a deeper understanding of hardware and software mechanisms for evaluating and developing energy-efficient embedded systems • They have a deeper understanding of the electrotechnical basics of power dissipation in digital systems • They can analyze the power dissipation of systems at any level and apply appropriate methods to increase efficiency • They can use a variety of standard techniques to achieve "Energy Efficiency by Design" • They can model, evaluate as well as implement energy-autonomous systems
Personal Competence	
Social Competence	As part of the module, concepts learned in the lecture will be implemented on a hardware platform within small groups. Students learn to work in a team and to develop solutions together. Specific tasks are worked on within the group, whereby cross-group collaboration (exchange) also takes place. The second part is a challenge-based project in which the groups find the most energy-efficient solutions possible in healthy competition with each other. This strengthens the cohesion in the groups and reinforces mutual motivation, support and creativity.
Autonomy	After completing this module, students will be able to independently develop, optimize and evaluate solutions for embedded systems based on the knowledge they have acquired and further technical literature.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Wireless and Sensor Technologies: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory

Course L2870: Energy Efficiency in Embedded Systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Ulf Kulau
Language	DE/EN
Cycle	WiSe
Content	**Motivation:** In the field of computer science we have only limited possibilities to influence the efficiency of the hardware directly, respectively we are dependent on the manufacturers (e.g. of microcontrollers). However, in order to exploit the full potential of the hardware we are given at the system level, we need a deeper understanding of the background, processes and mechanisms of power dissipation in embedded systems. Where does the power dissipation come from, what happens at the hardware level, what mechanisms can I use directly/indirectly, what is the tradeoff between flexibility and efficiency,.... are only a few questions, which will be elaborated and discussed in this event. **Contents of teaching:** • Motivation and power dissipation on semiconductor level • Power dissipation of digital circuits, inparticular CMOS • Power Management in Hard- and Software (Sleep Modes, DVS, FS, Undervolting) • Energy efficient system design (applications) • Energy Harvesting and Transiently Powered Computing (TPC)
Literature	DE: Die Vorlesung basiert af einer Vielzahl von Quellen, welche in [1.] angegeben sind. ENG: The lecture is based on multiple sources which are listed in [1.]. 1. Kulau, Ulf: **Course: Energy Efficiency in Embedded Systems-A System-Level Perspective for Computer Scientists**, EWME, 2018. 2. Harris, David, and N. Weste: **CMOS VLSI Design** ed., Pearson Education, 2010 3. Rabaey, Jan: **Low Power Design Essentials** (Integrated Circuits and Systems), Springer, 2009

Course L2872: Energy Efficiency in Embedded Systems	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Ulf Kulau
Language	DE/EN
Cycle	WiSe
Content	In this project-based exercise, the learned aspects for achieving energy-efficient embedded systems are implemented and consolidated in practical environments in a small project. First, a tool set for the implementation of energy efficiency mechanisms is implemented in common exercises by means of defined tasks. In the second part, a challenge-based exercise is carried out in which a system that is as efficient as possible is to be implemented independently. A system based on an AVR micro-controller is used, which can be operated autonomously by a Solar-Energy Harvester. 1. Task phase: 6 "hands-on" tasks to gain experience and to create a SW library. 2. Project phase: Implementation of an energy autonomous system with the goal of highest possible energy efficiency (Challenge)
Literature	

Course L2871: Energy Efficiency in Embedded Systems	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Ulf Kulau
Language	DE/EN
Cycle	WiSe
Content	In the lecture hall exercise, the theoertical basics taught in the lecture are deepened. This is done through in-depth discussion of relevant aspects, but also through calculation examples, in which a deeper understanding of the topic of energy efficiency in embedded systems is gained. Exercises will be distributed in advance and solutions will be presented in the lecture hall exercise. Contents of the exercise are as follows: • Basics and calculation of power dissipation on semiconductor • Power dissipation of CMOS using the example of an inverter • Influence of the activity factor and external components • DVS and scheduling • Evaluation to show the benefit of undervolting • Aspects of energy harvesting (MPPT) •
Literature	

Specialization Intelligent Systems and Robotics

In the intelligent systems and robotics specialization, graduates learn how to work systematically and methodically on challenging tasks.

They have broad knowledge of automation and simulation and are able to select appropriate solution strategies and use these autonomously to develop intelligent systems.

Module M0692: Approximation and Stability

Courses

Title	Typ	Hrs/wk	CP
Approximation and Stability (L0487)	Lecture	3	4
Approximation and Stability (L0488)	Recitation Section (small)	1	2

Module Responsible	Prof. Marko Lindner
Admission Requirements	None
Recommended Previous Knowledge	• Linear Algebra: systems of linear equations, least squares problems, eigenvalues, singular values • Analysis: sequences, series, differentiation, integration
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • sketch and interrelate basic concepts of functional analysis (Hilbert space, operators), • name and understand concrete approximation methods, • name and explain basic stability theorems, • discuss spectral quantities, conditions numbers and methods of regularisation
Skills	Students are able to • apply basic results from functional analysis, • apply approximation methods, • apply stability theorems, • compute spectral quantities, • apply regularisation methods.
Personal Competence	
Social Competence	Students are able to solve specific problems in groups and to present their results appropriately (e.g. as a seminar presentation).
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
Course achievement	Compulsory: Yes; Bonus: None; Form: Presentation; Description:
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L0487: Approximation and Stability	
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	SoSe
Content	This course is about solving the following basic problems of Linear Algebra, • systems of linear equations, • least squares problems, • eigenvalue problems but now in function spaces (i.e. vector spaces of infinite dimension) by a stable approximation of the problem in a space of finite dimension. **Contents:** • crash course on Hilbert spaces: metric, norm, scalar product, completeness • crash course on operators: boundedness, norm, compactness, projections • uniform vs. strong convergence, approximation methods • applicability and stability of approximation methods, Polski's theorem • Galerkin methods, collocation, spline interpolation, truncation • convolution and Toeplitz operators • crash course on C*-algebras • convergence of condition numbers • convergence of spectral quantities: spectrum, eigen values, singular values, pseudospectra • regularisation methods (truncated SVD, Tichonov)
Literature	• R. Hagen, S. Roch, B. Silbermann: C*-Algebras in Numerical Analysis • H. W. Alt: Lineare Funktionalanalysis • M. Lindner: Infinite matrices and their finite sections

Course L0488: Approximation and Stability	
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	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0752: Nonlinear Dynamics

Courses

Title	Typ	Hrs/wk	CP
Nonlinear Dynamics (L0702)	Integrated Lecture	4	6

Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	None
Recommended Previous Knowledge	• Calculus • Linear Algebra • Engineering Mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to reflect existing terms and concepts in Nonlinear Dynamics and to develop and research new terms and concepts. • Students are able to denote and expand methods of modeling and analysis for nonlinear dynamical systems.
Skills	• Students are able to apply existing methods and procesures of Nonlinear Dynamics. • Students are able to develop novel methods and procedures for nonlinear dynamical systems.
Personal Competence	
Social Competence	• Students can analyze problems of nonlinear dynamics also in groups. • Students can achieve solution procedures for problems of nonlinear dynamical systems also in groups.
Autonomy	• Students are able to approach given research tasks on the basis of given methods individually. • Students are able to identify and follow up novel research tasks by themselves.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	2 Hours
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: 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: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L0702: Nonlinear Dynamics

Typ	Integrated Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Norbert Hoffmann
Language	DE/EN
Cycle	SoSe

Content	Fundamentals of Nonlinear Dynamics
	• One dimensional problems
	  ◦ Linear Stability
	  ◦ Local Bifurcations
	  ◦ Synchronisation
	• Two dimensional problems
	  ◦ Limit Cycles
	  ◦ Global Bifurcations
	• Chaos
	  ◦ Lorenz Equations
	  ◦ Fractals and Strange Attractors
	  ◦ Predictability and Horizons

Literature	Steven Strogatz: Nonlinear Dynamics and Chaos.

Module M0714: Numerical Methods for Ordinary Differential Equations

Courses

Title	Typ	Hrs/wk	CP
Numerical Treatment of Ordinary Differential Equations (L0576)	Lecture	2	3
Numerical Treatment of Ordinary Differential Equations (L0582)	Recitation Section (small)	2	3

Module Responsible	Prof. Daniel Ruprecht
Admission Requirements	None
Recommended Previous Knowledge	• Mathematik I, II, III für Ingenieurstudierende (deutsch oder englisch) oder Analysis & Lineare Algebra I + II sowie Analysis III für Technomathematiker • Basic knowledge of MATLAB, Python or a similar programming language
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • list numerical methods for the solution of ordinary differential equations and explain their core ideas, • formulate convergence statements for the treated numerical methods (including the assumptions about the underlying problem), • explain aspects regarding the practical realisation of a method. • select the appropriate numerical method for concrete problems, implement the numerical algorithms efficiently and interpret the numerical results
Skills	Students are able to • implement, apply and compare numerical methods for the solution of ordinary differential equations, • justify the convergence behaviour of numerical methods with respect to the posed problem and selected algorithm, • develop a suitable solution approach for a given problem, if necessary by combining of several algorithms, and to realise this approach and 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 progress and, if necessary, to ask questions and seek help.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
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 III. Mathematics: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Interdisciplinary Mathematics: Specialisation II. Numerical - Modelling Training: Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0576: Numerical Treatment of Ordinary Differential Equations	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Daniel Ruprecht
Language	DE/EN
Cycle	SoSe
Content	Numerical methods for Initial Value Problems • single step methods • multistep methods • stiff problems • differential algebraic equations (DAE) of index 1 Numerical methods for Boundary Value Problems • multiple shooting method • difference methods
Literature	• E. Hairer, S. Noersett, G. Wanner: Solving Ordinary Differential Equations I: Nonstiff Problems. • E. Hairer, G. Wanner: Solving Ordinary Differential Equations II: Stiff and Differential-Algebraic Problems. • D. Griffiths, D. Higham: Numerical Methods for Ordinary Differential Equations.

Course L0582: Numerical Treatment of Ordinary Differential Equations	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Daniel Ruprecht
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0840: Optimal and Robust Control

Courses

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

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• Classical control (frequency response, root locus) • State space methods • Linear algebra, singular value decomposition
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the significance of the matrix Riccati equation for the solution of LQ problems. • They can explain the duality between optimal state feedback and optimal state estimation. • They can explain how the H2 and H-infinity norms are used to represent stability and performance constraints. • They can explain how an LQG design problem can be formulated as special case of an H2 design problem. • They can explain how model uncertainty can be represented in a way that lends itself to robust controller design • They can explain how - based on the small gain theorem - a robust controller can guarantee stability and performance for an uncertain plant. • They understand how analysis and synthesis conditions on feedback loops can be represented as linear matrix inequalities.
Skills	• Students are capable of designing and tuning LQG controllers for multivariable plant models. • They are capable of representing a H2 or H-infinity design problem in the form of a generalized plant, and of using standard software tools for solving it. • They are capable of translating time and frequency domain specifications for control loops into constraints on closed-loop sensitivity functions, and of carrying out a mixed-sensitivity design. • They are capable of constructing an LFT uncertainty model for an uncertain system, and of designing a mixed-objective robust controller. • They are capable of formulating analysis and synthesis conditions as linear matrix inequalities (LMI), and of using standard LMI-solvers for solving them. • They can carry out all of the above using standard software tools (Matlab robust control toolbox).
Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: 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: Core Qualification: Elective Compulsory

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

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

Module M1156: Systems Engineering

Courses

Title	Typ	Hrs/wk	CP
Systems Engineering (L1547)	Lecture	3	4
Systems Engineering (L1548)	Recitation Section (large)	1	2

Module Responsible	Prof. Ralf God
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: • Aircraft Cabin Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • understand systems engineering process models, methods and tools for the development of complex Systems • describe innovation processes and the need for technology Management • explain the aircraft development process and the process of type certification for aircraft • explain the system development process, including requirements for systems reliability • identify environmental conditions and test procedures for airborne Equipment • value the methodology of requirements-based engineering (RBE) and model-based requirements engineering (MBRE)
Skills	Students are able to: • plan the process for the development of complex Systems • organize the development phases and development Tasks • assign required business activities and technical Tasks • apply systems engineering methods and tools
Personal Competence	
Social Competence	Students are able to: • understand and accept their tasks within a development team • be comfortable with their role their tasks within the overall process • understand and serve their suppliers and customers in large projects • assume responsibility for people and technology in the development of safety-critical systems
Autonomy	Students are able to: • interact and communicate in a development team with division of tasks. • independently research and identify certification specifications • formulate requirements on their own • create test plans on their own and accompany certification processes
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 Minutes
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L1547: Systems Engineering	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	The objective of the lecture with the corresponding exercise is to accomplish the prerequisites for the development and integration of complex systems using the example of commercial aircraft and cabin systems. Competences in the systems engineering process, tools and methods is to be achieved. Regulations, guidelines and certification issues will be known. Key aspects of the course are processes for innovation and technology management, system design, system integration and certification as well as tools and methods for systems engineering: • Innovation processes • IP-protection • Technology management • Systems engineering • Aircraft program • Certification issues • Systems development • Safety objectives and fault tolerance • Environmental and operating conditions • Tools for systems engineering • Requirements-based engineering (RBE) • Model-based requirements engineering (MBRE)
Literature	- Skript zur Vorlesung - diverse Normen und Richtlinien (EASA, FAA, RTCA, SAE) - Hauschildt, J., Salomo, S.: Innovationsmanagement. Vahlen, 5. Auflage, 2010 - NASA Systems Engineering Handbook, National Aeronautics and Space Administration, 2007 - Hinsch, M.: Industrielles Luftfahrtmanagement: Technik und Organisation luftfahrttechnischer Betriebe. Springer, 2010 - De Florio, P.: Airworthiness: An Introduction to Aircraft Certification. Elsevier Ltd., 2010 - Pohl, K.: Requirements Engineering. Grundlagen, Prinzipien, Techniken. 2. korrigierte Auflage, dpunkt.Verlag, 2008

Course L1548: Systems Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1212: Technical Complementary Course for IMPMEC (according to Subject Specific Regulations)	
Courses	
Title	**Typ** **Hrs/wk** **CP**
Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	See selected module according to FSPO
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	see selected module according to FSPO
Skills	see selected module according to FSPO
Personal Competence	
Social Competence	see selected module according to FSPO
Autonomy	see selected module according to FSPO
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Module M1223: Selected Topics of Mechatronics (Alternative A: 12 LP)

Courses

Title	Typ	Hrs/wk	CP
Applied Automation (L1592)	Project-/problem-based Learning	3	3
Advanced Training Course SE-ZERT (L2739)	Project-/problem-based Learning	2	3
Development Management for Mechatronics (L1512)	Lecture	2	3
Fatigue & Damage Tolerance (L0310)	Lecture	2	3
Industry 4.0 for engineers (L2012)	Lecture	2	3
Microcontroller Circuits: Implementation in Hardware and Software (L0087)	Seminar	2	2
Microsystems Technology (L0724)	Lecture	2	4
Model-Based Systems Engineering (MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Sustainable Industrial Production (L2863)	Lecture	2	4
Process Measurement Engineering (L1077)	Lecture	2	3
Process Measurement Engineering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medical Technology (L0664)	Lecture	2	3

Module Responsible	NN
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 express their extended knowledge and discuss the connection of different special fields or application areas of mechatronics • Students are qualified to connect different special fields with each other
Skills	• Students can apply specialized solution strategies and new scientific methods in selected areas • Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches
Personal Competence	
Social Competence	None
Autonomy	• Students are able to develop their knowledge and skills by autonomous election of courses.
Workload in Hours	Depends on choice of courses
Credit points	12
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Course L1592: Applied Automation	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Mündliche Prüfung
Examination duration and scale	30 Minuten
Lecturer	Prof. Thorsten Schüppstuhl
Language	DE
Cycle	WiSe
Content	-Project Based Learning -Robot Operating System -Robot structure and description -Motion description -Calibration -Accuracy
Literature	John J. Craig Introduction to Robotics - Mechanics and Control ISBN: 0131236296 Pearson Education, Inc., 2005 Stefan Hesse Grundlagen der Handhabungstechnik ISBN: 3446418725 München Hanser, 2010 K. Thulasiraman and M. N. S. Swamy Graphs: Theory and Algorithms ISBN: 9781118033104 %CITAVIPICKER£9781118033104£Titel anhand dieser ISBN in Citavi-Projekt übernehmen£% John Wüey & Sons, Inc., 1992

Course L2739: Advanced Training Course SE-ZERT	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	120 min
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	
Literature	INCOSE Systems Engineering Handbuch - Ein Leitfaden für Systemlebenszyklus-Prozesse und -Aktivitäten, GfSE (Hrsg. der deutschen Übersetzung), ISBN 978-3-9818805-0-2. ISO/IEC 15288 System- und Software-Engineering - System-Lebenszyklus-Prozesse (Systems and Software Engineering - System Life Cycle Processes).

Course L1512: Development Management for Mechatronics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 Minuten
Lecturer	NN, Dr. Johannes Nicolas Gebhardt
Language	DE
Cycle	SoSe

Content	• Processes and methods of product development - from idea to market launch
	  ◦ identification of market and technology potentials
	  ◦ development of a common product architecture
	  ◦ Synchronized product development across all engineering disciplines
	  ◦ product validation incl. customer view
	• Steering and optimization of product development
	  ◦ Design of processes for product development
	  ◦ IT systems for product development
	  ◦ Establishment of management standards
	  ◦ Typical types of organization

Literature	• Bender: Embedded Systems - qualitätsorientierte Entwicklung • Ehrlenspiel: Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit • Gausemeier/Ebbesmeyer/Kallmeyer: Produktinnovation - Strategische Planung und Entwicklung der Produkte von morgen • Haberfellner/de Weck/Fricke/Vössner: Systems Engineering: Grundlagen und Anwendung • Lindemann: Methodische Entwicklung technischer Produkte: Methoden flexibel und situationsgerecht anwenden • Pahl/Beitz: Konstruktionslehre: Grundlagen erfolgreicher Produktentwicklung. Methoden und Anwendung • VDI-Richtlinie 2206: Entwicklungsmethodik für mechatronische Systeme

Course L0310: Fatigue & Damage Tolerance	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 min
Lecturer	Dr. Martin Flamm
Language	EN
Cycle	WiSe
Content	Design principles, fatigue strength, crack initiation and crack growth, damage calculation, counting methods, methods to improve fatigue strength, environmental influences
Literature	Jaap Schijve, Fatigue of Structures and Materials. Kluver Academic Puplisher, Dordrecht, 2001 E. Haibach. Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung. VDI-Verlag, Düsseldorf, 1989

Course L2012: Industry 4.0 for engineers	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	120 min
Lecturer	Prof. Thorsten Schüppstuhl
Language	DE
Cycle	SoSe
Content	
Literature	

Course L0087: Microcontroller Circuits: Implementation in Hardware and Software	
Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	10 min. Vortrag + anschließende Diskussion
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe/SoSe
Content	
Literature	ATmega16A 8-bit Microcontroller with 16K Bytes In-System Programmable Flash - DATASHEET, Atmel Corporation 2014 Atmel AVR 8-bit Instruction Set Instruction Set Manual, Atmel Corporation 2016

Course L0724: Microsystems Technology	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	• Introduction (historical view, scientific and economic relevance, scaling laws) • Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting) • Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) • Etching and Bulk Micromachining (definitions, wet chemical etching, isotropic etch with HNA, electrochemical etching, anisotropic etching with KOH/TMAH: theory, corner undercutting, measures for compensation and etch-stop techniques; plasma processes, dry etching: back sputtering, plasma etching, RIE, Bosch process, cryo process, XeF2 etching) • Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping) • Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: thermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, IR sensor: thermopile and bolometer) • Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: piezoresistive, capacitive and fabrication process; accelerometer: piezoresistive, piezoelectric and capacitive; angular rate sensor: operating principle and fabrication process) • Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer) • Chemical and Bio Sensors (thermal gas sensors: pellistor and thermal conductivity sensor; metal oxide semiconductor gas sensor, organic semiconductor gas sensor, Lambda probe, MOSFET gas sensor, pH-FET, SAW sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip) • Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, microvalves: passive and active, micropumps, valveless micropump, electrokinetic micropumps, micromixer, filter, inkjet printhead, microdispenser, microfluidic switching elements, microreactor, lab-on-a-chip, microanalytics) • MEMS in medical Engineering (wireless energy and data transmission, smart pill, implantable drug delivery system, stimulators: microelectrodes, cochlear and retinal implant; implantable pressure sensors, intelligent osteosynthesis, implant for spinal cord regeneration) • Design, Simulation, Test (development and design flows, bottom-up approach, top-down approach, testability, modelling: multiphysics, FEM and equivalent circuit simulation; reliability test, physics-of-failure, Arrhenius equation, bath-tub relationship) • System Integration (monolithic and hybrid integration, assembly and packaging, dicing, electrical contact: wire bonding, TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L1551: Model-Based Systems Engineering (MBSE) with SysML/UML	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	ca. 10 Seiten
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	Objectives of the problem-oriented course are the acquisition of knowledge on system design using the formal languages SysML/UML, learning about tools for modeling and finally the implementation of a project with methods and tools of Model-Based Systems Engineering (MBSE) on a realistic hardware platform (e.g. Arduino®, Raspberry Pi®): • What is a model? • What is Systems Engineering? • Survey of MBSE methodologies • The modelling languages SysML /UML • Tools for MBSE • Best practices for MBSE • Requirements specification, functional architecture, specification of a solution • From model to software code • Validation and verification: XiL methods • Accompanying MBSE project
Literature	- Skript zur Vorlesung - Weilkiens, T.: Systems Engineering mit SysML/UML: Modellierung, Analyse, Design. 2. Auflage, dpunkt.Verlag, 2008 - Holt, J., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011

Course L2863: Sustainable Industrial Production	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Dr. Simon Markus Kothe
Language	DE
Cycle	SoSe
Content	Industrial production deals with the manufacture of physical products to satisfy human needs using various manufacturing processes that change the form and physical properties of raw materials. Manufacturing is a central driver of economic development and has a major impact on the well-being of humanity. However, the scale of current manufacturing activities results in enormous global energy and material demands that are harmful to both the environment and people. Historically, industrial activities were mostly oriented towards economic constraints, while social and environmental consequences were only hardly considered. As a result, today's global consumption rates of many resources and associated emissions often exceed the natural regeneration rate of our planet. In this respect, current industrial production can mostly be described as unsustainable. This is emphasized each year by the Earth Overshoot Day, which marks the day when humanity's ecological footprint exceeds the Earth's annual regenerative capacity. This lecture aims to provide the motivation, analytical methods as well as approaches for sustainable industrial production and to clarify the influence of the production phase in relation to the raw material, use and recycling phases in the entire life cycle of products. For this, the following topics will be highlighted: - Motivation for sustainable production, the 17 Sustainable Development Goals (SDGs) of the UN and their relevance for tomorrow's manufacturing; - raw material vs. production phase vs. use phase vs. recycling/end-of-life phase: importance of the production phase for the environmental impact of manufactured products; - Typical energy- and resource-intensive processes in industrial production and innovative approaches to increase energy and resource efficiency; - Methodology for optimizing the energy and resource efficiency of industrial manufacturing chains with the three steps of modeling (1), evaluating (2) and improving (3); - Resource efficiency of industrial manufacturing value chains and its assessment using life cycle analysis (LCA); - Exercise: LCA analysis of a manufacturing process (thermoplastic joining of an aircraft fuselage segment) as part of a product life cycle assessment.
Literature	Literatur: - Stefan Alexander (2020): Resource efficiency in manufacturing value chains. Cham: Springer International Publishing. - Hauschild, Michael Z.; Rosenbaum, Ralph K.; Olsen, Stig Irving (Hg.) (2018): Life Cycle Assessment. Theory and Practice. Cham: Springer International Publishing. - Kishita, Yusuke; Matsumoto, Mitsutaka; Inoue, Masato; Fukushige, Shinichi (2021): EcoDesign and sustainability. Singapore: Springer. - Schebek, Liselotte; Herrmann, Christoph; Cerdas, Felipe (2019): Progress in Life Cycle Assessment. Cham: Springer International Publishing. - Thiede, Sebastian; Hermann, Christoph (2019): Eco-factories of the future. Cham: Springer Nature Switzerland AG. - Vorlesungsskript.

Course L1077: Process Measurement Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 Minuten
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe

Content	• Process measurement engineering in the context of process control engineering
	  ◦ Challenges of process measurement engineering
	  ◦ Instrumentation of processes
	  ◦ Classification of pickups
	• Systems theory in process measurement engineering
	  ◦ Generic linear description of pickups
	  ◦ Mathematical description of two-port systems
	  ◦ Fourier and Laplace transformation
	• Correlational measurement
	  ◦ Wide band signals
	  ◦ Auto- and cross-correlation function and their applications
	  ◦ Fault-free operation of correlational methods
	• Transmission of analog and digital measurement signals
	  ◦ Modulation process (amplitude and frequency modulation)
	  ◦ Multiplexing
	  ◦ Analog to digital converter

Literature	- Färber: „Prozeßrechentechnik“, Springer-Verlag 1994 - Kiencke, Kronmüller: „Meßtechnik“, Springer Verlag Berlin Heidelberg, 1995 - A. Ambardar: „Analog and Digital Signal Processing“ (1), PWS Publishing Company, 1995, NTC 339 - A. Papoulis: „Signal Analysis“ (1), McGraw-Hill, 1987, NTC 312 (LB) - M. Schwartz: „Information Transmission, Modulation and Noise“ (3,4), McGraw-Hill, 1980, 2402095 - S. Haykin: „Communication Systems“ (1,3), Wiley&Sons, 1983, 2419072 - H. Sheingold: „Analog-Digital Conversion Handbook“ (5), Prentice-Hall, 1986, 2440072 - J. Fraden: „AIP Handbook of Modern Sensors“ (5,6), American Institute of Physics, 1993, MTB 346

Course L1083: Process Measurement Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Mündliche Prüfung
Examination duration and scale	
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0664: Feedback Control in Medical Technology	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	20 min
Lecturer	Johannes Kreuzer, Christian Neuhaus
Language	DE
Cycle	SoSe
Content	Always viewed from the engineer's point of view, the lecture is structured as follows: • Introduction to the topic • Fundamentals of physiological modelling • Introduction to Breathing and Ventilation • Physiology and Pathology in Cardiology • Introduction to the Regulation of Blood Glucose • kidney function and renal replacement therapy • Representation of the control technology on the concrete ventilator • Excursion to a medical technology company Techniques of modeling, simulation and controller development are discussed. In the models, simple equivalent block diagrams for physiological processes are derived and explained how sensors, controllers and actuators are operated. MATLAB and SIMULINK are used as development tools.
Literature	• Leonhardt, S., & Walter, M. (2016). Medizintechnische Systeme. Berlin, Heidelberg: Springer Vieweg. • Werner, J. (2005). Kooperative und autonome Systeme der Medizintechnik. München: Oldenbourg. • Oczenski, W. (2017). Atmen : Atemhilfen ; Atemphysiologie und Beatmungstechnik: Georg Thieme Verlag KG.

Module M1224: Selected Topics of Mechatronics (Alternative B: 6 LP)

Courses

Title	Typ	Hrs/wk	CP
Applied Automation (L1592)	Project-/problem-based Learning	3	3
Advanced Training Course SE-ZERT (L2739)	Project-/problem-based Learning	2	3
Development Management for Mechatronics (L1512)	Lecture	2	3
Fatigue & Damage Tolerance (L0310)	Lecture	2	3
Industry 4.0 for engineers (L2012)	Lecture	2	3
Microcontroller Circuits: Implementation in Hardware and Software (L0087)	Seminar	2	2
Microsystems Technology (L0724)	Lecture	2	4
Model-Based Systems Engineering (MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Sustainable Industrial Production (L2863)	Lecture	2	4
Process Measurement Engineering (L1077)	Lecture	2	3
Process Measurement Engineering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medical Technology (L0664)	Lecture	2	3

Module Responsible	NN
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 express their extended knowledge and discuss the connection of different special fields or application areas of mechatronics • Students are qualified to connect different special fields with each other
Skills	• Students can apply specialized solution strategies and new scientific methods in selected areas • Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches
Personal Competence	
Social Competence	None
Autonomy	• Students are able to develop their knowledge and skills by autonomous election of courses.
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L1592: Applied Automation	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Mündliche Prüfung
Examination duration and scale	30 Minuten
Lecturer	Prof. Thorsten Schüppstuhl
Language	DE
Cycle	WiSe
Content	-Project Based Learning -Robot Operating System -Robot structure and description -Motion description -Calibration -Accuracy
Literature	John J. Craig Introduction to Robotics - Mechanics and Control ISBN: 0131236296 Pearson Education, Inc., 2005 Stefan Hesse Grundlagen der Handhabungstechnik ISBN: 3446418725 München Hanser, 2010 K. Thulasiraman and M. N. S. Swamy Graphs: Theory and Algorithms ISBN: 9781118033104 %CITAVIPICKER£9781118033104£Titel anhand dieser ISBN in Citavi-Projekt übernehmen£% John Wüey & Sons, Inc., 1992

Course L2739: Advanced Training Course SE-ZERT	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	120 min
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	
Literature	INCOSE Systems Engineering Handbuch - Ein Leitfaden für Systemlebenszyklus-Prozesse und -Aktivitäten, GfSE (Hrsg. der deutschen Übersetzung), ISBN 978-3-9818805-0-2. ISO/IEC 15288 System- und Software-Engineering - System-Lebenszyklus-Prozesse (Systems and Software Engineering - System Life Cycle Processes).

Course L1512: Development Management for Mechatronics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 Minuten
Lecturer	NN, Dr. Johannes Nicolas Gebhardt
Language	DE
Cycle	SoSe

Content	• Processes and methods of product development - from idea to market launch
	  ◦ identification of market and technology potentials
	  ◦ development of a common product architecture
	  ◦ Synchronized product development across all engineering disciplines
	  ◦ product validation incl. customer view
	• Steering and optimization of product development
	  ◦ Design of processes for product development
	  ◦ IT systems for product development
	  ◦ Establishment of management standards
	  ◦ Typical types of organization

Literature	• Bender: Embedded Systems - qualitätsorientierte Entwicklung • Ehrlenspiel: Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit • Gausemeier/Ebbesmeyer/Kallmeyer: Produktinnovation - Strategische Planung und Entwicklung der Produkte von morgen • Haberfellner/de Weck/Fricke/Vössner: Systems Engineering: Grundlagen und Anwendung • Lindemann: Methodische Entwicklung technischer Produkte: Methoden flexibel und situationsgerecht anwenden • Pahl/Beitz: Konstruktionslehre: Grundlagen erfolgreicher Produktentwicklung. Methoden und Anwendung • VDI-Richtlinie 2206: Entwicklungsmethodik für mechatronische Systeme

Course L0310: Fatigue & Damage Tolerance	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 min
Lecturer	Dr. Martin Flamm
Language	EN
Cycle	WiSe
Content	Design principles, fatigue strength, crack initiation and crack growth, damage calculation, counting methods, methods to improve fatigue strength, environmental influences
Literature	Jaap Schijve, Fatigue of Structures and Materials. Kluver Academic Puplisher, Dordrecht, 2001 E. Haibach. Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung. VDI-Verlag, Düsseldorf, 1989

Course L2012: Industry 4.0 for engineers	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	120 min
Lecturer	Prof. Thorsten Schüppstuhl
Language	DE
Cycle	SoSe
Content	
Literature	

Course L0087: Microcontroller Circuits: Implementation in Hardware and Software	
Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	10 min. Vortrag + anschließende Diskussion
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe/SoSe
Content	
Literature	ATmega16A 8-bit Microcontroller with 16K Bytes In-System Programmable Flash - DATASHEET, Atmel Corporation 2014 Atmel AVR 8-bit Instruction Set Instruction Set Manual, Atmel Corporation 2016

Course L0724: Microsystems Technology	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	• Introduction (historical view, scientific and economic relevance, scaling laws) • Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting) • Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) • Etching and Bulk Micromachining (definitions, wet chemical etching, isotropic etch with HNA, electrochemical etching, anisotropic etching with KOH/TMAH: theory, corner undercutting, measures for compensation and etch-stop techniques; plasma processes, dry etching: back sputtering, plasma etching, RIE, Bosch process, cryo process, XeF2 etching) • Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping) • Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: thermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, IR sensor: thermopile and bolometer) • Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: piezoresistive, capacitive and fabrication process; accelerometer: piezoresistive, piezoelectric and capacitive; angular rate sensor: operating principle and fabrication process) • Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer) • Chemical and Bio Sensors (thermal gas sensors: pellistor and thermal conductivity sensor; metal oxide semiconductor gas sensor, organic semiconductor gas sensor, Lambda probe, MOSFET gas sensor, pH-FET, SAW sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip) • Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, microvalves: passive and active, micropumps, valveless micropump, electrokinetic micropumps, micromixer, filter, inkjet printhead, microdispenser, microfluidic switching elements, microreactor, lab-on-a-chip, microanalytics) • MEMS in medical Engineering (wireless energy and data transmission, smart pill, implantable drug delivery system, stimulators: microelectrodes, cochlear and retinal implant; implantable pressure sensors, intelligent osteosynthesis, implant for spinal cord regeneration) • Design, Simulation, Test (development and design flows, bottom-up approach, top-down approach, testability, modelling: multiphysics, FEM and equivalent circuit simulation; reliability test, physics-of-failure, Arrhenius equation, bath-tub relationship) • System Integration (monolithic and hybrid integration, assembly and packaging, dicing, electrical contact: wire bonding, TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L1551: Model-Based Systems Engineering (MBSE) with SysML/UML	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	ca. 10 Seiten
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	Objectives of the problem-oriented course are the acquisition of knowledge on system design using the formal languages SysML/UML, learning about tools for modeling and finally the implementation of a project with methods and tools of Model-Based Systems Engineering (MBSE) on a realistic hardware platform (e.g. Arduino®, Raspberry Pi®): • What is a model? • What is Systems Engineering? • Survey of MBSE methodologies • The modelling languages SysML /UML • Tools for MBSE • Best practices for MBSE • Requirements specification, functional architecture, specification of a solution • From model to software code • Validation and verification: XiL methods • Accompanying MBSE project
Literature	- Skript zur Vorlesung - Weilkiens, T.: Systems Engineering mit SysML/UML: Modellierung, Analyse, Design. 2. Auflage, dpunkt.Verlag, 2008 - Holt, J., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011

Course L2863: Sustainable Industrial Production	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Dr. Simon Markus Kothe
Language	DE
Cycle	SoSe
Content	Industrial production deals with the manufacture of physical products to satisfy human needs using various manufacturing processes that change the form and physical properties of raw materials. Manufacturing is a central driver of economic development and has a major impact on the well-being of humanity. However, the scale of current manufacturing activities results in enormous global energy and material demands that are harmful to both the environment and people. Historically, industrial activities were mostly oriented towards economic constraints, while social and environmental consequences were only hardly considered. As a result, today's global consumption rates of many resources and associated emissions often exceed the natural regeneration rate of our planet. In this respect, current industrial production can mostly be described as unsustainable. This is emphasized each year by the Earth Overshoot Day, which marks the day when humanity's ecological footprint exceeds the Earth's annual regenerative capacity. This lecture aims to provide the motivation, analytical methods as well as approaches for sustainable industrial production and to clarify the influence of the production phase in relation to the raw material, use and recycling phases in the entire life cycle of products. For this, the following topics will be highlighted: - Motivation for sustainable production, the 17 Sustainable Development Goals (SDGs) of the UN and their relevance for tomorrow's manufacturing; - raw material vs. production phase vs. use phase vs. recycling/end-of-life phase: importance of the production phase for the environmental impact of manufactured products; - Typical energy- and resource-intensive processes in industrial production and innovative approaches to increase energy and resource efficiency; - Methodology for optimizing the energy and resource efficiency of industrial manufacturing chains with the three steps of modeling (1), evaluating (2) and improving (3); - Resource efficiency of industrial manufacturing value chains and its assessment using life cycle analysis (LCA); - Exercise: LCA analysis of a manufacturing process (thermoplastic joining of an aircraft fuselage segment) as part of a product life cycle assessment.
Literature	Literatur: - Stefan Alexander (2020): Resource efficiency in manufacturing value chains. Cham: Springer International Publishing. - Hauschild, Michael Z.; Rosenbaum, Ralph K.; Olsen, Stig Irving (Hg.) (2018): Life Cycle Assessment. Theory and Practice. Cham: Springer International Publishing. - Kishita, Yusuke; Matsumoto, Mitsutaka; Inoue, Masato; Fukushige, Shinichi (2021): EcoDesign and sustainability. Singapore: Springer. - Schebek, Liselotte; Herrmann, Christoph; Cerdas, Felipe (2019): Progress in Life Cycle Assessment. Cham: Springer International Publishing. - Thiede, Sebastian; Hermann, Christoph (2019): Eco-factories of the future. Cham: Springer Nature Switzerland AG. - Vorlesungsskript.

Course L1077: Process Measurement Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 Minuten
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe

Content	• Process measurement engineering in the context of process control engineering
	  ◦ Challenges of process measurement engineering
	  ◦ Instrumentation of processes
	  ◦ Classification of pickups
	• Systems theory in process measurement engineering
	  ◦ Generic linear description of pickups
	  ◦ Mathematical description of two-port systems
	  ◦ Fourier and Laplace transformation
	• Correlational measurement
	  ◦ Wide band signals
	  ◦ Auto- and cross-correlation function and their applications
	  ◦ Fault-free operation of correlational methods
	• Transmission of analog and digital measurement signals
	  ◦ Modulation process (amplitude and frequency modulation)
	  ◦ Multiplexing
	  ◦ Analog to digital converter

Literature	- Färber: „Prozeßrechentechnik“, Springer-Verlag 1994 - Kiencke, Kronmüller: „Meßtechnik“, Springer Verlag Berlin Heidelberg, 1995 - A. Ambardar: „Analog and Digital Signal Processing“ (1), PWS Publishing Company, 1995, NTC 339 - A. Papoulis: „Signal Analysis“ (1), McGraw-Hill, 1987, NTC 312 (LB) - M. Schwartz: „Information Transmission, Modulation and Noise“ (3,4), McGraw-Hill, 1980, 2402095 - S. Haykin: „Communication Systems“ (1,3), Wiley&Sons, 1983, 2419072 - H. Sheingold: „Analog-Digital Conversion Handbook“ (5), Prentice-Hall, 1986, 2440072 - J. Fraden: „AIP Handbook of Modern Sensors“ (5,6), American Institute of Physics, 1993, MTB 346

Course L1083: Process Measurement Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Mündliche Prüfung
Examination duration and scale	
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0664: Feedback Control in Medical Technology	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	20 min
Lecturer	Johannes Kreuzer, Christian Neuhaus
Language	DE
Cycle	SoSe
Content	Always viewed from the engineer's point of view, the lecture is structured as follows: • Introduction to the topic • Fundamentals of physiological modelling • Introduction to Breathing and Ventilation • Physiology and Pathology in Cardiology • Introduction to the Regulation of Blood Glucose • kidney function and renal replacement therapy • Representation of the control technology on the concrete ventilator • Excursion to a medical technology company Techniques of modeling, simulation and controller development are discussed. In the models, simple equivalent block diagrams for physiological processes are derived and explained how sensors, controllers and actuators are operated. MATLAB and SIMULINK are used as development tools.
Literature	• Leonhardt, S., & Walter, M. (2016). Medizintechnische Systeme. Berlin, Heidelberg: Springer Vieweg. • Werner, J. (2005). Kooperative und autonome Systeme der Medizintechnik. München: Oldenbourg. • Oczenski, W. (2017). Atmen : Atemhilfen ; Atemphysiologie und Beatmungstechnik: Georg Thieme Verlag KG.

Module M1302: Applied Humanoid Robotics

Courses

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

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

Course L1794: Applied Humanoid Robotics

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

Module M1269: Lab Cyber-Physical Systems

Courses

Title	Typ	Hrs/wk	CP
Lab Cyber-Physical Systems (L1740)	Project-/problem-based Learning	4	6

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Module "Embedded Systems"
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Cyber-Physical Systems (CPS) are tightly integrated with their surrounding environment, via sensors, A/D and D/A converters, and actors. Due to their particular application areas, highly specialized sensors, processors and actors are common. Accordingly, there is a large variety of different specification approaches for CPS - in contrast to classical software engineering approaches. Based on practical experiments using robot kits and computers, the basics of specification and modelling of CPS are taught. The lab introduces into the area (basic notions, characteristical properties) and their specification techniques (models of computation, hierarchical automata, data flow models, petri nets, imperative approaches). Since CPS frequently perform control tasks, the lab's experiments will base on simple control applications. The experiments will use state-of-the-art industrial specification tools (MATLAB/Simulink, LabVIEW, NXC) in order to model cyber-physical models that interact with the environment via sensors and actors.
Skills	After successful attendance of the lab, students are able to develop simple CPS. They understand the interdependencies between a CPS and its surrounding processes which stem from the fact that a CPS interacts with the environment via sensors, A/D converters, digital processors, D/A converters and actors. The lab enables students to compare modelling approaches, to evaluate their advantages and limitations, and to decide which technique to use for a concrete task. They will be able to apply these techniques to practical problems. They obtain first experiences in hardware-related software development, in industry-relevant specification tools and in the area of simple control applications.
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
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Execution and documentation of all lab experiments
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory

Course L1740: Lab Cyber-Physical Systems

Typ	Project-/problem-based Learning
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	• Experiment 1: Programming in NXC • Experiment 2: Programming the Robot in Matlab/Simulink • Experiment 3: Programming the Robot in LabVIEW
Literature	• Peter Marwedel. Embedded System Design - Embedded System Foundations of Cyber-Physical Systems. 2 nd Edition, Springer, 2012. • Begleitende Foliensätze

Module M1306: Control Lab C

Courses

Title	Typ	Hrs/wk	CP
Control Lab IX (L1836)	Practical Course	1	1
Control Lab VII (L1834)	Practical Course	1	1
Control Lab VIII (L1835)	Practical Course	1	1

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Credit points	3
Course achievement	None
Examination	Written elaboration
Examination duration and scale	1
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L1836: Control Lab IX

Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1834: Control Lab VII

Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1835: Control Lab VIII	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Module M1281: Advanced Topics in Vibration

Courses

Title	Typ	Hrs/wk	CP
Advanced Topics in Vibration (L1743)	Project-/problem-based Learning	4	6

Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	None
Recommended Previous Knowledge	Vibration Theory
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to reflect existing terms and concepts of Advanced Vibrations. • Students are able to identify the need to develop and research new terms and concepts in vibrations.
Skills	• Students are able to apply existing methods and procesures of Advanced Vibrations. • Students are able to develop novel methods and procedures for advanced vibration problems.
Personal Competence	
Social Competence	• Students can reach working results also in groups. • Students can present working results also in groups.
Autonomy	• Students are able to approach given research tasks individually • Students are able to identify and follow up novel research tasks by themselves.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	2 Hours
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L1743: Advanced Topics in Vibration

Typ	Project-/problem-based Learning
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Norbert Hoffmann
Language	DE/EN
Cycle	SoSe
Content	Advanced and Research Topics in Vibrations • Rotor Dynamics • Modal Analysis • Model Order Reduction • Stability of Periodic Solutions • Random Vibrations
Literature	Aktuelle Veröffentlichungen / Recent research publications Bücher/Books: Gasch, Nordmann, Pfützner: Rotordynamik Gasch, Knothe, Liebich: Strukturdynamik

Module M0835: Humanoid Robotics

Courses

Title	Typ	Hrs/wk	CP
Humanoid Robotics (L0663)	Seminar	2	2

Module Responsible	Patrick Göttsch
Admission Requirements	None
Recommended Previous Knowledge	• Introduction to control systems • Control theory and design
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain humanoid robots. • Students learn to apply basic control concepts for different tasks in humanoid robotics.
Skills	• Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature • Students generalize developed results and present them to the participants • Students practice to prepare and give a presentation
Personal Competence	
Social Competence	• Students are capable of developing solutions in interdisciplinary teams and present them • They are able to provide appropriate feedback and handle constructive criticism of their own results
Autonomy	• Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the best solution • Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other students, such that a scientific discussion develops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Presentation
Examination duration and scale	30 min
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: 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 Robotics and Computer Science: Elective Compulsory

Course L0663: Humanoid Robotics

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Patrick Göttsch
Language	DE
Cycle	SoSe
Content	• Grundlagen der Regelungstechnik • Control systems theory and design
Literature	- B. Siciliano, O. Khatib. "Handbook of Robotics. Part A: Robotics Foundations", Springer (2008).

Module M0838: Linear and Nonlinear System Identifikation

Courses

Title	Typ	Hrs/wk	CP
Linear and Nonlinear System Identification (L0660)	Lecture	2	3

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• Classical control (frequency response, root locus) • State space methods • Discrete-time systems • Linear algebra, singular value decomposition • Basic knowledge about stochastic processes
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the general framework of the prediction error method and its application to a variety of linear and nonlinear model structures • They can explain how multilayer perceptron networks are used to model nonlinear dynamics • They can explain how an approximate predictive control scheme can be based on neural network models • They can explain the idea of subspace identification and its relation to Kalman realisation theory
Skills	• Students are capable of applying the predicition error method to the experimental identification of linear and nonlinear models for dynamic systems • They are capable of implementing a nonlinear predictive control scheme based on a neural network model • They are capable of applying subspace algorithms to the experimental identification of linear models for dynamic systems • They can do the above using standard software tools (including the Matlab System Identification Toolbox)
Personal Competence	
Social Competence	Students can work in mixed groups on specific problems to arrive at joint solutions.
Autonomy	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: 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: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L0660: Linear and Nonlinear System Identification

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	SoSe
Content	• Prediction error method • Linear and nonlinear model structures • Nonlinear model structure based on multilayer perceptron network • Approximate predictive control based on multilayer perceptron network model • Subspace identification
Literature	• Lennart Ljung, System Identification - Theory for the User, Prentice Hall 1999 • M. Norgaard, O. Ravn, N.K. Poulsen and L.K. Hansen, Neural Networks for Modeling and Control of Dynamic Systems, Springer Verlag, London 2003 • T. Kailath, A.H. Sayed and B. Hassibi, Linear Estimation, Prentice Hall 2000

Module M0939: Control Lab A

Courses

Title	Typ	Hrs/wk	CP
Control Lab I (L1093)	Practical Course	1	1
Control Lab II (L1291)	Practical Course	1	1
Control Lab III (L1665)	Practical Course	1	1
Control Lab IV (L1666)	Practical Course	1	1

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Credit points	4
Course achievement	None
Examination	Written elaboration
Examination duration and scale	1
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L1093: Control Lab I

Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1291: Control Lab II	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1665: Control Lab III	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1666: Control Lab IV	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

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. Bernd-Christian Renner
Admission Requirements	None
Recommended Previous Knowledge	• Very Good knowledge and practical experience in programming in the C language • Basic knowledge in software engineering • Basic understanding of assembly language
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know the basic principles and procedures of software engineering for embedded systems. They are able to describe the usage and pros of event based programming using interrupts. They know the components and functions of a concrete microcontroller. The participants explain requirements of real time systems. They know at least three scheduling algorithms for real time operating systems including their pros and cons.
Skills	Students build interrupt-based programs for a concrete microcontroller. They build and use a preemptive scheduler. They use peripheral components (timer, ADC, EEPROM) to realize complex tasks for embedded systems. To interface with external components they utilize serial protocols.
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	Compulsory: No; Bonus: 10 %; Form: Attestation; Description:
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: 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. Bernd-Christian Renner
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. Bernd-Christian Renner
Language	DE/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)	Project-/problem-based Learning	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
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L1692: Compilers for Embedded Systems	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	• Introduction and Motivation • Compilers for Embedded Systems - Requirements and Dependencies • Internal Structure of Compilers • Pre-Pass Optimizations • HIR Optimizations and Transformations • Code Generation • LIR Optimizations and Transformations • Register Allocation • WCET-Aware Compilation • Outlook
Literature	• Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2 nd 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	Project-/problem-based Learning
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 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) • principles of programming, e.g., in Java or C++ • solid R or Matlab skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can explain kinematics and tracking systems in clinical contexts and illustrate systems and their components in detail. 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 are able to grasp practical tasks in groups, develop solution strategies independently, define work processes and work on them collaboratively. The students are able to collaboratively organize their work processes and software solutions using virtual communication and software management tools. The students can critically reflect on the results of other groups, make constructive suggestions for improvement, and also incorporate them into their own work.
Autonomy	The students can assess their level of knowledge and independently control their learning processes on this basis as well as document their work results. They can critically evaluate the results achieved and present them in an appropriate argumentative manner to the other groups.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	Compulsory: Yes, Bonus: 10 %, Form: Written elaboration Compulsory: Yes, Bonus: 10 %, Form: Presentation
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: 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 M1203: Applied Dynamics: Numerical and experimental methods

Courses

Title	Typ	Hrs/wk	CP
Lab Applied Dynamics (L1631)	Practical Course	2	2
Applied Dynamics (L1630)	Lecture	4	4

Module Responsible	Prof. Robert Seifried
Admission Requirements	None
Recommended Previous Knowledge	Mathematics I, II, III, Mechanics I, II, III, IV Numerical Treatment of Ordinary Differential Equations
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can represent the most important methods of dynamics after successful completion of the module Technical dynamics and have a good understanding of the main concepts in the technical dynamics.
Skills	Students are able + to think holistically + to independently, securly and critically analyze and optimize basic problems of the dynamics of rigid and flexible multibody systems + to describe dynamics problems mathematically + to investigate dynamics problems both experimentally and numerically
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups and to document the corresponding results.
Autonomy	Students are able to + assess their knowledge by means of exercises and experiments. + acquaint themselves with the necessary knowledge to solve research oriented tasks.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / None / Subject theoretical and practical work / Versuche Fachlabor
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory

Course L1631: Lab Applied Dynamics

Typ	Practical Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Marc-André Pick
Language	DE
Cycle	SoSe
Content	Practical exercises are performed in groups. The examples are taken from different areas of applied dynamics, such as numerical simulation, experimental validation and experimental vibration analysis.
Literature	Schiehlen, W.; Eberhard, P.: Technische Dynamik, 4. Auflage, Vieweg+Teubner: Wiesbaden, 2014.

Course L1630: Applied Dynamics	
Typ	Lecture
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Prof. Robert Seifried, Dr. Marc-André Pick
Language	DE
Cycle	SoSe
Content	1. Modelling of Multibody Systems 2. Basics from kinematics and kinetics 3. Constraints 4. Multibody systems in minimal coordinates 5. State space, linearization and modal analysis 6. Multibody systems with kinematic constraints 7. Multibody systems as DAE 8. Non-holonomic multibody systems 9. Experimental Methods in Dynamics
Literature	Schiehlen, W.; Eberhard, P.: Technische Dynamik, 4. Auflage, Vieweg+Teubner: Wiesbaden, 2014. Woernle, C.: Mehrkörpersysteme, Springer: Heidelberg, 2011. Seifried, R.: Dynamics of Underactuated Multibody Systems, Springer, 2014.

Module M0803: Embedded Systems

Courses

Title	Typ	Hrs/wk	CP
Embedded Systems (L0805)	Lecture	3	3
Embedded Systems (L2938)	Project-/problem-based Learning	1	1
Embedded Systems (L0806)	Recitation Section (small)	1	2

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Computer Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Embedded systems can be defined as information processing systems embedded into enclosing products. This course teaches the foundations of such systems. In particular, it deals with an introduction into these systems (notions, common characteristics) and their specification languages (models of computation, hierarchical automata, specification of distributed systems, task graphs, specification of real-time applications, translations between different models). Another part covers the hardware of embedded systems: Sonsors, A/D and D/A converters, real-time capable communication hardware, embedded processors, memories, energy dissipation, reconfigurable logic and actuators. The course also features an introduction into real-time operating systems, middleware and real-time scheduling. Finally, the implementation of embedded systems using hardware/software co-design (hardware/software partitioning, high-level transformations of specifications, energy-efficient realizations, compilers for embedded processors) is covered.
Skills	After having attended the course, students shall be able to realize simple embedded systems. The students shall realize which relevant parts of technological competences to use in order to obtain a functional embedded systems. In particular, they shall be able to compare different models of computations and feasible techniques for system-level design. They shall be able to judge in which areas of embedded system design specific risks exist.
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 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** 10 %; **Form** Subject theoretical and practical work; **Description**
Examination	Written exam
Examination duration and scale	90 minutes, contents of course and labs
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Electrical Engineering: Core Qualification: Elective Compulsory Engineering Science: Specialisation Mechatronics: Elective Compulsory Engineering Science: Specialisation Electrical Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechatronics: Elective Compulsory Computer Science in Engineering: Core Qualification: Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory

Course L0805: Embedded Systems

Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	EN
Cycle	SoSe
Content	• Introduction • Specifications and Modeling • Embedded/Cyber-Physical Systems Hardware • System Software • Evaluation and Validation • Mapping of Applications to Execution Platforms • Optimization
Literature	• Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2 nd Edition, Springer, 2012., Springer, 2012.

Course L2938: Embedded Systems	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	EN
Cycle	SoSe
Content	• Introduction • Specifications and Modeling • Embedded/Cyber-Physical Systems Hardware • System Software • Evaluation and Validation • Mapping of Applications to Execution Platforms • Optimization
Literature	• Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2 nd Edition, Springer, 2012., Springer, 2012.

Course L0806: Embedded Systems	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
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	None
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
Course achievement	None
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics 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	Rainer Marrone
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	Rainer Marrone
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1173: Applied Statistics

Courses

Title	Typ	Hrs/wk	CP
Applied Statistics (L1584)	Lecture	2	3
Applied Statistics (L1586)	Project-/problem-based Learning	2	2
Applied Statistics (L1585)	Recitation Section (small)	1	1

Module Responsible	Prof. Michael Morlock
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of statistical methods
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the statistical methods and the conditions of their use.
Skills	Students are able to use the statistics program to solve statistics problems and to interpret and depict the results
Personal Competence	
Social Competence	Team Work, joined presentation of results
Autonomy	To understand and interpret the question and solve
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 minutes, 28 questions
Assignment for the Following Curricula	Mechanical Engineering and Management: Specialisation Management: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Biomedical Engineering: Core Qualification: Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L1584: Applied Statistics

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
Content	The goal is to introduce students to the basic statistical methods and their application to simple problems. The topics include: • Chi square test • Simple regression and correlation • Multiple regression and correlation • One way analysis of variance • Two way analysis of variance • Discriminant analysis • Analysis of categorial data • Chossing the appropriate statistical method • Determining critical sample sizes
Literature	Applied Regression Analysis and Multivariable Methods, 3rd Edition, David G. Kleinbaum Emory University, Lawrence L. Kupper University of North Carolina at Chapel Hill, Keith E. Muller University of North Carolina at Chapel Hill, Azhar Nizam Emory University, Published by Duxbury Press, CB © 1998, ISBN/ISSN: 0-534-20910-6

Course L1586: Applied Statistics	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
Content	The students receive a problem task, which they have to solve in small groups (n=5). They do have to collect their own data and work with them. The results have to be presented in an executive summary at the end of the course.
Literature	Selbst zu finden

Course L1585: Applied Statistics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
Content	The different statistical tests are applied for the solution of realistic problems using actual data sets and the most common used commercial statistical software package (SPSS).
Literature	Student Solutions Manual for Kleinbaum/Kupper/Muller/Nizam's Applied Regression Analysis and Multivariable Methods, 3rd Edition, David G. Kleinbaum Emory University Lawrence L. Kupper University of North Carolina at Chapel Hill, Keith E. Muller University of North Carolina at Chapel Hill, Azhar Nizam Emory University, Published by Duxbury Press, Paperbound © 1998, ISBN/ISSN: 0-534-20913-0

Module M1398: Selected Topics in Multibody Dynamics and Robotics

Courses

Title	Typ	Hrs/wk	CP
Formulas and Vehicles - Dynamics and Control of Autonomous Vehicles (L2869)	Integrated Lecture	1	1
Formulas and Vehicles - Introduction into Mobile Underwater Robotics (L1981)	Project-/problem-based Learning	4	5

Module Responsible	Prof. Robert Seifried
Admission Requirements	None
Recommended Previous Knowledge	Mechanics IV, Applied Dynamics or Robotics Numerical Treatment of Ordinary Differential Equations Control Systems Theory and Design
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After successful completion of the module students demonstrate deeper knowledge and understanding in selected application areas of multibody dynamics and robotics
Skills	Students are able + to think holistically + to independently, securly and critically analyze and optimize basic problems of the dynamics of rigid and flexible multibody systems + to describe dynamics problems mathematically + to implement dynamical problems on hardware
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups and to document the corresponding results and present them
Autonomy	Students are able to + assess their knowledge by means of exercises and projects. + acquaint themselves with the necessary knowledge to solve research oriented tasks.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Presentation
Examination duration and scale	TBA
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L2869: Formulas and Vehicles - Dynamics and Control of Autonomous Vehicles

Typ	Integrated Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Robert Seifried, Daniel-André Dücker
Language	DE
Cycle	WiSe
Content	
Literature	

Course L1981: Formulas and Vehicles - Introduction into Mobile Underwater Robotics

Typ	Project-/problem-based Learning
Hrs/wk	4
CP	5
Workload in Hours	Independent Study Time 94, Study Time in Lecture 56
Lecturer	Prof. Robert Seifried, Daniel-André Dücker
Language	DE
Cycle	WiSe
Content	
Literature	Seifried, R.: Dynamics of underactuated multibody systems, Springer, 2014 Popp, K.; Schiehlen, W.: Ground vehicle dynamics, Springer, 2010

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	NN
Admission Requirements	None
Recommended Previous Knowledge	H-infinity optimal control, mixed-sensitivity design, linear matrix inequalities
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the advantages and shortcomings of the classical gain scheduling approach • They can explain the representation of nonlinear systems in the form of quasi-LPV systems • They can explain how stability and performance conditions for LPV systems can be formulated as LMI conditions • They can explain how gridding techniques can be used to solve analysis and synthesis problems for LPV systems • They are familiar with polytopic and LFT representations of LPV systems and some of the basic synthesis techniques associated with each of these model structures • Students can explain how graph theoretic concepts are used to represent the communication topology of multiagent systems • They can explain the convergence properties of first order consensus protocols • They can explain analysis and synthesis conditions for formation control loops involving either LTI or LPV agent models • Students can explain concepts behind linear and qLPV Model Predictive Control (MPC)
Skills	• Students can construct 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 can use standard software tools (Matlab robust control toolbox) for these tasks • Students can design distributed formation controllers for groups of agents with either LTI or LPV dynamics, using Matlab tools provided • Students can design MPC controllers for linear and non-linear systems using Matlab tools
Personal Competence	
Social Competence	Students can work in small groups and arrive at joint results.
Autonomy	Students can 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
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: 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 Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: 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	NN
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 • Linear and Nonlinear Model Predictive Control based on LMIs
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	NN
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1748: Construction Robotics

Courses

Title	Typ	Hrs/wk	CP
Construction Robotics (L2867)	Project-/problem-based Learning	6	6

Module Responsible	Prof. Kay Smarsly
Admission Requirements	None
Recommended Previous Knowledge	Basics of project-oriented programming
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Basics of robotics
	Applications in civil engineering
	Kinematics
Skills	Use of specific hardware
	Development of software routines
	Python programming language
	Image processing
	Basics of localization (LIDAR, SLAM)
Personal Competence	
Social Competence	Teamwork
	Communication skills
Autonomy	Independent work
	Independent decisions
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	ca. 10 Seiten
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Computational Engineering: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L2867: Construction Robotics	
Typ	Project-/problem-based Learning
Hrs/wk	6
CP	6
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Lecturer	Prof. Kay Smarsly, Jan Stührenberg, Mathias Worm
Language	DE/EN
Cycle	WiSe

Content	1. Introduction: Robotics in civil engineering
	2. Presentation of potential topics
	3. Programming of algorithms in Python
	4. Application of software systems: LINUX distribution, ROS, CloudCompare, ...
	5. Application of hardware systems: Petoi Bittle Dog, Raspberry Pi, Arduino, sensing ...
	6. Topics considered for robotics using the Petoi Bittle Dog:
	  1. Movement
	  2. Use of sensors (camera, infrared, ...)
	  3. Data structures/data acquisition
	  4. Programming
	7. Topics technically relevant to building inspection:
	  1. Geodetic evaluations
	  2. Image processing
	  3. Localization

Literature	Bock/Linner: Construction Robotics Verl et al.: Soft Robotics Pasquale: New Laws of robotics

Module M1598: Image Processing

Courses

Title	Typ	Hrs/wk	CP
Image Processing (L2443)	Lecture	2	4
Image Processing (L2444)	Recitation Section (small)	2	2

Module Responsible	Prof. Tobias Knopp
Admission Requirements	None
Recommended Previous Knowledge	Signal and Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know about • visual perception • multidimensional signal processing • sampling and sampling theorem • filtering • image enhancement • edge detection • multi-resolution procedures: Gauss and Laplace pyramid, wavelets • image compression • image segmentation • morphological image processing
Skills	The students can • analyze, process, and improve multidimensional image data • implement simple compression algorithms • design custom filters for specific applications
Personal Competence	
Social Competence	Students can work on complex problems both independently and in teams. They can exchange ideas with each other and use their individual strengths to solve the problem.
Autonomy	Students are able to independently investigate a complex problem and assess which competencies are required to solve it.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory Data Science: Specialisation II. Computer Science: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Medical 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 International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L2443: Image Processing	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	DE/EN
Cycle	WiSe
Content	• Visual perception • Multidimensional signal processing • Sampling and sampling theorem • Filtering • Image enhancement • Edge detection • Multi-resolution procedures: Gauss and Laplace pyramid, wavelets • Image Compression • Segmentation • Morphological image processing
Literature	Bredies/Lorenz, Mathematische Bildverarbeitung, Vieweg, 2011 Pratt, Digital Image Processing, Wiley, 2001 Bernd Jähne: Digitale Bildverarbeitung - Springer, Berlin 2005

Course L2444: Image Processing	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0677: Digital Signal Processing and Digital Filters

Courses

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

Module Responsible	Prof. Gerhard Bauch
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics 1-3 • Signals and Systems • Fundamentals of signal and system theory as well as random processes. • Fundamentals of spectral transforms (Fourier series, Fourier transform, Laplace transform)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know and understand basic algorithms of digital signal processing. They are familiar with the spectral transforms of discrete-time signals and are able to describe and analyse signals and systems in time and image domain. They know basic structures of digital filters and can identify and assess important properties including stability. They are aware of the effects caused by quantization of filter coefficients and signals. They are familiar with the basics of adaptive filters. They can perform traditional and parametric methods of spectrum estimation, also taking a limited observation window into account. The students are familiar with the contents of lecture and tutorials. They can explain and apply them to new problems.
Skills	The students are able to apply methods of digital signal processing to new problems. They can choose and parameterize suitable filter striuctures. In particular, the can design adaptive filters according to the minimum mean squared error (MMSE) criterion and develop an efficient implementation, e.g. based on the LMS or RLS algorithm. Furthermore, the students are able to apply methods of spectrum estimation and to take the effects of a limited observation window into account.
Personal Competence	
Social Competence	The students can jointly solve specific problems.
Autonomy	The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Computer Science in Engineering: Specialisation II. Engineering Science: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L0446: Digital Signal Processing and Digital Filters	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Gerhard Bauch
Language	EN
Cycle	WiSe

Content	• Transforms of discrete-time signals:
	  ◦ Discrete-time Fourier Transform (DTFT)
	  ◦ Discrete Fourier-Transform (DFT), Fast Fourier Transform (FFT)
	  ◦ Z-Transform
	• Correspondence of continuous-time and discrete-time signals, sampling, sampling theorem
	• Fast convolution, Overlap-Add-Method, Overlap-Save-Method
	• Fundamental structures and basic types of digital filters
	• Characterization of digital filters using pole-zero plots, important properties of digital filters
	• Quantization effects
	• Design of linear-phase filters
	• Fundamentals of stochastic signal processing and adaptive filters
	  ◦ MMSE criterion
	  ◦ Wiener Filter
	  ◦ LMS- and RLS-algorithm
	• Traditional and parametric methods of spectrum estimation

Literature	K.-D. Kammeyer, K. Kroschel: Digitale Signalverarbeitung. Vieweg Teubner. V. Oppenheim, R. W. Schafer, J. R. Buck: Zeitdiskrete Signalverarbeitung. Pearson StudiumA. V. W. Hess: Digitale Filter. Teubner. Oppenheim, R. W. Schafer: Digital signal processing. Prentice Hall. S. Haykin: Adaptive filter theory. L. B. Jackson: Digital filters and signal processing. Kluwer. T.W. Parks, C.S. Burrus: Digital filter design. Wiley.

Course L0447: Digital Signal Processing and Digital Filters	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Gerhard Bauch
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1552: Advanced Machine Learning

Courses

Title	Typ	Hrs/wk	CP
Advanced Machine Learning (L2322)	Lecture	2	3
Advanced Machine Learning (L2323)	Recitation Section (small)	2	3

Module Responsible	Dr. Jens-Peter Zemke
Admission Requirements	None
Recommended Previous Knowledge	1. Mathematics I-III 2. Numerical Mathematics 1/ Numerics 3. Programming skills, preferably in Python
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to name, state and classify state-of-the-art neural networks and their corresponding mathematical basics. They can assess the difficulties of different neural networks.
Skills	Students are able to implement, understand, and, tailored to the field of application, apply neural networks.
Personal Competence	
Social Competence	Students can • develop and document joint solutions in small teams; • form groups to further develop the ideas and transfer them to other areas of applicability; • form a team to develop, build, and advance a software library.
Autonomy	Students are able to • correctly assess the time and effort of self-defined work; • assess whether the supporting theoretical and practical excercises are better solved individually or in a team; • define test problems for testing and expanding the methods; • 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
Course achievement	None
Examination	Oral exam
Examination duration and scale	25 min
Assignment for the Following Curricula	Computer Science: Specialisation III. Mathematics: Elective Compulsory Data Science: Core Qualification: Compulsory Computer Science in Engineering: Specialisation III. Mathematics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L2322: Advanced Machine Learning

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jens-Peter Zemke
Language	DE/EN
Cycle	WiSe
Content	1. Basics: analogy; layout of neural nets, universal approximation, NP-completeness 2. Feedforward nets: backpropagation, variants of Stochastistic Gradients 3. Deep Learning: problems and solution strategies 4. Deep Belief Networks: energy based models, Contrastive Divergence 5. CNN: idea, layout, FFT and Winograds algorithms, implementation details 6. RNN: idea, dynamical systems, training, LSTM 7. ResNN: idea, relation to neural ODEs 8. Standard libraries: Tensorflow, Keras, PyTorch 9. Recent trends
Literature	1. Skript 2. Online-Werke: ◦ http://neuralnetworksanddeeplearning.com/ ◦ https://www.deeplearningbook.org/

Course L2323: Advanced Machine Learning	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jens-Peter Zemke
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1596: Engineering Haptic Systems

Courses

Title	Typ	Hrs/wk	CP
Haptic Technology for Human-Machine-Interfaces (HMI) (L2439)	Lecture	4	3
Haptic Technology for Human-Machine-Interfaces (HMI) (L2859)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Thorsten Kern
Admission Requirements	None
Recommended Previous Knowledge	We recommend knowledge in the areas of general engineering sciences, mechatronics and/or control-engineering. However also neighbouring technical areas like mechanical-engineering or even process-engineers can join the course and will be introduced into the content properly.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	This course is an introduction to the design methods and design-requirements to consider when creating haptic systems from scratch. It covers a physiological part, an actuator development part, and goes up to fundamentals of higher system integration with consideration on control theory for more complex projects. Beside design-related topics, it gives a valuable overview on existing haptic applications and research in that field with many examples. This is supported by on-site experiments in the laboratories of M-4. • Motivation and application of haptic systems • Haptic perception • The role of the user in direct system interaction • Development of haptic systems • Identification of requirements • System-structure and control • Kinematic fundamentals • Actuation & Sensors technology for haptic applications • Control and system-design aspects • Fundamental considerations in simulating haptics
Skills	Executing the course the competency will be developed to apply the general engineering capabilities of the individual course towards the design and application of active haptic systems. The resulting competencies will open an entry into specialized position in avionic-industries, automotive-industry and consumer-device-development.
Personal Competence	
Social Competence	As a side-effect this module teaches basics of a general design for human-machine-interfaces, independent from the specific application of "haptics". It teaches methods to execute user-studies, judge on user-feedback and how to deal with soft design-requirements which are common when dealing with subjective perception.
Autonomy	Independent design-capability of haptic systems, general competency in engineering from a design-perspective
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** 20 %; **Form** Subject theoretical and practical work; **Description** Durchführung von Laborversuchen
Examination	Subject theoretical and practical work
Examination duration and scale	30 min
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory

Course L2439: Haptic Technology for Human-Machine-Interfaces (HMI)	
Typ	Lecture
Hrs/wk	4
CP	3
Workload in Hours	Independent Study Time 34, Study Time in Lecture 56
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	WiSe
Content	This course is an introduction to the design methods and design-requirements to consider when creating haptic systems from scratch. It covers a physiological part, an actuator development part, and goes up to fundamentals of higher system integration with consideration on control theory for more complex projects. Beside design-related topics, it gives a valuable overview on existing haptic applications and research in that field with many examples. • Motivation and application of haptic systems • Haptic perception • The role of the user in direct system interaction • Development of haptic systems • Identification of requirements • System-structure and control • Kinematic fundamentals • Actuation & Sensors technology for haptic applications • Control and system-design aspects • Fundamental considerations in simulating haptics
Literature	

Course L2859: Haptic Technology for Human-Machine-Interfaces (HMI)	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Thorsten Kern
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
Course achievement	None
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Computer Science: Specialisation III. Mathematics: Elective Compulsory Computer Science in Engineering: Specialisation III. Mathematics: Elective Compulsory Interdisciplinary Mathematics: Specialisation Computational Methods in Biomedical Imaging: Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: 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 methods of image processing • smoothing filters • the diffusion / heat equation • variational formulations in image processing • edge detection • de-convolution • inpainting • 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 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	None
Recommended Previous Knowledge	Vectors, matrices, Calculus
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the agent abstraction, define intelligence in terms of rational behavior, and give details about agent design (goals, utilities, environments). They can describe the main features of environments. The notion of adversarial agent cooperation can be discussed in terms of decision problems and algorithms for solving these problems. For dealing with uncertainty in real-world scenarios, students can summarize how Bayesian networks can be employed as a knowledge representation and reasoning formalism in static and dynamic settings. In addition, students can define decision making procedures in simple and sequential settings, with and with complete access to the state of the environment. In this context, students can describe techniques for solving (partially observable) Markov decision problems, and they can recall techniques for measuring the value of information. Students can identify techniques for simultaneous localization and mapping, and can explain planning techniques for achieving desired states. Students can explain coordination problems and decision making in a multi-agent setting in term of different types of equilibria, social choice functions, voting protocol, and mechanism design techniques.
Skills	Students can select an appropriate agent architecture for concrete agent application scenarios. For simplified agent application students can derive decision trees and apply basic optimization techniques. For those applications they can also create Bayesian networks/dynamic Bayesian networks and apply bayesian reasoning for simple queries. Students can also name and apply different sampling techniques for simplified agent scenarios. For simple and complex decision making students can compute the best action or policies for concrete settings. In multi-agent situations students will apply techniques for finding different equilibria states,e.g., Nash equilibria. For multi-agent decision making students will apply different voting protocols and compare and explain the results.
Personal Competence	
Social Competence	Students are able to discuss their solutions to problems with others. They communicate in English
Autonomy	Students are able of checking their understanding of complex concepts by solving varaints of concrete problems
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Core Qualification: 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 Robotics and Computer Science: 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 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 are able to grasp practical tasks in groups, develop solution strategies independently, define work processes and work on them collaboratively. The students can critically reflect on the results of other groups, make constructive suggestions for improvement and also incorporate them into their own work.
Autonomy	The students can assess their level of knowledge and document their work results. They can critically evaluate the results achieved and present them in an appropriate argumentative manner to the other groups.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	Compulsory: Yes, Bonus: 10 %, Form: Presentation Compulsory: Yes, Bonus: 10 %, Form: Written elaboration
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Data Science: Specialisation III. Applications: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Interdisciplinary Mathematics: Specialisation Computational Methods in Biomedical Imaging: Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: 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 M1204: Modelling and Optimization in Dynamics

Courses

Title	Typ	Hrs/wk	CP
Flexible Multibody Systems (L1632)	Lecture	2	3
Optimization of dynamical systems (L1633)	Lecture	2	3

Module Responsible	Prof. Robert Seifried
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics I, II, III • Mechanics I, II, III, IV • Simulation of dynamical Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students demonstrate basic knowledge and understanding of modeling, simulation and analysis of complex rigid and flexible multibody systems and methods for optimizing dynamic systems after successful completion of the module.
Skills	Students are able + to think holistically + to independently, securly and critically analyze and optimize basic problems of the dynamics of rigid and flexible multibody systems + to describe dynamics problems mathematically + to optimize dynamics problems
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups and to document the corresponding results.
Autonomy	Students are able to + assess their knowledge by means of exercises. + acquaint themselves with the necessary knowledge to solve research oriented tasks.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L1632: Flexible Multibody Systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Robert Seifried, Dr. Alexander Held
Language	DE
Cycle	WiSe
Content	1. Basics of Multibody Systems 2. Basics of Continuum Mechanics 3. Linear finite element modelles and modell reduction 4. Nonlinear finite element Modelles: absolute nodal coordinate formulation 5. Kinematics of an elastic body 6. Kinetics of an elastic body 7. System assembly
Literature	Schwertassek, R. und Wallrapp, O.: Dynamik flexibler Mehrkörpersysteme. Braunschweig, Vieweg, 1999. Seifried, R.: Dynamics of Underactuated Multibody Systems, Springer, 2014. Shabana, A.A.: Dynamics of Multibody Systems. Cambridge Univ. Press, Cambridge, 2004, 3. Auflage.

Course L1633: Optimization of dynamical systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Robert Seifried, Dr. Svenja Drücker
Language	DE
Cycle	WiSe
Content	1. Formulation and classification of optimization problems 2. Scalar Optimization 3. Sensitivity Analysis 4. Unconstrained Parameter Optimization 5. Constrained Parameter Optimization 6. Stochastic optimization 7. Multicriteria Optimization 8. Topology Optimization
Literature	Bestle, D.: Analyse und Optimierung von Mehrkörpersystemen. Springer, Berlin, 1994. Nocedal, J. , Wright , S.J. : Numerical Optimization. New York: Springer, 2006.

Module M0720: Matrix Algorithms

Courses

Title	Typ	Hrs/wk	CP
Matrix Algorithms (L0984)	Lecture	2	3
Matrix Algorithms (L0985)	Recitation Section (small)	2	3

Module Responsible	Dr. Jens-Peter Zemke
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics I - III • Numerical Mathematics 1/ Numerics • Basic knowledge of the programming languages Matlab and C
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to 1. name, state and classify state-of-the-art Krylov subspace methods for the solution of the core problems of the engineering sciences, namely, eigenvalue problems, solution of linear systems, and model reduction; 2. state approaches for the solution of matrix equations (Sylvester, Lyapunov, Riccati).
Skills	Students are capable to 1. implement and assess basic Krylov subspace methods for the solution of eigenvalue problems, linear systems, and model reduction; 2. assess methods used in modern software with respect to computing time, stability, and domain of applicability; 3. adapt the approaches learned to new, unknown types of problem.
Personal Competence	
Social Competence	Students can • develop and document joint solutions in small teams; • form groups to further develop the ideas and transfer them to other areas of applicability; • form a team to develop, build, and advance a software library.
Autonomy	Students are able to • correctly assess the time and effort of self-defined work; • assess whether the supporting theoretical and practical excercises are better solved individually or in a team; • define test problems for testing and expanding the methods; • 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
Course achievement	None
Examination	Oral exam
Examination duration and scale	25 min
Assignment for the Following Curricula	Computer Science: Specialisation III. Mathematics: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Data Science: Specialisation I. Mathematics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L0984: Matrix Algorithms	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jens-Peter Zemke
Language	DE/EN
Cycle	WiSe

Content	• Part A: Krylov Subspace Methods:
	  ◦ Basics (derivation, basis, Ritz, OR, MR)
	  ◦ Arnoldi-based methods (Arnoldi, GMRes)
	  ◦ Lanczos-based methods (Lanczos, CG, BiCG, QMR, SymmLQ, PvL)
	  ◦ Sonneveld-based methods (IDR, BiCGStab, TFQMR, IDR(s))
	• Part B: Matrix Equations:
	  ◦ Sylvester Equation
	  ◦ Lyapunov Equation
	  ◦ Algebraic Riccati Equation

Literature	Skript (224 Seiten) Ergänzend können die folgenden Lehrbücher herangezogen werden: 1. Saad, Yousef. Numerical methods for large eigenvalue problems: revised edition. Society for Industrial and Applied Mathematics, 2011. 2. Saad, Yousef. Iterative methods for sparse linear systems. Society for Industrial and Applied Mathematics, 2003. 3. Van der Vorst, Henk A. Iterative Krylov methods for large linear systems. No. 13. Cambridge University Press, 2003. 4. Liesen, Jörg, and Zdenek Strakos. Krylov subspace methods: principles and analysis. Oxford University Press, 2013.

Course L0985: Matrix Algorithms	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jens-Peter Zemke
Language	DE/EN
Cycle	WiSe
Content	
Literature	Siehe korrespondierende Vorlesung

Module M1614: Optics for Engineers

Courses

Title	Typ	Hrs/wk	CP
Optics for Engineers (L2437)	Lecture	3	3
Optics for Engineers (L2438)	Project-/problem-based Learning	3	3

Module Responsible	Prof. Thorsten Kern
Admission Requirements	None
Recommended Previous Knowledge	- Basics of physics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Teaching subject ist the design of simple optical systems for illumination and imaging optics • Basic values for optical systems and lighting technology • Spectrum, black-bodies, color-perception • Light-Sources und their characterization • Photometrics • Ray-Optics • Matrix-Optics • Stops, Pupils and Windows • Light-field Technology • Introduction to Wave-Optics • Introduction to Holography
Skills	Understandings of optics as part of light and electromagnetic spectrum. Design rules, approach to designing optics
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / None / Subject theoretical and practical work / Teilnahme an Laborübungen und Simulation
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L2437: Optics for Engineers

Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	WiSe
Content	• Basic values for optical systems and lighting technology • Spectrum, black-bodies, color-perception • Light-Sources und their characterization • Photometrics • Ray-Optics • Matrix-Optics • Stops, Pupils and Windows • Light-field Technology • Introduction to Wave-Optics • Introduction to Holography
Literature	

Course L2438: Optics for Engineers	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Thorsten Kern
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 discrete 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. The students can relate process automation to methods from robotics and sensor systems as well as to recent topics like 'cyberphysical systems' and 'industry 4.0'.
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 can independently define work processes within their groups, distribute tasks within the group and develop solutions collaboratively.
Autonomy	The students are able to assess their level of knowledge and to document their work results adequately.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** **Bonus** **Form** **Description** No 10 % Excercises
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 II: Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: 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 M1229: Control Lab B

Courses

Title	Typ	Hrs/wk	CP
Control Lab V (L1667)	Practical Course	1	1
Control Lab VI (L1668)	Practical Course	1	1

Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Written elaboration
Examination duration and scale	1
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory

Course L1667: Control Lab V

Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1668: Control Lab VI

Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Module M1305: Seminar Advanced Topics in Control

Courses

Title	Typ	Hrs/wk	CP
Advanced Topics in Control (L1803)	Seminar	2	2

Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	• Introduction to control systems • Control theory and design • optimal and robust control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain modern control. • Students learn to apply basic control concepts for different tasks
Skills	• Students acquire knowledge about selected aspects of modern control, based on specified literature • Students generalize developed results and present them to the participants • Students practice to prepare and give a presentation
Personal Competence	
Social Competence	• Students are capable of developing solutions and present them • They are able to provide appropriate feedback and handle constructive criticism of their own results
Autonomy	• Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the best solution • Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other students, such that a scientific discussion develops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Presentation
Examination duration and scale	90 min
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory

Course L1803: Advanced Topics in Control

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	NN
Language	EN
Cycle	WiSe/SoSe
Content	• Seminar on selected topics in modern control
Literature	• To be specified

Module M1919: Sustainable operation of technical assets

Courses

Title	Typ	Hrs/wk	CP
Fundamentals of Maintenance, Repair and Overhaul (MRO) (L3160)	Lecture	3	4
Fundamentals of Maintenance, Repair and Overhaul (MRO) (L3161)	Recitation Section (large)	1	2

Module Responsible	Prof. Gerko Wende
Admission Requirements	None
Recommended Previous Knowledge	We recommend knowledge in the areas of general engineering sciences, aeronautics and aircraft systems engineering. Technical fields like mechanical engineering, mechatronics and production engineering will be introduced into the relevant aeronautical content.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to describe fundamental correlations for the sustainable operation of technical assets and to identify solution approaches for complex optimization problems.
Skills	The students are enabled to apply the general engineering capabilities of the individual course towards the optimization of the sustainability in operation of technical assets. The resulting competencies will open an entry into positions in the development, production and technical operation of sustainable products in the mobility and engineering industries.
Personal Competence	
Social Competence	The students are able to work in mixed groups with a clear focus on the approached solutions by respecting the complex environment of multiple stakeholders.
Autonomy	The students are enabled to find solutions for optimization problems and to take required decision for the assessment of determining factors independently.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: 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 Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L3160: Fundamentals of Maintenance, Repair and Overhaul (MRO)

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Gerko Wende
Language	DE
Cycle	WiSe
Content	Fundamentals for the sustainable operation of technical assets by means of maintenance, repair and overhaul (MRO): • Life cycle analytics • Material circularity and service products • Rules and regulations • Processes and production methods • Tools and technologies • Data handling and usage • Design for maintenance • Self-healing technical systems
Literature	-

Course L3161: Fundamentals of Maintenance, Repair and Overhaul (MRO)	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Gerko Wende
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Specialization System Design

In the system design specialization, graduates learn how to work systematically and methodically on challenging design tasks.

They have broad knowledge of new development methods, are able to select appropriate solution strategies and use these autonomously to develop new products. They are qualified to use the approaches of integrated system development, such as simulation or modern testing procedures.

Module M0752: Nonlinear Dynamics

Courses

Title	Typ	Hrs/wk	CP
Nonlinear Dynamics (L0702)	Integrated Lecture	4	6

Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	None
Recommended Previous Knowledge	• Calculus • Linear Algebra • Engineering Mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to reflect existing terms and concepts in Nonlinear Dynamics and to develop and research new terms and concepts. • Students are able to denote and expand methods of modeling and analysis for nonlinear dynamical systems.
Skills	• Students are able to apply existing methods and procesures of Nonlinear Dynamics. • Students are able to develop novel methods and procedures for nonlinear dynamical systems.
Personal Competence	
Social Competence	• Students can analyze problems of nonlinear dynamics also in groups. • Students can achieve solution procedures for problems of nonlinear dynamical systems also in groups.
Autonomy	• Students are able to approach given research tasks on the basis of given methods individually. • Students are able to identify and follow up novel research tasks by themselves.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	2 Hours
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: 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: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L0702: Nonlinear Dynamics	
Typ	Integrated Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Norbert Hoffmann
Language	DE/EN
Cycle	SoSe

Content	Fundamentals of Nonlinear Dynamics
	• One dimensional problems
	  ◦ Linear Stability
	  ◦ Local Bifurcations
	  ◦ Synchronisation
	• Two dimensional problems
	  ◦ Limit Cycles
	  ◦ Global Bifurcations
	• Chaos
	  ◦ Lorenz Equations
	  ◦ Fractals and Strange Attractors
	  ◦ Predictability and Horizons

Literature	Steven Strogatz: Nonlinear Dynamics and Chaos.

Module M0803: Embedded Systems

Courses

Title	Typ	Hrs/wk	CP
Embedded Systems (L0805)	Lecture	3	3
Embedded Systems (L2938)	Project-/problem-based Learning	1	1
Embedded Systems (L0806)	Recitation Section (small)	1	2

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Computer Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Embedded systems can be defined as information processing systems embedded into enclosing products. This course teaches the foundations of such systems. In particular, it deals with an introduction into these systems (notions, common characteristics) and their specification languages (models of computation, hierarchical automata, specification of distributed systems, task graphs, specification of real-time applications, translations between different models). Another part covers the hardware of embedded systems: Sonsors, A/D and D/A converters, real-time capable communication hardware, embedded processors, memories, energy dissipation, reconfigurable logic and actuators. The course also features an introduction into real-time operating systems, middleware and real-time scheduling. Finally, the implementation of embedded systems using hardware/software co-design (hardware/software partitioning, high-level transformations of specifications, energy-efficient realizations, compilers for embedded processors) is covered.
Skills	After having attended the course, students shall be able to realize simple embedded systems. The students shall realize which relevant parts of technological competences to use in order to obtain a functional embedded systems. In particular, they shall be able to compare different models of computations and feasible techniques for system-level design. They shall be able to judge in which areas of embedded system design specific risks exist.
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 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** 10 %; **Form** Subject theoretical and practical work; **Description**
Examination	Written exam
Examination duration and scale	90 minutes, contents of course and labs
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Electrical Engineering: Core Qualification: Elective Compulsory Engineering Science: Specialisation Mechatronics: Elective Compulsory Engineering Science: Specialisation Electrical Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechatronics: Elective Compulsory Computer Science in Engineering: Core Qualification: Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory

Course L0805: Embedded Systems

Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	EN
Cycle	SoSe
Content	• Introduction • Specifications and Modeling • Embedded/Cyber-Physical Systems Hardware • System Software • Evaluation and Validation • Mapping of Applications to Execution Platforms • Optimization
Literature	• Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2 nd Edition, Springer, 2012., Springer, 2012.

Course L2938: Embedded Systems	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	EN
Cycle	SoSe
Content	• Introduction • Specifications and Modeling • Embedded/Cyber-Physical Systems Hardware • System Software • Evaluation and Validation • Mapping of Applications to Execution Platforms • Optimization
Literature	• Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2 nd Edition, Springer, 2012., Springer, 2012.

Course L0806: Embedded Systems	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0805: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)

Courses

Title	Typ	Hrs/wk	CP
Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics) (L0516)	Lecture	2	3
Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics) (L0518)	Recitation Section (large)	2	3

Module Responsible	Prof. Otto von Estorff
Admission Requirements	None
Recommended Previous Knowledge	Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics) Mathematics I, II, III (in particular differential equations)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students possess an in-depth knowledge in acoustics regarding acoustic waves, noise protection, and psycho acoustics and are able to give an overview of the corresponding theoretical and methodical basis.
Skills	The students are capable to handle engineering problems in acoustics by theory-based application of the demanding methodologies and measurement procedures treated within the module.
Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	The students are able to independently solve challenging acoustical problems in the areas treated within the module. Possible conflicting issues and limitations can be identified and the results are critically scrutinized.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L0516: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Benedikt Kriegesmann, Dr.-Ing. Sören Keuchel
Language	EN
Cycle	SoSe
Content	- Introduction and Motivation - Acoustic quantities - Acoustic waves - Sound sources, sound radiation - Sound engergy and intensity - Sound propagation - Signal processing - Psycho acoustics - Noise - Measurements in acoustics
Literature	Cremer, L.; Heckl, M. (1996): Körperschall. Springer Verlag, Berlin Veit, I. (1988): Technische Akustik. Vogel-Buchverlag, Würzburg Veit, I. (1988): Flüssigkeitsschall. Vogel-Buchverlag, Würzburg

Course L0518: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Benedikt Kriegesmann, Dr.-Ing. Sören Keuchel
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0807: Boundary Element Methods

Courses

Title	Typ	Hrs/wk	CP
Boundary Element Methods (L0523)	Lecture	2	3
Boundary Element Methods (L0524)	Recitation Section (large)	2	3

Module Responsible	Prof. Otto von Estorff
Admission Requirements	None
Recommended Previous Knowledge	Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics) Mathematics I, II, III (in particular differential equations)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students possess an in-depth knowledge regarding the derivation of the boundary element method and are able to give an overview of the theoretical and methodical basis of the method.
Skills	The students are capable to handle engineering problems by formulating suitable boundary elements, assembling the corresponding system matrices, and solving the resulting system of equations.
Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	The students are able to independently solve challenging computational problems and develop own boundary element routines. Problems can be identified and the results are critically scrutinized.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** No / 20 % / Midterm
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Energy Systems: Core Qualification: Elective Compulsory Mechanical Engineering and Management: Specialisation Product Development and Production: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L0523: Boundary Element Methods

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	SoSe
Content	- Boundary value problems - Integral equations - Fundamental Solutions - Element formulations - Numerical integration - Solving systems of equations (statics, dynamics) - Special BEM formulations - Coupling of FEM and BEM - Hands-on Sessions (programming of BE routines) - Applications
Literature	Gaul, L.; Fiedler, Ch. (1997): Methode der Randelemente in Statik und Dynamik. Vieweg, Braunschweig, Wiesbaden Bathe, K.-J. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin

Course L0524: Boundary Element Methods	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1212: Technical Complementary Course for IMPMEC (according to Subject Specific Regulations)	
Courses	
Title	**Typ** **Hrs/wk** **CP**
Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	See selected module according to FSPO
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	see selected module according to FSPO
Skills	see selected module according to FSPO
Personal Competence	
Social Competence	see selected module according to FSPO
Autonomy	see selected module according to FSPO
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Module M1156: Systems Engineering

Courses

Title	Typ	Hrs/wk	CP
Systems Engineering (L1547)	Lecture	3	4
Systems Engineering (L1548)	Recitation Section (large)	1	2

Module Responsible	Prof. Ralf God
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: • Aircraft Cabin Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • understand systems engineering process models, methods and tools for the development of complex Systems • describe innovation processes and the need for technology Management • explain the aircraft development process and the process of type certification for aircraft • explain the system development process, including requirements for systems reliability • identify environmental conditions and test procedures for airborne Equipment • value the methodology of requirements-based engineering (RBE) and model-based requirements engineering (MBRE)
Skills	Students are able to: • plan the process for the development of complex Systems • organize the development phases and development Tasks • assign required business activities and technical Tasks • apply systems engineering methods and tools
Personal Competence	
Social Competence	Students are able to: • understand and accept their tasks within a development team • be comfortable with their role their tasks within the overall process • understand and serve their suppliers and customers in large projects • assume responsibility for people and technology in the development of safety-critical systems
Autonomy	Students are able to: • interact and communicate in a development team with division of tasks. • independently research and identify certification specifications • formulate requirements on their own • create test plans on their own and accompany certification processes
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 Minutes
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L1547: Systems Engineering	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	The objective of the lecture with the corresponding exercise is to accomplish the prerequisites for the development and integration of complex systems using the example of commercial aircraft and cabin systems. Competences in the systems engineering process, tools and methods is to be achieved. Regulations, guidelines and certification issues will be known. Key aspects of the course are processes for innovation and technology management, system design, system integration and certification as well as tools and methods for systems engineering: • Innovation processes • IP-protection • Technology management • Systems engineering • Aircraft program • Certification issues • Systems development • Safety objectives and fault tolerance • Environmental and operating conditions • Tools for systems engineering • Requirements-based engineering (RBE) • Model-based requirements engineering (MBRE)
Literature	- Skript zur Vorlesung - diverse Normen und Richtlinien (EASA, FAA, RTCA, SAE) - Hauschildt, J., Salomo, S.: Innovationsmanagement. Vahlen, 5. Auflage, 2010 - NASA Systems Engineering Handbook, National Aeronautics and Space Administration, 2007 - Hinsch, M.: Industrielles Luftfahrtmanagement: Technik und Organisation luftfahrttechnischer Betriebe. Springer, 2010 - De Florio, P.: Airworthiness: An Introduction to Aircraft Certification. Elsevier Ltd., 2010 - Pohl, K.: Requirements Engineering. Grundlagen, Prinzipien, Techniken. 2. korrigierte Auflage, dpunkt.Verlag, 2008

Course L1548: Systems Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1223: Selected Topics of Mechatronics (Alternative A: 12 LP)

Courses

Title	Typ	Hrs/wk	CP
Applied Automation (L1592)	Project-/problem-based Learning	3	3
Advanced Training Course SE-ZERT (L2739)	Project-/problem-based Learning	2	3
Development Management for Mechatronics (L1512)	Lecture	2	3
Fatigue & Damage Tolerance (L0310)	Lecture	2	3
Industry 4.0 for engineers (L2012)	Lecture	2	3
Microcontroller Circuits: Implementation in Hardware and Software (L0087)	Seminar	2	2
Microsystems Technology (L0724)	Lecture	2	4
Model-Based Systems Engineering (MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Sustainable Industrial Production (L2863)	Lecture	2	4
Process Measurement Engineering (L1077)	Lecture	2	3
Process Measurement Engineering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medical Technology (L0664)	Lecture	2	3

Module Responsible	NN
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 express their extended knowledge and discuss the connection of different special fields or application areas of mechatronics • Students are qualified to connect different special fields with each other
Skills	• Students can apply specialized solution strategies and new scientific methods in selected areas • Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches
Personal Competence	
Social Competence	None
Autonomy	• Students are able to develop their knowledge and skills by autonomous election of courses.
Workload in Hours	Depends on choice of courses
Credit points	12
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Course L1592: Applied Automation	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Mündliche Prüfung
Examination duration and scale	30 Minuten
Lecturer	Prof. Thorsten Schüppstuhl
Language	DE
Cycle	WiSe
Content	-Project Based Learning -Robot Operating System -Robot structure and description -Motion description -Calibration -Accuracy
Literature	John J. Craig Introduction to Robotics - Mechanics and Control ISBN: 0131236296 Pearson Education, Inc., 2005 Stefan Hesse Grundlagen der Handhabungstechnik ISBN: 3446418725 München Hanser, 2010 K. Thulasiraman and M. N. S. Swamy Graphs: Theory and Algorithms ISBN: 9781118033104 %CITAVIPICKER£9781118033104£Titel anhand dieser ISBN in Citavi-Projekt übernehmen£% John Wüey & Sons, Inc., 1992

Course L2739: Advanced Training Course SE-ZERT	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	120 min
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	
Literature	INCOSE Systems Engineering Handbuch - Ein Leitfaden für Systemlebenszyklus-Prozesse und -Aktivitäten, GfSE (Hrsg. der deutschen Übersetzung), ISBN 978-3-9818805-0-2. ISO/IEC 15288 System- und Software-Engineering - System-Lebenszyklus-Prozesse (Systems and Software Engineering - System Life Cycle Processes).

Course L1512: Development Management for Mechatronics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 Minuten
Lecturer	NN, Dr. Johannes Nicolas Gebhardt
Language	DE
Cycle	SoSe

Content	• Processes and methods of product development - from idea to market launch
	  ◦ identification of market and technology potentials
	  ◦ development of a common product architecture
	  ◦ Synchronized product development across all engineering disciplines
	  ◦ product validation incl. customer view
	• Steering and optimization of product development
	  ◦ Design of processes for product development
	  ◦ IT systems for product development
	  ◦ Establishment of management standards
	  ◦ Typical types of organization

Literature	• Bender: Embedded Systems - qualitätsorientierte Entwicklung • Ehrlenspiel: Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit • Gausemeier/Ebbesmeyer/Kallmeyer: Produktinnovation - Strategische Planung und Entwicklung der Produkte von morgen • Haberfellner/de Weck/Fricke/Vössner: Systems Engineering: Grundlagen und Anwendung • Lindemann: Methodische Entwicklung technischer Produkte: Methoden flexibel und situationsgerecht anwenden • Pahl/Beitz: Konstruktionslehre: Grundlagen erfolgreicher Produktentwicklung. Methoden und Anwendung • VDI-Richtlinie 2206: Entwicklungsmethodik für mechatronische Systeme

Course L0310: Fatigue & Damage Tolerance	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 min
Lecturer	Dr. Martin Flamm
Language	EN
Cycle	WiSe
Content	Design principles, fatigue strength, crack initiation and crack growth, damage calculation, counting methods, methods to improve fatigue strength, environmental influences
Literature	Jaap Schijve, Fatigue of Structures and Materials. Kluver Academic Puplisher, Dordrecht, 2001 E. Haibach. Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung. VDI-Verlag, Düsseldorf, 1989

Course L2012: Industry 4.0 for engineers	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	120 min
Lecturer	Prof. Thorsten Schüppstuhl
Language	DE
Cycle	SoSe
Content	
Literature	

Course L0087: Microcontroller Circuits: Implementation in Hardware and Software	
Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	10 min. Vortrag + anschließende Diskussion
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe/SoSe
Content	
Literature	ATmega16A 8-bit Microcontroller with 16K Bytes In-System Programmable Flash - DATASHEET, Atmel Corporation 2014 Atmel AVR 8-bit Instruction Set Instruction Set Manual, Atmel Corporation 2016

Course L0724: Microsystems Technology	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	• Introduction (historical view, scientific and economic relevance, scaling laws) • Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting) • Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) • Etching and Bulk Micromachining (definitions, wet chemical etching, isotropic etch with HNA, electrochemical etching, anisotropic etching with KOH/TMAH: theory, corner undercutting, measures for compensation and etch-stop techniques; plasma processes, dry etching: back sputtering, plasma etching, RIE, Bosch process, cryo process, XeF2 etching) • Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping) • Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: thermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, IR sensor: thermopile and bolometer) • Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: piezoresistive, capacitive and fabrication process; accelerometer: piezoresistive, piezoelectric and capacitive; angular rate sensor: operating principle and fabrication process) • Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer) • Chemical and Bio Sensors (thermal gas sensors: pellistor and thermal conductivity sensor; metal oxide semiconductor gas sensor, organic semiconductor gas sensor, Lambda probe, MOSFET gas sensor, pH-FET, SAW sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip) • Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, microvalves: passive and active, micropumps, valveless micropump, electrokinetic micropumps, micromixer, filter, inkjet printhead, microdispenser, microfluidic switching elements, microreactor, lab-on-a-chip, microanalytics) • MEMS in medical Engineering (wireless energy and data transmission, smart pill, implantable drug delivery system, stimulators: microelectrodes, cochlear and retinal implant; implantable pressure sensors, intelligent osteosynthesis, implant for spinal cord regeneration) • Design, Simulation, Test (development and design flows, bottom-up approach, top-down approach, testability, modelling: multiphysics, FEM and equivalent circuit simulation; reliability test, physics-of-failure, Arrhenius equation, bath-tub relationship) • System Integration (monolithic and hybrid integration, assembly and packaging, dicing, electrical contact: wire bonding, TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L1551: Model-Based Systems Engineering (MBSE) with SysML/UML	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	ca. 10 Seiten
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	Objectives of the problem-oriented course are the acquisition of knowledge on system design using the formal languages SysML/UML, learning about tools for modeling and finally the implementation of a project with methods and tools of Model-Based Systems Engineering (MBSE) on a realistic hardware platform (e.g. Arduino®, Raspberry Pi®): • What is a model? • What is Systems Engineering? • Survey of MBSE methodologies • The modelling languages SysML /UML • Tools for MBSE • Best practices for MBSE • Requirements specification, functional architecture, specification of a solution • From model to software code • Validation and verification: XiL methods • Accompanying MBSE project
Literature	- Skript zur Vorlesung - Weilkiens, T.: Systems Engineering mit SysML/UML: Modellierung, Analyse, Design. 2. Auflage, dpunkt.Verlag, 2008 - Holt, J., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011

Course L2863: Sustainable Industrial Production	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Dr. Simon Markus Kothe
Language	DE
Cycle	SoSe
Content	Industrial production deals with the manufacture of physical products to satisfy human needs using various manufacturing processes that change the form and physical properties of raw materials. Manufacturing is a central driver of economic development and has a major impact on the well-being of humanity. However, the scale of current manufacturing activities results in enormous global energy and material demands that are harmful to both the environment and people. Historically, industrial activities were mostly oriented towards economic constraints, while social and environmental consequences were only hardly considered. As a result, today's global consumption rates of many resources and associated emissions often exceed the natural regeneration rate of our planet. In this respect, current industrial production can mostly be described as unsustainable. This is emphasized each year by the Earth Overshoot Day, which marks the day when humanity's ecological footprint exceeds the Earth's annual regenerative capacity. This lecture aims to provide the motivation, analytical methods as well as approaches for sustainable industrial production and to clarify the influence of the production phase in relation to the raw material, use and recycling phases in the entire life cycle of products. For this, the following topics will be highlighted: - Motivation for sustainable production, the 17 Sustainable Development Goals (SDGs) of the UN and their relevance for tomorrow's manufacturing; - raw material vs. production phase vs. use phase vs. recycling/end-of-life phase: importance of the production phase for the environmental impact of manufactured products; - Typical energy- and resource-intensive processes in industrial production and innovative approaches to increase energy and resource efficiency; - Methodology for optimizing the energy and resource efficiency of industrial manufacturing chains with the three steps of modeling (1), evaluating (2) and improving (3); - Resource efficiency of industrial manufacturing value chains and its assessment using life cycle analysis (LCA); - Exercise: LCA analysis of a manufacturing process (thermoplastic joining of an aircraft fuselage segment) as part of a product life cycle assessment.
Literature	Literatur: - Stefan Alexander (2020): Resource efficiency in manufacturing value chains. Cham: Springer International Publishing. - Hauschild, Michael Z.; Rosenbaum, Ralph K.; Olsen, Stig Irving (Hg.) (2018): Life Cycle Assessment. Theory and Practice. Cham: Springer International Publishing. - Kishita, Yusuke; Matsumoto, Mitsutaka; Inoue, Masato; Fukushige, Shinichi (2021): EcoDesign and sustainability. Singapore: Springer. - Schebek, Liselotte; Herrmann, Christoph; Cerdas, Felipe (2019): Progress in Life Cycle Assessment. Cham: Springer International Publishing. - Thiede, Sebastian; Hermann, Christoph (2019): Eco-factories of the future. Cham: Springer Nature Switzerland AG. - Vorlesungsskript.

Course L1077: Process Measurement Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 Minuten
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe

Content	• Process measurement engineering in the context of process control engineering
	  ◦ Challenges of process measurement engineering
	  ◦ Instrumentation of processes
	  ◦ Classification of pickups
	• Systems theory in process measurement engineering
	  ◦ Generic linear description of pickups
	  ◦ Mathematical description of two-port systems
	  ◦ Fourier and Laplace transformation
	• Correlational measurement
	  ◦ Wide band signals
	  ◦ Auto- and cross-correlation function and their applications
	  ◦ Fault-free operation of correlational methods
	• Transmission of analog and digital measurement signals
	  ◦ Modulation process (amplitude and frequency modulation)
	  ◦ Multiplexing
	  ◦ Analog to digital converter

Literature	- Färber: „Prozeßrechentechnik“, Springer-Verlag 1994 - Kiencke, Kronmüller: „Meßtechnik“, Springer Verlag Berlin Heidelberg, 1995 - A. Ambardar: „Analog and Digital Signal Processing“ (1), PWS Publishing Company, 1995, NTC 339 - A. Papoulis: „Signal Analysis“ (1), McGraw-Hill, 1987, NTC 312 (LB) - M. Schwartz: „Information Transmission, Modulation and Noise“ (3,4), McGraw-Hill, 1980, 2402095 - S. Haykin: „Communication Systems“ (1,3), Wiley&Sons, 1983, 2419072 - H. Sheingold: „Analog-Digital Conversion Handbook“ (5), Prentice-Hall, 1986, 2440072 - J. Fraden: „AIP Handbook of Modern Sensors“ (5,6), American Institute of Physics, 1993, MTB 346

Course L1083: Process Measurement Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Mündliche Prüfung
Examination duration and scale	
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0664: Feedback Control in Medical Technology	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	20 min
Lecturer	Johannes Kreuzer, Christian Neuhaus
Language	DE
Cycle	SoSe
Content	Always viewed from the engineer's point of view, the lecture is structured as follows: • Introduction to the topic • Fundamentals of physiological modelling • Introduction to Breathing and Ventilation • Physiology and Pathology in Cardiology • Introduction to the Regulation of Blood Glucose • kidney function and renal replacement therapy • Representation of the control technology on the concrete ventilator • Excursion to a medical technology company Techniques of modeling, simulation and controller development are discussed. In the models, simple equivalent block diagrams for physiological processes are derived and explained how sensors, controllers and actuators are operated. MATLAB and SIMULINK are used as development tools.
Literature	• Leonhardt, S., & Walter, M. (2016). Medizintechnische Systeme. Berlin, Heidelberg: Springer Vieweg. • Werner, J. (2005). Kooperative und autonome Systeme der Medizintechnik. München: Oldenbourg. • Oczenski, W. (2017). Atmen : Atemhilfen ; Atemphysiologie und Beatmungstechnik: Georg Thieme Verlag KG.

Module M1224: Selected Topics of Mechatronics (Alternative B: 6 LP)

Courses

Title	Typ	Hrs/wk	CP
Applied Automation (L1592)	Project-/problem-based Learning	3	3
Advanced Training Course SE-ZERT (L2739)	Project-/problem-based Learning	2	3
Development Management for Mechatronics (L1512)	Lecture	2	3
Fatigue & Damage Tolerance (L0310)	Lecture	2	3
Industry 4.0 for engineers (L2012)	Lecture	2	3
Microcontroller Circuits: Implementation in Hardware and Software (L0087)	Seminar	2	2
Microsystems Technology (L0724)	Lecture	2	4
Model-Based Systems Engineering (MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Sustainable Industrial Production (L2863)	Lecture	2	4
Process Measurement Engineering (L1077)	Lecture	2	3
Process Measurement Engineering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medical Technology (L0664)	Lecture	2	3

Module Responsible	NN
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 express their extended knowledge and discuss the connection of different special fields or application areas of mechatronics • Students are qualified to connect different special fields with each other
Skills	• Students can apply specialized solution strategies and new scientific methods in selected areas • Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches
Personal Competence	
Social Competence	None
Autonomy	• Students are able to develop their knowledge and skills by autonomous election of courses.
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L1592: Applied Automation	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Mündliche Prüfung
Examination duration and scale	30 Minuten
Lecturer	Prof. Thorsten Schüppstuhl
Language	DE
Cycle	WiSe
Content	-Project Based Learning -Robot Operating System -Robot structure and description -Motion description -Calibration -Accuracy
Literature	John J. Craig Introduction to Robotics - Mechanics and Control ISBN: 0131236296 Pearson Education, Inc., 2005 Stefan Hesse Grundlagen der Handhabungstechnik ISBN: 3446418725 München Hanser, 2010 K. Thulasiraman and M. N. S. Swamy Graphs: Theory and Algorithms ISBN: 9781118033104 %CITAVIPICKER£9781118033104£Titel anhand dieser ISBN in Citavi-Projekt übernehmen£% John Wüey & Sons, Inc., 1992

Course L2739: Advanced Training Course SE-ZERT	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	120 min
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	
Literature	INCOSE Systems Engineering Handbuch - Ein Leitfaden für Systemlebenszyklus-Prozesse und -Aktivitäten, GfSE (Hrsg. der deutschen Übersetzung), ISBN 978-3-9818805-0-2. ISO/IEC 15288 System- und Software-Engineering - System-Lebenszyklus-Prozesse (Systems and Software Engineering - System Life Cycle Processes).

Course L1512: Development Management for Mechatronics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 Minuten
Lecturer	NN, Dr. Johannes Nicolas Gebhardt
Language	DE
Cycle	SoSe

Content	• Processes and methods of product development - from idea to market launch
	  ◦ identification of market and technology potentials
	  ◦ development of a common product architecture
	  ◦ Synchronized product development across all engineering disciplines
	  ◦ product validation incl. customer view
	• Steering and optimization of product development
	  ◦ Design of processes for product development
	  ◦ IT systems for product development
	  ◦ Establishment of management standards
	  ◦ Typical types of organization

Literature	• Bender: Embedded Systems - qualitätsorientierte Entwicklung • Ehrlenspiel: Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit • Gausemeier/Ebbesmeyer/Kallmeyer: Produktinnovation - Strategische Planung und Entwicklung der Produkte von morgen • Haberfellner/de Weck/Fricke/Vössner: Systems Engineering: Grundlagen und Anwendung • Lindemann: Methodische Entwicklung technischer Produkte: Methoden flexibel und situationsgerecht anwenden • Pahl/Beitz: Konstruktionslehre: Grundlagen erfolgreicher Produktentwicklung. Methoden und Anwendung • VDI-Richtlinie 2206: Entwicklungsmethodik für mechatronische Systeme

Course L0310: Fatigue & Damage Tolerance	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 min
Lecturer	Dr. Martin Flamm
Language	EN
Cycle	WiSe
Content	Design principles, fatigue strength, crack initiation and crack growth, damage calculation, counting methods, methods to improve fatigue strength, environmental influences
Literature	Jaap Schijve, Fatigue of Structures and Materials. Kluver Academic Puplisher, Dordrecht, 2001 E. Haibach. Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung. VDI-Verlag, Düsseldorf, 1989

Course L2012: Industry 4.0 for engineers	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	120 min
Lecturer	Prof. Thorsten Schüppstuhl
Language	DE
Cycle	SoSe
Content	
Literature	

Course L0087: Microcontroller Circuits: Implementation in Hardware and Software	
Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	10 min. Vortrag + anschließende Diskussion
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe/SoSe
Content	
Literature	ATmega16A 8-bit Microcontroller with 16K Bytes In-System Programmable Flash - DATASHEET, Atmel Corporation 2014 Atmel AVR 8-bit Instruction Set Instruction Set Manual, Atmel Corporation 2016

Course L0724: Microsystems Technology	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	• Introduction (historical view, scientific and economic relevance, scaling laws) • Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting) • Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) • Etching and Bulk Micromachining (definitions, wet chemical etching, isotropic etch with HNA, electrochemical etching, anisotropic etching with KOH/TMAH: theory, corner undercutting, measures for compensation and etch-stop techniques; plasma processes, dry etching: back sputtering, plasma etching, RIE, Bosch process, cryo process, XeF2 etching) • Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping) • Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: thermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, IR sensor: thermopile and bolometer) • Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: piezoresistive, capacitive and fabrication process; accelerometer: piezoresistive, piezoelectric and capacitive; angular rate sensor: operating principle and fabrication process) • Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer) • Chemical and Bio Sensors (thermal gas sensors: pellistor and thermal conductivity sensor; metal oxide semiconductor gas sensor, organic semiconductor gas sensor, Lambda probe, MOSFET gas sensor, pH-FET, SAW sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip) • Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, microvalves: passive and active, micropumps, valveless micropump, electrokinetic micropumps, micromixer, filter, inkjet printhead, microdispenser, microfluidic switching elements, microreactor, lab-on-a-chip, microanalytics) • MEMS in medical Engineering (wireless energy and data transmission, smart pill, implantable drug delivery system, stimulators: microelectrodes, cochlear and retinal implant; implantable pressure sensors, intelligent osteosynthesis, implant for spinal cord regeneration) • Design, Simulation, Test (development and design flows, bottom-up approach, top-down approach, testability, modelling: multiphysics, FEM and equivalent circuit simulation; reliability test, physics-of-failure, Arrhenius equation, bath-tub relationship) • System Integration (monolithic and hybrid integration, assembly and packaging, dicing, electrical contact: wire bonding, TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L1551: Model-Based Systems Engineering (MBSE) with SysML/UML	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	ca. 10 Seiten
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	Objectives of the problem-oriented course are the acquisition of knowledge on system design using the formal languages SysML/UML, learning about tools for modeling and finally the implementation of a project with methods and tools of Model-Based Systems Engineering (MBSE) on a realistic hardware platform (e.g. Arduino®, Raspberry Pi®): • What is a model? • What is Systems Engineering? • Survey of MBSE methodologies • The modelling languages SysML /UML • Tools for MBSE • Best practices for MBSE • Requirements specification, functional architecture, specification of a solution • From model to software code • Validation and verification: XiL methods • Accompanying MBSE project
Literature	- Skript zur Vorlesung - Weilkiens, T.: Systems Engineering mit SysML/UML: Modellierung, Analyse, Design. 2. Auflage, dpunkt.Verlag, 2008 - Holt, J., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011

Course L2863: Sustainable Industrial Production	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Dr. Simon Markus Kothe
Language	DE
Cycle	SoSe
Content	Industrial production deals with the manufacture of physical products to satisfy human needs using various manufacturing processes that change the form and physical properties of raw materials. Manufacturing is a central driver of economic development and has a major impact on the well-being of humanity. However, the scale of current manufacturing activities results in enormous global energy and material demands that are harmful to both the environment and people. Historically, industrial activities were mostly oriented towards economic constraints, while social and environmental consequences were only hardly considered. As a result, today's global consumption rates of many resources and associated emissions often exceed the natural regeneration rate of our planet. In this respect, current industrial production can mostly be described as unsustainable. This is emphasized each year by the Earth Overshoot Day, which marks the day when humanity's ecological footprint exceeds the Earth's annual regenerative capacity. This lecture aims to provide the motivation, analytical methods as well as approaches for sustainable industrial production and to clarify the influence of the production phase in relation to the raw material, use and recycling phases in the entire life cycle of products. For this, the following topics will be highlighted: - Motivation for sustainable production, the 17 Sustainable Development Goals (SDGs) of the UN and their relevance for tomorrow's manufacturing; - raw material vs. production phase vs. use phase vs. recycling/end-of-life phase: importance of the production phase for the environmental impact of manufactured products; - Typical energy- and resource-intensive processes in industrial production and innovative approaches to increase energy and resource efficiency; - Methodology for optimizing the energy and resource efficiency of industrial manufacturing chains with the three steps of modeling (1), evaluating (2) and improving (3); - Resource efficiency of industrial manufacturing value chains and its assessment using life cycle analysis (LCA); - Exercise: LCA analysis of a manufacturing process (thermoplastic joining of an aircraft fuselage segment) as part of a product life cycle assessment.
Literature	Literatur: - Stefan Alexander (2020): Resource efficiency in manufacturing value chains. Cham: Springer International Publishing. - Hauschild, Michael Z.; Rosenbaum, Ralph K.; Olsen, Stig Irving (Hg.) (2018): Life Cycle Assessment. Theory and Practice. Cham: Springer International Publishing. - Kishita, Yusuke; Matsumoto, Mitsutaka; Inoue, Masato; Fukushige, Shinichi (2021): EcoDesign and sustainability. Singapore: Springer. - Schebek, Liselotte; Herrmann, Christoph; Cerdas, Felipe (2019): Progress in Life Cycle Assessment. Cham: Springer International Publishing. - Thiede, Sebastian; Hermann, Christoph (2019): Eco-factories of the future. Cham: Springer Nature Switzerland AG. - Vorlesungsskript.

Course L1077: Process Measurement Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 Minuten
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe

Content	• Process measurement engineering in the context of process control engineering
	  ◦ Challenges of process measurement engineering
	  ◦ Instrumentation of processes
	  ◦ Classification of pickups
	• Systems theory in process measurement engineering
	  ◦ Generic linear description of pickups
	  ◦ Mathematical description of two-port systems
	  ◦ Fourier and Laplace transformation
	• Correlational measurement
	  ◦ Wide band signals
	  ◦ Auto- and cross-correlation function and their applications
	  ◦ Fault-free operation of correlational methods
	• Transmission of analog and digital measurement signals
	  ◦ Modulation process (amplitude and frequency modulation)
	  ◦ Multiplexing
	  ◦ Analog to digital converter

Literature	- Färber: „Prozeßrechentechnik“, Springer-Verlag 1994 - Kiencke, Kronmüller: „Meßtechnik“, Springer Verlag Berlin Heidelberg, 1995 - A. Ambardar: „Analog and Digital Signal Processing“ (1), PWS Publishing Company, 1995, NTC 339 - A. Papoulis: „Signal Analysis“ (1), McGraw-Hill, 1987, NTC 312 (LB) - M. Schwartz: „Information Transmission, Modulation and Noise“ (3,4), McGraw-Hill, 1980, 2402095 - S. Haykin: „Communication Systems“ (1,3), Wiley&Sons, 1983, 2419072 - H. Sheingold: „Analog-Digital Conversion Handbook“ (5), Prentice-Hall, 1986, 2440072 - J. Fraden: „AIP Handbook of Modern Sensors“ (5,6), American Institute of Physics, 1993, MTB 346

Course L1083: Process Measurement Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Mündliche Prüfung
Examination duration and scale	
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0664: Feedback Control in Medical Technology	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	20 min
Lecturer	Johannes Kreuzer, Christian Neuhaus
Language	DE
Cycle	SoSe
Content	Always viewed from the engineer's point of view, the lecture is structured as follows: • Introduction to the topic • Fundamentals of physiological modelling • Introduction to Breathing and Ventilation • Physiology and Pathology in Cardiology • Introduction to the Regulation of Blood Glucose • kidney function and renal replacement therapy • Representation of the control technology on the concrete ventilator • Excursion to a medical technology company Techniques of modeling, simulation and controller development are discussed. In the models, simple equivalent block diagrams for physiological processes are derived and explained how sensors, controllers and actuators are operated. MATLAB and SIMULINK are used as development tools.
Literature	• Leonhardt, S., & Walter, M. (2016). Medizintechnische Systeme. Berlin, Heidelberg: Springer Vieweg. • Werner, J. (2005). Kooperative und autonome Systeme der Medizintechnik. München: Oldenbourg. • Oczenski, W. (2017). Atmen : Atemhilfen ; Atemphysiologie und Beatmungstechnik: Georg Thieme Verlag KG.

Module M1269: Lab Cyber-Physical Systems

Courses

Title	Typ	Hrs/wk	CP
Lab Cyber-Physical Systems (L1740)	Project-/problem-based Learning	4	6

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Module "Embedded Systems"
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Cyber-Physical Systems (CPS) are tightly integrated with their surrounding environment, via sensors, A/D and D/A converters, and actors. Due to their particular application areas, highly specialized sensors, processors and actors are common. Accordingly, there is a large variety of different specification approaches for CPS - in contrast to classical software engineering approaches. Based on practical experiments using robot kits and computers, the basics of specification and modelling of CPS are taught. The lab introduces into the area (basic notions, characteristical properties) and their specification techniques (models of computation, hierarchical automata, data flow models, petri nets, imperative approaches). Since CPS frequently perform control tasks, the lab's experiments will base on simple control applications. The experiments will use state-of-the-art industrial specification tools (MATLAB/Simulink, LabVIEW, NXC) in order to model cyber-physical models that interact with the environment via sensors and actors.
Skills	After successful attendance of the lab, students are able to develop simple CPS. They understand the interdependencies between a CPS and its surrounding processes which stem from the fact that a CPS interacts with the environment via sensors, A/D converters, digital processors, D/A converters and actors. The lab enables students to compare modelling approaches, to evaluate their advantages and limitations, and to decide which technique to use for a concrete task. They will be able to apply these techniques to practical problems. They obtain first experiences in hardware-related software development, in industry-relevant specification tools and in the area of simple control applications.
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
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Execution and documentation of all lab experiments
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory

Course L1740: Lab Cyber-Physical Systems

Typ	Project-/problem-based Learning
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	• Experiment 1: Programming in NXC • Experiment 2: Programming the Robot in Matlab/Simulink • Experiment 3: Programming the Robot in LabVIEW
Literature	• Peter Marwedel. Embedded System Design - Embedded System Foundations of Cyber-Physical Systems. 2 nd Edition, Springer, 2012. • Begleitende Foliensätze

Module M1306: Control Lab C

Courses

Title	Typ	Hrs/wk	CP
Control Lab IX (L1836)	Practical Course	1	1
Control Lab VII (L1834)	Practical Course	1	1
Control Lab VIII (L1835)	Practical Course	1	1

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Credit points	3
Course achievement	None
Examination	Written elaboration
Examination duration and scale	1
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L1836: Control Lab IX

Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1834: Control Lab VII

Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1835: Control Lab VIII	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Module M1281: Advanced Topics in Vibration

Courses

Title	Typ	Hrs/wk	CP
Advanced Topics in Vibration (L1743)	Project-/problem-based Learning	4	6

Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	None
Recommended Previous Knowledge	Vibration Theory
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to reflect existing terms and concepts of Advanced Vibrations. • Students are able to identify the need to develop and research new terms and concepts in vibrations.
Skills	• Students are able to apply existing methods and procesures of Advanced Vibrations. • Students are able to develop novel methods and procedures for advanced vibration problems.
Personal Competence	
Social Competence	• Students can reach working results also in groups. • Students can present working results also in groups.
Autonomy	• Students are able to approach given research tasks individually • Students are able to identify and follow up novel research tasks by themselves.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	2 Hours
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L1743: Advanced Topics in Vibration

Typ	Project-/problem-based Learning
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Norbert Hoffmann
Language	DE/EN
Cycle	SoSe
Content	Advanced and Research Topics in Vibrations • Rotor Dynamics • Modal Analysis • Model Order Reduction • Stability of Periodic Solutions • Random Vibrations
Literature	Aktuelle Veröffentlichungen / Recent research publications Bücher/Books: Gasch, Nordmann, Pfützner: Rotordynamik Gasch, Knothe, Liebich: Strukturdynamik

Module M0835: Humanoid Robotics

Courses

Title	Typ	Hrs/wk	CP
Humanoid Robotics (L0663)	Seminar	2	2

Module Responsible	Patrick Göttsch
Admission Requirements	None
Recommended Previous Knowledge	• Introduction to control systems • Control theory and design
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain humanoid robots. • Students learn to apply basic control concepts for different tasks in humanoid robotics.
Skills	• Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature • Students generalize developed results and present them to the participants • Students practice to prepare and give a presentation
Personal Competence	
Social Competence	• Students are capable of developing solutions in interdisciplinary teams and present them • They are able to provide appropriate feedback and handle constructive criticism of their own results
Autonomy	• Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the best solution • Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other students, such that a scientific discussion develops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Presentation
Examination duration and scale	30 min
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: 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 Robotics and Computer Science: Elective Compulsory

Course L0663: Humanoid Robotics

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Patrick Göttsch
Language	DE
Cycle	SoSe
Content	• Grundlagen der Regelungstechnik • Control systems theory and design
Literature	- B. Siciliano, O. Khatib. "Handbook of Robotics. Part A: Robotics Foundations", Springer (2008).

Module M0838: Linear and Nonlinear System Identifikation

Courses

Title	Typ	Hrs/wk	CP
Linear and Nonlinear System Identification (L0660)	Lecture	2	3

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• Classical control (frequency response, root locus) • State space methods • Discrete-time systems • Linear algebra, singular value decomposition • Basic knowledge about stochastic processes
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the general framework of the prediction error method and its application to a variety of linear and nonlinear model structures • They can explain how multilayer perceptron networks are used to model nonlinear dynamics • They can explain how an approximate predictive control scheme can be based on neural network models • They can explain the idea of subspace identification and its relation to Kalman realisation theory
Skills	• Students are capable of applying the predicition error method to the experimental identification of linear and nonlinear models for dynamic systems • They are capable of implementing a nonlinear predictive control scheme based on a neural network model • They are capable of applying subspace algorithms to the experimental identification of linear models for dynamic systems • They can do the above using standard software tools (including the Matlab System Identification Toolbox)
Personal Competence	
Social Competence	Students can work in mixed groups on specific problems to arrive at joint solutions.
Autonomy	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: 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: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L0660: Linear and Nonlinear System Identification

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	SoSe
Content	• Prediction error method • Linear and nonlinear model structures • Nonlinear model structure based on multilayer perceptron network • Approximate predictive control based on multilayer perceptron network model • Subspace identification
Literature	• Lennart Ljung, System Identification - Theory for the User, Prentice Hall 1999 • M. Norgaard, O. Ravn, N.K. Poulsen and L.K. Hansen, Neural Networks for Modeling and Control of Dynamic Systems, Springer Verlag, London 2003 • T. Kailath, A.H. Sayed and B. Hassibi, Linear Estimation, Prentice Hall 2000

Module M0939: Control Lab A

Courses

Title	Typ	Hrs/wk	CP
Control Lab I (L1093)	Practical Course	1	1
Control Lab II (L1291)	Practical Course	1	1
Control Lab III (L1665)	Practical Course	1	1
Control Lab IV (L1666)	Practical Course	1	1

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Credit points	4
Course achievement	None
Examination	Written elaboration
Examination duration and scale	1
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L1093: Control Lab I

Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1291: Control Lab II	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1665: Control Lab III	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1666: Control Lab IV	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

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. Bernd-Christian Renner
Admission Requirements	None
Recommended Previous Knowledge	• Very Good knowledge and practical experience in programming in the C language • Basic knowledge in software engineering • Basic understanding of assembly language
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know the basic principles and procedures of software engineering for embedded systems. They are able to describe the usage and pros of event based programming using interrupts. They know the components and functions of a concrete microcontroller. The participants explain requirements of real time systems. They know at least three scheduling algorithms for real time operating systems including their pros and cons.
Skills	Students build interrupt-based programs for a concrete microcontroller. They build and use a preemptive scheduler. They use peripheral components (timer, ADC, EEPROM) to realize complex tasks for embedded systems. To interface with external components they utilize serial protocols.
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	Compulsory: No; Bonus: 10 %; Form: Attestation; Description:
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: 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. Bernd-Christian Renner
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. Bernd-Christian Renner
Language	DE/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)	Project-/problem-based Learning	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
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L1692: Compilers for Embedded Systems	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	• Introduction and Motivation • Compilers for Embedded Systems - Requirements and Dependencies • Internal Structure of Compilers • Pre-Pass Optimizations • HIR Optimizations and Transformations • Code Generation • LIR Optimizations and Transformations • Register Allocation • WCET-Aware Compilation • Outlook
Literature	• Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2 nd 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	Project-/problem-based Learning
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 M0840: Optimal and Robust Control

Courses

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

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• Classical control (frequency response, root locus) • State space methods • Linear algebra, singular value decomposition
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the significance of the matrix Riccati equation for the solution of LQ problems. • They can explain the duality between optimal state feedback and optimal state estimation. • They can explain how the H2 and H-infinity norms are used to represent stability and performance constraints. • They can explain how an LQG design problem can be formulated as special case of an H2 design problem. • They can explain how model uncertainty can be represented in a way that lends itself to robust controller design • They can explain how - based on the small gain theorem - a robust controller can guarantee stability and performance for an uncertain plant. • They understand how analysis and synthesis conditions on feedback loops can be represented as linear matrix inequalities.
Skills	• Students are capable of designing and tuning LQG controllers for multivariable plant models. • They are capable of representing a H2 or H-infinity design problem in the form of a generalized plant, and of using standard software tools for solving it. • They are capable of translating time and frequency domain specifications for control loops into constraints on closed-loop sensitivity functions, and of carrying out a mixed-sensitivity design. • They are capable of constructing an LFT uncertainty model for an uncertain system, and of designing a mixed-objective robust controller. • They are capable of formulating analysis and synthesis conditions as linear matrix inequalities (LMI), and of using standard LMI-solvers for solving them. • They can carry out all of the above using standard software tools (Matlab robust control toolbox).
Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: 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: Core Qualification: Elective Compulsory

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

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

Module M1400: Design of Dependable Systems

Courses

Title	Typ	Hrs/wk	CP
Designing Dependable Systems (L2000)	Lecture	2	3
Designing Dependable Systems (L2001)	Recitation Section (small)	2	3

Module Responsible	Prof. Görschwin Fey
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge about data structures and algorithms
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	In the following "dependable" summarizes the concepts Reliability, Availability, Maintainability, Safety and Security. Knowledge about approaches for designing dependable systems, e.g., • Structural solutions like modular redundancy • Algorithmic solutions like handling byzantine faults or checkpointing Knowledge about methods for the analysis of dependable systems
Skills	Ability to implement dependable systems using the above approaches. Ability to analyzs the dependability of systems using the above methods for analysis.
Personal Competence	
Social Competence	Students • discuss relevant topics in class and • present their solutions orally.
Autonomy	Using accompanying material students independently learn in-depth relations between concepts explained in the lecture and additional solution strategies.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	Compulsory: Yes; Bonus: None; Form: Subject theoretical and practical work; Description: Die Lösung einer Aufgabe ist Zuslassungsvoraussetzung für die Prüfung. Die Aufgabe wird in Vorlesung und Übung definiert.
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory

Course L2000: Designing Dependable Systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Görschwin Fey
Language	DE/EN
Cycle	SoSe
Content	Description The term dependability comprises various aspects of a system. These are typically: • Reliability • Availability • Maintainability • Safety • Security This makes dependability a core aspect that has to be considered early in system design, no matter whether software, embedded systems or full scale cyber-physical systems are considered. Contents The module introduces the basic concepts for the design and the analysis of dependable systems. Design examples for getting practical hands-on-experience in dependable design techniques. The module focuses towards embedded systems. The following topics are covered: • Modelling • Fault Tolerance • Design Concepts • Analysis Techniques
Literature	

Course L2001: Designing Dependable Systems	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Görschwin Fey
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1143: Applied Design Methodology in Mechatronics

Courses

Title	Typ	Hrs/wk	CP
Applied Design Methodology in Mechatronics (L1523)	Lecture	2	2
Applied Design Methodology in Mechatronics (L1524)	Project-/problem-based Learning	3	4

Module Responsible	Prof. Thorsten Kern
Admission Requirements	None
Recommended Previous Knowledge	Basics of mechanical design, electrical design or computer-sciences
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Science-based working on interdisciplinary product design considering targeted application of specific product design techniques
Skills	Creative handling of processes used for scientific preparation and formulation of complex product design problems / Application of various product design techniques following theoretical aspects.
Personal Competence	
Social Competence	Students will solve and execute technical-scientific tasks from an industrial context in small design-teams with application of common, creative methodologies.
Autonomy	Students are enabled to optimize the design and development process according to the target and topic of the design Students are educated to operate in a development team Students learn about the right application of creative methods in engineering.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	30 min Presentation for a group design-work
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Product Development and Production: Elective Compulsory Mechatronics: Specialisation System Design: 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 Product Development and Production: Elective Compulsory

Course L1523: Applied Design Methodology in Mechatronics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	SoSe
Content	• Systematic analysis and planning of the design process for products combining a multitude of disciplines • Structure of the engineering process with focus on engineering steps (task-definition, functional decomposition, physical principles, elements for solution, combination to systems and products, execution of design, component-tests, system-tests, product-testing and qualification/validation) • Creative methods (Basics, methods like lead-user-method, 6-3-5, BrainStorming, Intergalactic Thinking, ... - Applications in examples all around mechatronics topics) • Several design-supporting methods and tools (functional strcutures, GALFMOS, AEIOU-method, GAMPFT, simulation and its application, TRIZ, design for SixSigma, continous integration and testing, ...) • Evaluation and final selection of solution (technical and business-considerations, preference-matrix, pair-comparision), dealing with uncertainties, decision-making • Value-analysis • Derivation of architectures and architectural management • Project-tracking and -guidance (project-lead, guiding of employees, organization of multidisciplinary R&D departments, idea-identification, responsibilities and communication) • Project-execution methods (Scrum, Kanbaan, ...) • Presentation-skills • Questions of aesthetic product design and design for subjective requirements (industrial design, color, haptic/optic/acoustic interfaces) • Evaluation of selected methods at practical examples in small teams
Literature	• Definition folgt... • Pahl, G.; Beitz, W.; Feldhusen, J.; Grote, K.-H.: Konstruktionslehre: Grundlage erfolgreicher Produktentwicklung, Methoden und Anwendung, 7. Auflage, Springer Verlag, Berlin 2007 • VDI-Richtlinien: 2206; 2221ff

Course L1524: Applied Design Methodology in Mechatronics	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1340: Introduction to Waveguides, Antennas, and Electromagnetic Compatibility

Courses

Title	Typ	Hrs/wk	CP
Introduction to Waveguides, Antennas, and Electromagnetic Compatibility (L1669)	Lecture	3	4
Introduction to Waveguides, Antennas, and Electromagnetic Compatibility (L1877)	Recitation Section (small)	2	2

Module Responsible	Prof. Christian Schuster
Admission Requirements	None
Recommended Previous Knowledge	Basic principles of physics and electrical engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the basic principles, relationships, and methods for the design of waveguides and antennas as well as of Electromagnetic Compatibility. Specific topics are: - Fundamental properties and phenomena of electrical circuits - Steady-state sinusoidal analysis of electrical circuits - Fundamental properties and phenomena of electromagnetic fields and waves - Steady-state sinusoidal description of electromagnetic fields and waves - Useful microwave network parameters - Transmission lines and basic results from transmission line theory - Plane wave propagation, superposition, reflection and refraction - General theory of waveguides - Most important types of waveguides and their properties - Radiation and basic antenna parameters - Most important types of antennas and their properties - Numerical techniques and CAD tools for waveguide and antenna design - Fundamentals of Electromagnetic Compatibility - Coupling mechanisms and countermeasures - Shielding, grounding, filtering - Standards and regulations - EMC measurement techniques
Skills	Students know how to apply various methods and models for characterization and choice of waveguides and antennas. They are able to assess and qualify their basic electromagnetic properties. They can apply results and strategies from the field of Electromagnetic Compatibilty to the development of electrical components and systems.
Personal Competence	
Social Competence	Students are able to work together on subject related tasks in small groups. They are able to present their results effectively in English (e.g. during small group exercises).
Autonomy	Students are capable to gather information from subject related, professional publications and relate that information to the context of the lecture. They are able to make a connection between their knowledge obtained in this lecture with the content of other lectures (e.g. theory of electromagnetic fields, fundamentals of electrical engineering / physics). They can discuss technical problems and physical effects in English.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	45 min
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Electrical Engineering: Elective Compulsory Electrical Engineering: Core Qualification: Elective Compulsory Engineering Science: Specialisation Electrical Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory

Course L1669: Introduction to Waveguides, Antennas, and Electromagnetic Compatibility	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	SoSe
Content	This course is intended as an introduction to the topics of wave propagation, guiding, sending, and receiving as well as Electromagnetic Compatibility (EMC). It will be useful for engineers that face the technical challenge of transmitting high frequency / high bandwidth data in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of wave propagation and Electromagnetic Compatibility will be introduced and discussed. Topics: - Fundamental properties and phenomena of electrical circuits - Steady-state sinusoidal analysis of electrical circuits - Fundamental properties and phenomena of electromagnetic fields and waves - Steady-state sinusoidal description of electromagnetic fields and waves - Useful microwave network parameters - Transmission lines and basic results from transmission line theory - Plane wave propagation, superposition, reflection and refraction - General theory of waveguides - Most important types of waveguides and their properties - Radiation and basic antenna parameters - Most important types of antennas and their properties - Numerical techniques and CAD tools for waveguide and antenna design - Fundamentals of Electromagnetic Compatibility - Coupling mechanisms and countermeasures - Shielding, grounding, filtering - Standards and regulations - EMC measurement techniques
Literature	- Zinke, Brunswig, "Hochfrequenztechnik 1", Springer (1999) - J. Detlefsen, U. Siart, "Grundlagen der Hochfrequenztechnik", Oldenbourg (2012) - D. M. Pozar, "Microwave Engineering", Wiley (2011) - Y. Huang, K. Boyle, "Antenna: From Theory to Practice", Wiley (2008) - H. Ott, "Electromagnetic Compatibility Engineering", Wiley (2009) - A. Schwab, W. Kürner, "Elektromagnetische Verträglichkeit", Springer (2007)

Course L1877: Introduction to Waveguides, Antennas, and Electromagnetic Compatibility	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0627: Machine Learning and Data Mining

Courses

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

Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	• Calculus • 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
Course achievement	None
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics 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	Rainer Marrone
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	Rainer Marrone
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1616: Flight Control Law Design and Application

Courses

Title	Typ	Hrs/wk	CP
Flight Control Law Design and Application (L2448)	Lecture	2	4
Flight Control Law Design and Application (L2449)	Project-/problem-based Learning	2	2

Module Responsible	Prof. Frank Thielecke
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: * mathematics (linear algebra and ordinary differential equations) * control systems (transfer functions and state space representation) * mechanics (rigid-body kinetics) * flight mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: * describe and understand flight dynamics models for control tasks * assess handling qualities and understand the need for augmentation through control systems * identify fundamental performance limitations of control laws
Skills	Students are able to: * design model-based control laws for stability augmentation * design model-based flight control laws * assess robustness and performance of control laws
Personal Competence	
Social Competence	Students are able to: * design control laws in groups as well as discuss the requirements and results
Autonomy	Students are able to: * reflect on the contents of lectures and extend their knowledge through literature research * solve control design tasks with software tools
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / None / Attestation / Die in der Vorlesung vermittelten Kenntnisse werden in einem semesterbegleitenden Projekt direkt auf das Modell eines Passagierflugzeugs angewendet.
Examination	Written exam
Examination duration and scale	60 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L2448: Flight Control Law Design and Application	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Frank Thielecke, Dr. Julian Theis
Language	EN
Cycle	SoSe
Content	* flight dynamics (equations of motion, trim and linearization, linear models of longitudinal and lateral-directional motion, eigenforms) * stability augmentation (modal dynamics, damper design with root-loci, pole placement and eigenstructure assignment) * primary flight control laws and autopilots * design of flight control laws (loopshaping design, robustness criteria and analysis, cascaded control loops, gain-scheduling) * verification of flight control laws in simulation
Literature	J. Theis: Lecture Notes Flight Control Law Design D. Schmidt: Modern Flight Dynamics B. Stevens, F. Lewis: Aircraft Control and Simulation D. McGruer, D. Graham, I. Ashkenas: Aircraft Dynamics and Automatic Control SAE Aerospace Standard 94900 - Flight Control Systems The MathWorks: Control Systems Design Toolbox User Guide

Course L2449: Flight Control Law Design and Application	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Frank Thielecke, Dr. Julian Theis
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1203: Applied Dynamics: Numerical and experimental methods

Courses

Title	Typ	Hrs/wk	CP
Lab Applied Dynamics (L1631)	Practical Course	2	2
Applied Dynamics (L1630)	Lecture	4	4

Module Responsible	Prof. Robert Seifried
Admission Requirements	None
Recommended Previous Knowledge	Mathematics I, II, III, Mechanics I, II, III, IV Numerical Treatment of Ordinary Differential Equations
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can represent the most important methods of dynamics after successful completion of the module Technical dynamics and have a good understanding of the main concepts in the technical dynamics.
Skills	Students are able + to think holistically + to independently, securly and critically analyze and optimize basic problems of the dynamics of rigid and flexible multibody systems + to describe dynamics problems mathematically + to investigate dynamics problems both experimentally and numerically
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups and to document the corresponding results.
Autonomy	Students are able to + assess their knowledge by means of exercises and experiments. + acquaint themselves with the necessary knowledge to solve research oriented tasks.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / None / Subject theoretical and practical work / Versuche Fachlabor
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory

Course L1631: Lab Applied Dynamics

Typ	Practical Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Marc-André Pick
Language	DE
Cycle	SoSe
Content	Practical exercises are performed in groups. The examples are taken from different areas of applied dynamics, such as numerical simulation, experimental validation and experimental vibration analysis.
Literature	Schiehlen, W.; Eberhard, P.: Technische Dynamik, 4. Auflage, Vieweg+Teubner: Wiesbaden, 2014.

Course L1630: Applied Dynamics	
Typ	Lecture
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Prof. Robert Seifried, Dr. Marc-André Pick
Language	DE
Cycle	SoSe
Content	1. Modelling of Multibody Systems 2. Basics from kinematics and kinetics 3. Constraints 4. Multibody systems in minimal coordinates 5. State space, linearization and modal analysis 6. Multibody systems with kinematic constraints 7. Multibody systems as DAE 8. Non-holonomic multibody systems 9. Experimental Methods in Dynamics
Literature	Schiehlen, W.; Eberhard, P.: Technische Dynamik, 4. Auflage, Vieweg+Teubner: Wiesbaden, 2014. Woernle, C.: Mehrkörpersysteme, Springer: Heidelberg, 2011. Seifried, R.: Dynamics of Underactuated Multibody Systems, Springer, 2014.

Module M1173: Applied Statistics

Courses

Title	Typ	Hrs/wk	CP
Applied Statistics (L1584)	Lecture	2	3
Applied Statistics (L1586)	Project-/problem-based Learning	2	2
Applied Statistics (L1585)	Recitation Section (small)	1	1

Module Responsible	Prof. Michael Morlock
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of statistical methods
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the statistical methods and the conditions of their use.
Skills	Students are able to use the statistics program to solve statistics problems and to interpret and depict the results
Personal Competence	
Social Competence	Team Work, joined presentation of results
Autonomy	To understand and interpret the question and solve
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 minutes, 28 questions
Assignment for the Following Curricula	Mechanical Engineering and Management: Specialisation Management: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Biomedical Engineering: Core Qualification: Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L1584: Applied Statistics

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
Content	The goal is to introduce students to the basic statistical methods and their application to simple problems. The topics include: • Chi square test • Simple regression and correlation • Multiple regression and correlation • One way analysis of variance • Two way analysis of variance • Discriminant analysis • Analysis of categorial data • Chossing the appropriate statistical method • Determining critical sample sizes
Literature	Applied Regression Analysis and Multivariable Methods, 3rd Edition, David G. Kleinbaum Emory University, Lawrence L. Kupper University of North Carolina at Chapel Hill, Keith E. Muller University of North Carolina at Chapel Hill, Azhar Nizam Emory University, Published by Duxbury Press, CB © 1998, ISBN/ISSN: 0-534-20910-6

Course L1586: Applied Statistics	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
Content	The students receive a problem task, which they have to solve in small groups (n=5). They do have to collect their own data and work with them. The results have to be presented in an executive summary at the end of the course.
Literature	Selbst zu finden

Course L1585: Applied Statistics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
Content	The different statistical tests are applied for the solution of realistic problems using actual data sets and the most common used commercial statistical software package (SPSS).
Literature	Student Solutions Manual for Kleinbaum/Kupper/Muller/Nizam's Applied Regression Analysis and Multivariable Methods, 3rd Edition, David G. Kleinbaum Emory University Lawrence L. Kupper University of North Carolina at Chapel Hill, Keith E. Muller University of North Carolina at Chapel Hill, Azhar Nizam Emory University, Published by Duxbury Press, Paperbound © 1998, ISBN/ISSN: 0-534-20913-0

Module M1398: Selected Topics in Multibody Dynamics and Robotics

Courses

Title	Typ	Hrs/wk	CP
Formulas and Vehicles - Dynamics and Control of Autonomous Vehicles (L2869)	Integrated Lecture	1	1
Formulas and Vehicles - Introduction into Mobile Underwater Robotics (L1981)	Project-/problem-based Learning	4	5

Module Responsible	Prof. Robert Seifried
Admission Requirements	None
Recommended Previous Knowledge	Mechanics IV, Applied Dynamics or Robotics Numerical Treatment of Ordinary Differential Equations Control Systems Theory and Design
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After successful completion of the module students demonstrate deeper knowledge and understanding in selected application areas of multibody dynamics and robotics
Skills	Students are able + to think holistically + to independently, securly and critically analyze and optimize basic problems of the dynamics of rigid and flexible multibody systems + to describe dynamics problems mathematically + to implement dynamical problems on hardware
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups and to document the corresponding results and present them
Autonomy	Students are able to + assess their knowledge by means of exercises and projects. + acquaint themselves with the necessary knowledge to solve research oriented tasks.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Presentation
Examination duration and scale	TBA
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L2869: Formulas and Vehicles - Dynamics and Control of Autonomous Vehicles

Typ	Integrated Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Robert Seifried, Daniel-André Dücker
Language	DE
Cycle	WiSe
Content	
Literature	

Course L1981: Formulas and Vehicles - Introduction into Mobile Underwater Robotics

Typ	Project-/problem-based Learning
Hrs/wk	4
CP	5
Workload in Hours	Independent Study Time 94, Study Time in Lecture 56
Lecturer	Prof. Robert Seifried, Daniel-André Dücker
Language	DE
Cycle	WiSe
Content	
Literature	Seifried, R.: Dynamics of underactuated multibody systems, Springer, 2014 Popp, K.; Schiehlen, W.: Ground vehicle dynamics, Springer, 2010

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	NN
Admission Requirements	None
Recommended Previous Knowledge	H-infinity optimal control, mixed-sensitivity design, linear matrix inequalities
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the advantages and shortcomings of the classical gain scheduling approach • They can explain the representation of nonlinear systems in the form of quasi-LPV systems • They can explain how stability and performance conditions for LPV systems can be formulated as LMI conditions • They can explain how gridding techniques can be used to solve analysis and synthesis problems for LPV systems • They are familiar with polytopic and LFT representations of LPV systems and some of the basic synthesis techniques associated with each of these model structures • Students can explain how graph theoretic concepts are used to represent the communication topology of multiagent systems • They can explain the convergence properties of first order consensus protocols • They can explain analysis and synthesis conditions for formation control loops involving either LTI or LPV agent models • Students can explain concepts behind linear and qLPV Model Predictive Control (MPC)
Skills	• Students can construct 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 can use standard software tools (Matlab robust control toolbox) for these tasks • Students can design distributed formation controllers for groups of agents with either LTI or LPV dynamics, using Matlab tools provided • Students can design MPC controllers for linear and non-linear systems using Matlab tools
Personal Competence	
Social Competence	Students can work in small groups and arrive at joint results.
Autonomy	Students can 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
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: 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 Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: 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	NN
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 • Linear and Nonlinear Model Predictive Control based on LMIs
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	NN
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1598: Image Processing

Courses

Title	Typ	Hrs/wk	CP
Image Processing (L2443)	Lecture	2	4
Image Processing (L2444)	Recitation Section (small)	2	2

Module Responsible	Prof. Tobias Knopp
Admission Requirements	None
Recommended Previous Knowledge	Signal and Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know about • visual perception • multidimensional signal processing • sampling and sampling theorem • filtering • image enhancement • edge detection • multi-resolution procedures: Gauss and Laplace pyramid, wavelets • image compression • image segmentation • morphological image processing
Skills	The students can • analyze, process, and improve multidimensional image data • implement simple compression algorithms • design custom filters for specific applications
Personal Competence	
Social Competence	Students can work on complex problems both independently and in teams. They can exchange ideas with each other and use their individual strengths to solve the problem.
Autonomy	Students are able to independently investigate a complex problem and assess which competencies are required to solve it.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory Data Science: Specialisation II. Computer Science: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Medical 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 International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L2443: Image Processing	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	DE/EN
Cycle	WiSe
Content	• Visual perception • Multidimensional signal processing • Sampling and sampling theorem • Filtering • Image enhancement • Edge detection • Multi-resolution procedures: Gauss and Laplace pyramid, wavelets • Image Compression • Segmentation • Morphological image processing
Literature	Bredies/Lorenz, Mathematische Bildverarbeitung, Vieweg, 2011 Pratt, Digital Image Processing, Wiley, 2001 Bernd Jähne: Digitale Bildverarbeitung - Springer, Berlin 2005

Course L2444: Image Processing	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1048: Integrated Circuit Design

Courses

Title	Typ	Hrs/wk	CP
Integrated Circuit Design (L0691)	Lecture	3	4
Integrated Circuit Design (L0998)	Recitation Section (small)	1	2

Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of (solid-state) physics and mathematics. Knowledge in fundamentals of electrical engineering and electrical networks.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain basic concepts of electron transport in semiconductor devices (energy bands, generation/recombination, carrier concentrations, drift and diffusion current densities, semiconductor device equations). • Students are able to explain functional principles of pn-diodes, MOS capacitors, and MOSFETs using energy band diagrams. • Students can present and discuss current-voltage relationships and small-signal equivalent circuits of these devices. • Students can explain the physics and current-voltage behavior transistors based on charged carrier flow. • Students are able to explain the basic concepts for static and dynamic logic gates for integrated circuits • Students can exemplify approaches for low power consumption on the device and circuit level • Students can describe the potential and limitations of analytical expression for device and circuit analysis. • Students can explain characterization techniques for MOS devices.
Skills	• Students can qualitatively construct energy band diagrams of the devices for varying applied voltages. • Students are able to qualitatively determine electric field, carrier concentrations, and charge flow from energy band diagrams. • Students can understand scientific publications from the field of semiconductor devices. • Students can calculate the dimensions of MOS devices in dependence of the circuits properties • Students can design complex electronic circuits and anticipate possible problems. • Students know procedure for optimization regarding high performance and low power consumption
Personal Competence	
Social Competence	• Students can team up with other experts in the field to work out innovative solutions. • Students are able to work by their own or in small groups for solving problems and answer scientific questions. • Students have the ability to critically question the value of their contributions to working groups.
Autonomy	• Students are able to assess their knowledge in a realistic manner. • Students are able to define their personal approaches to solve challenging problems
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems 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 Mechatronics: Core Qualification: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory

Course L0691: Integrated Circuit Design	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Matthias Kuhl
Language	EN
Cycle	WiSe
Content	• Electron transport in semiconductors • Electronic operating principles of diodes, MOS capacitors, and MOS field-effect transistors • MOS transistor as four terminal device • Performace degradation due to short channel effects • Scaling-down of MOS technology • Digital logic circuits • Basic analog circuits • Operational amplifiers • Bipolar and BiCMOS circuits
Literature	• Yuan Taur, Tak H. Ning: Fundamentals of Modern VLSI Devices, Cambridge University Press 1998 • R. Jacob Baker: CMOS, Circuit Design, Layout and Simulation, IEEE Press, Wiley Interscience, 3rd Edition, 2010 • Neil H.E. Weste and David Money Harris, Integrated Circuit Design, Pearson, 4th International Edition, 2013 • John E. Ayers, Digital Integrated Circuits: Analysis and Design, CRC Press, 2009 • Richard C. Jaeger and Travis N. Blalock: Microelectronic Circuit Design, Mc Graw-Hill, 4rd. Edition, 2010

Course L0998: Integrated Circuit Design	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Matthias Kuhl
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1596: Engineering Haptic Systems

Courses

Title	Typ	Hrs/wk	CP
Haptic Technology for Human-Machine-Interfaces (HMI) (L2439)	Lecture	4	3
Haptic Technology for Human-Machine-Interfaces (HMI) (L2859)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Thorsten Kern
Admission Requirements	None
Recommended Previous Knowledge	We recommend knowledge in the areas of general engineering sciences, mechatronics and/or control-engineering. However also neighbouring technical areas like mechanical-engineering or even process-engineers can join the course and will be introduced into the content properly.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	This course is an introduction to the design methods and design-requirements to consider when creating haptic systems from scratch. It covers a physiological part, an actuator development part, and goes up to fundamentals of higher system integration with consideration on control theory for more complex projects. Beside design-related topics, it gives a valuable overview on existing haptic applications and research in that field with many examples. This is supported by on-site experiments in the laboratories of M-4. • Motivation and application of haptic systems • Haptic perception • The role of the user in direct system interaction • Development of haptic systems • Identification of requirements • System-structure and control • Kinematic fundamentals • Actuation & Sensors technology for haptic applications • Control and system-design aspects • Fundamental considerations in simulating haptics
Skills	Executing the course the competency will be developed to apply the general engineering capabilities of the individual course towards the design and application of active haptic systems. The resulting competencies will open an entry into specialized position in avionic-industries, automotive-industry and consumer-device-development.
Personal Competence	
Social Competence	As a side-effect this module teaches basics of a general design for human-machine-interfaces, independent from the specific application of "haptics". It teaches methods to execute user-studies, judge on user-feedback and how to deal with soft design-requirements which are common when dealing with subjective perception.
Autonomy	Independent design-capability of haptic systems, general competency in engineering from a design-perspective
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	Compulsory: Yes; Bonus: 20 %; Form: Subject theoretical and practical work; Description: Durchführung von Laborversuchen
Examination	Subject theoretical and practical work
Examination duration and scale	30 min
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory

Course L2439: Haptic Technology for Human-Machine-Interfaces (HMI)	
Typ	Lecture
Hrs/wk	4
CP	3
Workload in Hours	Independent Study Time 34, Study Time in Lecture 56
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	WiSe
Content	This course is an introduction to the design methods and design-requirements to consider when creating haptic systems from scratch. It covers a physiological part, an actuator development part, and goes up to fundamentals of higher system integration with consideration on control theory for more complex projects. Beside design-related topics, it gives a valuable overview on existing haptic applications and research in that field with many examples. • Motivation and application of haptic systems • Haptic perception • The role of the user in direct system interaction • Development of haptic systems • Identification of requirements • System-structure and control • Kinematic fundamentals • Actuation & Sensors technology for haptic applications • Control and system-design aspects • Fundamental considerations in simulating haptics
Literature	

Course L2859: Haptic Technology for Human-Machine-Interfaces (HMI)	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1552: Advanced Machine Learning

Courses

Title	Typ	Hrs/wk	CP
Advanced Machine Learning (L2322)	Lecture	2	3
Advanced Machine Learning (L2323)	Recitation Section (small)	2	3

Module Responsible	Dr. Jens-Peter Zemke
Admission Requirements	None
Recommended Previous Knowledge	1. Mathematics I-III 2. Numerical Mathematics 1/ Numerics 3. Programming skills, preferably in Python
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to name, state and classify state-of-the-art neural networks and their corresponding mathematical basics. They can assess the difficulties of different neural networks.
Skills	Students are able to implement, understand, and, tailored to the field of application, apply neural networks.
Personal Competence	
Social Competence	Students can • develop and document joint solutions in small teams; • form groups to further develop the ideas and transfer them to other areas of applicability; • form a team to develop, build, and advance a software library.
Autonomy	Students are able to • correctly assess the time and effort of self-defined work; • assess whether the supporting theoretical and practical excercises are better solved individually or in a team; • define test problems for testing and expanding the methods; • 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
Course achievement	None
Examination	Oral exam
Examination duration and scale	25 min
Assignment for the Following Curricula	Computer Science: Specialisation III. Mathematics: Elective Compulsory Data Science: Core Qualification: Compulsory Computer Science in Engineering: Specialisation III. Mathematics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L2322: Advanced Machine Learning

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jens-Peter Zemke
Language	DE/EN
Cycle	WiSe
Content	1. Basics: analogy; layout of neural nets, universal approximation, NP-completeness 2. Feedforward nets: backpropagation, variants of Stochastistic Gradients 3. Deep Learning: problems and solution strategies 4. Deep Belief Networks: energy based models, Contrastive Divergence 5. CNN: idea, layout, FFT and Winograds algorithms, implementation details 6. RNN: idea, dynamical systems, training, LSTM 7. ResNN: idea, relation to neural ODEs 8. Standard libraries: Tensorflow, Keras, PyTorch 9. Recent trends
Literature	1. Skript 2. Online-Werke: ◦ http://neuralnetworksanddeeplearning.com/ ◦ https://www.deeplearningbook.org/

Course L2323: Advanced Machine Learning	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jens-Peter Zemke
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1268: Linear and Nonlinear Waves

Courses

Title	Typ	Hrs/wk	CP
Linear and Nonlinear Waves (L1737)	Project-/problem-based Learning	4	6

Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	None
Recommended Previous Knowledge	Calculus, Algebra, Engineering Mechanics, Vibrations.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to reflect existing terms and concepts in Wave Mechanics • Students are able to identify and express the need to develop and research new terms and concepts.
Skills	• Students are able to apply existing research methods and procedures of wave mechanics. • Students are able to develop novel research methods and procedures in wave mechanics.
Personal Competence	
Social Competence	• Students can reach working results also in groups. • Students can present and communicate working results also in groups.
Autonomy	• Students are able to approach given research tasks individually. • Studetns are able to identify and follow up novel research tasks by themselves.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	2 Hours
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Maritime Technology: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L1737: Linear and Nonlinear Waves

Typ	Project-/problem-based Learning
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Norbert Hoffmann
Language	DE/EN
Cycle	WiSe

Content	Introduction into the Dynamics of Linear and Nonlinear Waves
	• Linear Waves
	  ◦ Dispersion
	  ◦ Phase and Group Velocity
	  ◦ Envelopes
	  ◦ Discrete Systems
	• Nonlinear Waves
	  ◦ Model Equations
	  ◦ Solitons, Breathers, Extreme Waves
	• Water Waves, Ocean Waves
	  ◦ Airy and Stokes
	  ◦ Natural Sea State
	  ◦ Kinetic Modelling
	• Other topics

Literature	F.K. Kneubühl: Oscillations and Waves. Springer. G.B. Witham, Linear and Nonlinear Waves. Wiley. C.C. Mei, Theory and Applications of Ocean Surface Waves. World Scientific. L.H. Holthuijsen, Waves in Oceanic and Coastal Waters. Cambridge. And others.

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
Course achievement	None
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Computer Science: Specialisation III. Mathematics: Elective Compulsory Computer Science in Engineering: Specialisation III. Mathematics: Elective Compulsory Interdisciplinary Mathematics: Specialisation Computational Methods in Biomedical Imaging: Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: 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 methods of image processing • smoothing filters • the diffusion / heat equation • variational formulations in image processing • edge detection • de-convolution • inpainting • 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 M0720: Matrix Algorithms

Courses

Title	Typ	Hrs/wk	CP
Matrix Algorithms (L0984)	Lecture	2	3
Matrix Algorithms (L0985)	Recitation Section (small)	2	3

Module Responsible	Dr. Jens-Peter Zemke
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics I - III • Numerical Mathematics 1/ Numerics • Basic knowledge of the programming languages Matlab and C
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to 1. name, state and classify state-of-the-art Krylov subspace methods for the solution of the core problems of the engineering sciences, namely, eigenvalue problems, solution of linear systems, and model reduction; 2. state approaches for the solution of matrix equations (Sylvester, Lyapunov, Riccati).
Skills	Students are capable to 1. implement and assess basic Krylov subspace methods for the solution of eigenvalue problems, linear systems, and model reduction; 2. assess methods used in modern software with respect to computing time, stability, and domain of applicability; 3. adapt the approaches learned to new, unknown types of problem.
Personal Competence	
Social Competence	Students can • develop and document joint solutions in small teams; • form groups to further develop the ideas and transfer them to other areas of applicability; • form a team to develop, build, and advance a software library.
Autonomy	Students are able to • correctly assess the time and effort of self-defined work; • assess whether the supporting theoretical and practical excercises are better solved individually or in a team; • define test problems for testing and expanding the methods; • 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
Course achievement	None
Examination	Oral exam
Examination duration and scale	25 min
Assignment for the Following Curricula	Computer Science: Specialisation III. Mathematics: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Data Science: Specialisation I. Mathematics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L0984: Matrix Algorithms	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jens-Peter Zemke
Language	DE/EN
Cycle	WiSe

Content	• Part A: Krylov Subspace Methods:
	  ◦ Basics (derivation, basis, Ritz, OR, MR)
	  ◦ Arnoldi-based methods (Arnoldi, GMRes)
	  ◦ Lanczos-based methods (Lanczos, CG, BiCG, QMR, SymmLQ, PvL)
	  ◦ Sonneveld-based methods (IDR, BiCGStab, TFQMR, IDR(s))
	• Part B: Matrix Equations:
	  ◦ Sylvester Equation
	  ◦ Lyapunov Equation
	  ◦ Algebraic Riccati Equation

Literature	Skript (224 Seiten) Ergänzend können die folgenden Lehrbücher herangezogen werden: 1. Saad, Yousef. Numerical methods for large eigenvalue problems: revised edition. Society for Industrial and Applied Mathematics, 2011. 2. Saad, Yousef. Iterative methods for sparse linear systems. Society for Industrial and Applied Mathematics, 2003. 3. Van der Vorst, Henk A. Iterative Krylov methods for large linear systems. No. 13. Cambridge University Press, 2003. 4. Liesen, Jörg, and Zdenek Strakos. Krylov subspace methods: principles and analysis. Oxford University Press, 2013.

Course L0985: Matrix Algorithms	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jens-Peter Zemke
Language	DE/EN
Cycle	WiSe
Content	
Literature	Siehe korrespondierende Vorlesung

Module M1024: Methods of Product Development

Courses

Title	Typ	Hrs/wk	CP
Methods of Product Development (L1254)	Lecture	3	3
Methods of Product Development (L1255)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Dieter Krause
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of Integrated product development and applying CAE systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After passing the module students are able to: • explain technical terms of design methodology, • describe essential elements of construction management, • describe current problems and the current state of research of integrated product development.
Skills	After passing the module students are able to: • select and apply proper construction methods for non-standardized solutions of problems as well as adapt new boundary conditions, • solve product development problems with the assistance of a workshop based approach, • choose and execute appropriate moderation techniques.
Personal Competence	
Social Competence	After passing the module students are able to: • prepare and lead team meetings and moderation processes, • work in teams on complex tasks, • represent problems and solutions and advance ideas.
Autonomy	After passing the module students are able to: • give a structured feedback and accept a critical feedback, • implement the accepted feedback autonomous.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 Minuten
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory

Course L1254: Methods of Product Development	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Dieter Krause
Language	DE
Cycle	WiSe
Content	**Lecture** The lecture extends and enhances the learned content of the module “Integrated Product Development and lightweight design” and is based on the knowledge and skills acquired there. Topics of the course include in particular: • Methods of product development, • Presentation techniques, • Industrial Design, • Design for variety • Modularization methods, • Design catalogs, • Adapted QFD matrix, • Systematic material selection, • Assembly oriented design, Construction management • CE mark, declaration of conformity including risk assessment, • Patents, patent rights, patent monitoring • Project management (cost, time, quality) and escalation principles, • Development management for mechatronics, • Technical Supply Chain Management. **Exercise (PBL)** In the exercise the content presented in the lecture “Integrated Product Development II” and methods of product development and design management will be enhanced. Students learn an independently moderated and workshop based approach through industry related practice examples to solve complex and currently existing issues in product development. They will learn the ability to apply important methods of product development and design management autonomous and acquire further expertise in the field of integrated product development. Besides personal skills, such as teamwork, guiding discussions and representing work results will be acquired through the workshop based structure of the event under its own planning and management.
Literature	• Andreasen, M.M., Design for Assembly, Berlin, Springer 1985. • Ashby, M. F.: Materials Selection in Mechanical Design, München, Spektrum 2007. • Beckmann, H.: Supply Chain Management, Berlin, Springer 2004. • Hartmann, M., Rieger, M., Funk, R., Rath, U.: Zielgerichtet moderieren. Ein Handbuch für Führungskräfte, Berater und Trainer, Weinheim, Beltz 2007. • Pahl, G., Beitz, W.: Konstruktionslehre, Berlin, Springer 2006. • Roth, K.H.: Konstruieren mit Konstruktionskatalogen, Band 1-3, Berlin, Springer 2000. • Simpson, T.W., Siddique, Z., Jiao, R.J.: Product Platform and Product Family Design. Methods and Applications, New York, Springer 2013.

Course L1255: Methods of Product Development	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Dieter Krause
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0746: Microsystem Engineering

Courses

Title	Typ	Hrs/wk	CP
Microsystem Engineering (L0680)	Lecture	2	4
Microsystem Engineering (L0682)	Project-/problem-based Learning	2	2

Module Responsible	Dr. Timo Lipka
Admission Requirements	None
Recommended Previous Knowledge	Basic courses in physics, mathematics and electric engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know about the most important technologies and materials of MEMS as well as their applications in sensors and actuators.
Skills	Students are able to analyze and describe the functional behaviour of MEMS components and to evaluate the potential of microsystems.
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 particular knowledge using specialized literature and to integrate and associate this knowledge with other fields.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description**: No / 10 % / Presentation
Examination	Written exam
Examination duration and scale	2h
Assignment for the Following Curricula	Electrical Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0680: Microsystem Engineering	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Dr. Timo Lipka
Language	EN
Cycle	WiSe
Content	Object and goal of MEMS Scaling Rules Lithography Film deposition Structuring and etching Energy conversion and force generation Electromagnetic Actuators Reluctance motors Piezoelectric actuators, bi-metal-actuator Transducer principles Signal detection and signal processing Mechanical and physical sensors Acceleration sensor, pressure sensor Sensor arrays System integration Yield, test and reliability
Literature	M. Kasper: Mikrosystementwurf, Springer (2000) M. Madou: Fundamentals of Microfabrication, CRC Press (1997)

Course L0682: Microsystem Engineering	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Timo Lipka
Language	EN
Cycle	WiSe
Content	Examples of MEMS components Layout consideration Electric, thermal and mechanical behaviour Design aspects
Literature	Wird in der Veranstaltung bekannt gegeben

Module M1204: Modelling and Optimization in Dynamics

Courses

Title	Typ	Hrs/wk	CP
Flexible Multibody Systems (L1632)	Lecture	2	3
Optimization of dynamical systems (L1633)	Lecture	2	3

Module Responsible	Prof. Robert Seifried
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics I, II, III • Mechanics I, II, III, IV • Simulation of dynamical Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students demonstrate basic knowledge and understanding of modeling, simulation and analysis of complex rigid and flexible multibody systems and methods for optimizing dynamic systems after successful completion of the module.
Skills	Students are able + to think holistically + to independently, securly and critically analyze and optimize basic problems of the dynamics of rigid and flexible multibody systems + to describe dynamics problems mathematically + to optimize dynamics problems
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups and to document the corresponding results.
Autonomy	Students are able to + assess their knowledge by means of exercises. + acquaint themselves with the necessary knowledge to solve research oriented tasks.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L1632: Flexible Multibody Systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Robert Seifried, Dr. Alexander Held
Language	DE
Cycle	WiSe
Content	1. Basics of Multibody Systems 2. Basics of Continuum Mechanics 3. Linear finite element modelles and modell reduction 4. Nonlinear finite element Modelles: absolute nodal coordinate formulation 5. Kinematics of an elastic body 6. Kinetics of an elastic body 7. System assembly
Literature	Schwertassek, R. und Wallrapp, O.: Dynamik flexibler Mehrkörpersysteme. Braunschweig, Vieweg, 1999. Seifried, R.: Dynamics of Underactuated Multibody Systems, Springer, 2014. Shabana, A.A.: Dynamics of Multibody Systems. Cambridge Univ. Press, Cambridge, 2004, 3. Auflage.

Course L1633: Optimization of dynamical systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Robert Seifried, Dr. Svenja Drücker
Language	DE
Cycle	WiSe
Content	1. Formulation and classification of optimization problems 2. Scalar Optimization 3. Sensitivity Analysis 4. Unconstrained Parameter Optimization 5. Constrained Parameter Optimization 6. Stochastic optimization 7. Multicriteria Optimization 8. Topology Optimization
Literature	Bestle, D.: Analyse und Optimierung von Mehrkörpersystemen. Springer, Berlin, 1994. Nocedal, J. , Wright , S.J. : Numerical Optimization. New York: Springer, 2006.

Module M1614: Optics for Engineers

Courses

Title	Typ	Hrs/wk	CP
Optics for Engineers (L2437)	Lecture	3	3
Optics for Engineers (L2438)	Project-/problem-based Learning	3	3

Module Responsible	Prof. Thorsten Kern
Admission Requirements	None
Recommended Previous Knowledge	- Basics of physics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Teaching subject ist the design of simple optical systems for illumination and imaging optics • Basic values for optical systems and lighting technology • Spectrum, black-bodies, color-perception • Light-Sources und their characterization • Photometrics • Ray-Optics • Matrix-Optics • Stops, Pupils and Windows • Light-field Technology • Introduction to Wave-Optics • Introduction to Holography
Skills	Understandings of optics as part of light and electromagnetic spectrum. Design rules, approach to designing optics
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	Compulsory: Yes; Bonus: None; Form: Subject theoretical and practical work; Description: Teilnahme an Laborübungen und Simulation
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L2437: Optics for Engineers

Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	WiSe
Content	• Basic values for optical systems and lighting technology • Spectrum, black-bodies, color-perception • Light-Sources und their characterization • Photometrics • Ray-Optics • Matrix-Optics • Stops, Pupils and Windows • Light-field Technology • Introduction to Wave-Optics • Introduction to Holography
Literature	

Course L2438: Optics for Engineers	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0603: Nonlinear Structural Analysis

Courses

Title	Typ	Hrs/wk	CP
Nonlinear Structural Analysis (L0277)	Lecture	3	4
Nonlinear Structural Analysis (L0279)	Recitation Section (small)	1	2

Module Responsible	Prof. Alexander Düster
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of partial differential equations is recommended.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to + give an overview of the different nonlinear phenomena in structural mechanics. + explain the mechanical background of nonlinear phenomena in structural mechanics. + to specify problems of nonlinear structural analysis, to identify them in a given situation and to explain their mathematical and mechanical background.
Skills	Students are able to + model nonlinear structural problems. + select for a given nonlinear structural problem a suitable computational procedure. + apply finite element procedures for nonlinear structural analysis. + critically verify and judge results of nonlinear finite elements. + to transfer their knowledge of nonlinear solution procedures to new problems.
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups. + present and discuss their results in front of others. + give and accept professional constructive criticism.
Autonomy	Students are able to + assess their knowledge by means of exercises and E-Learning. + acquaint themselves with the necessary knowledge to solve research oriented tasks. + to transform the acquired knowledge to similar problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Computational Engineering: Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory Materials Science: Specialisation Modeling: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Ship and Offshore Technology: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L0277: Nonlinear Structural Analysis	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Alexander Düster
Language	DE/EN
Cycle	WiSe
Content	1. Introduction 2. Nonlinear phenomena 3. Mathematical preliminaries 4. Basic equations of continuum mechanics 5. Spatial discretization with finite elements 6. Solution of nonlinear systems of equations 7. Solution of elastoplastic problems 8. Stability problems 9. Contact problems
Literature	[1] Alexander Düster, Nonlinear Structrual Analysis, Lecture Notes, Technische Universität Hamburg-Harburg, 2014. [2] Peter Wriggers, Nonlinear Finite Element Methods, Springer 2008. [3] Peter Wriggers, Nichtlineare Finite-Elemente-Methoden, Springer 2001. [4] Javier Bonet and Richard D. Wood, Nonlinear Continuum Mechanics for Finite Element Analysis, Cambridge University Press, 2008.

Course L0279: Nonlinear Structural Analysis	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Alexander Düster
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1229: Control Lab B

Courses

Title	Typ	Hrs/wk	CP
Control Lab V (L1667)	Practical Course	1	1
Control Lab VI (L1668)	Practical Course	1	1

Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Written elaboration
Examination duration and scale	1
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory

Course L1667: Control Lab V

Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1668: Control Lab VI

Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Module M1305: Seminar Advanced Topics in Control

Courses

Title	Typ	Hrs/wk	CP
Advanced Topics in Control (L1803)	Seminar	2	2

Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	• Introduction to control systems • Control theory and design • optimal and robust control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain modern control. • Students learn to apply basic control concepts for different tasks
Skills	• Students acquire knowledge about selected aspects of modern control, based on specified literature • Students generalize developed results and present them to the participants • Students practice to prepare and give a presentation
Personal Competence	
Social Competence	• Students are capable of developing solutions and present them • They are able to provide appropriate feedback and handle constructive criticism of their own results
Autonomy	• Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the best solution • Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other students, such that a scientific discussion develops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Presentation
Examination duration and scale	90 min
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory

Course L1803: Advanced Topics in Control

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	NN
Language	EN
Cycle	WiSe/SoSe
Content	• Seminar on selected topics in modern control
Literature	• To be specified

Module M0806: Technical Acoustics II (Room Acoustics, Computational Methods)

Courses

Title	Typ	Hrs/wk	CP
Technical Acoustics II (Room Acoustics, Computational Methods) (L0519)	Lecture	2	3
Technical Acoustics II (Room Acoustics, Computational Methods) (L0521)	Recitation Section (large)	2	3

Module Responsible	Prof. Benedikt Kriegesmann
Admission Requirements	None
Recommended Previous Knowledge	Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics) Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics) Mathematics I, II, III (in particular differential equations)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students possess an in-depth knowledge in acoustics regarding room acoustics and computational methods and are able to give an overview of the corresponding theoretical and methodical basis.
Skills	The students are capable to handle engineering problems in acoustics by theory-based application of the demanding computational methods and procedures treated within the module.
Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	The students are able to independently solve challenging acoustical problems in the areas treated within the module. Possible conflicting issues and limitations can be identified and the results are critically scrutinized.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L0519: Technical Acoustics II (Room Acoustics, Computational Methods)

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr.-Ing. Sören Keuchel
Language	EN
Cycle	WiSe
Content	- Room acoustics - Sound absorber - Standard computations - Statistical Energy Approaches - Finite Element Methods - Boundary Element Methods - Geometrical acoustics - Special formulations - Practical applications - Hands-on Sessions: Programming of elements (Matlab)
Literature	Cremer, L.; Heckl, M. (1996): Körperschall. Springer Verlag, Berlin Veit, I. (1988): Technische Akustik. Vogel-Buchverlag, Würzburg Veit, I. (1988): Flüssigkeitsschall. Vogel-Buchverlag, Würzburg Gaul, L.; Fiedler, Ch. (1997): Methode der Randelemente in Statik und Dynamik. Vieweg, Braunschweig, Wiesbaden Bathe, K.-J. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin

Course L0521: Technical Acoustics II (Room Acoustics, Computational Methods)	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr.-Ing. Sören Keuchel
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1919: Sustainable operation of technical assets

Courses

Title	Typ	Hrs/wk	CP
Fundamentals of Maintenance, Repair and Overhaul (MRO) (L3160)	Lecture	3	4
Fundamentals of Maintenance, Repair and Overhaul (MRO) (L3161)	Recitation Section (large)	1	2

Module Responsible	Prof. Gerko Wende
Admission Requirements	None
Recommended Previous Knowledge	We recommend knowledge in the areas of general engineering sciences, aeronautics and aircraft systems engineering. Technical fields like mechanical engineering, mechatronics and production engineering will be introduced into the relevant aeronautical content.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to describe fundamental correlations for the sustainable operation of technical assets and to identify solution approaches for complex optimization problems.
Skills	The students are enabled to apply the general engineering capabilities of the individual course towards the optimization of the sustainability in operation of technical assets. The resulting competencies will open an entry into positions in the development, production and technical operation of sustainable products in the mobility and engineering industries.
Personal Competence	
Social Competence	The students are able to work in mixed groups with a clear focus on the approached solutions by respecting the complex environment of multiple stakeholders.
Autonomy	The students are enabled to find solutions for optimization problems and to take required decision for the assessment of determining factors independently.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: 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 Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L3160: Fundamentals of Maintenance, Repair and Overhaul (MRO)

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Gerko Wende
Language	DE
Cycle	WiSe
Content	Fundamentals for the sustainable operation of technical assets by means of maintenance, repair and overhaul (MRO): • Life cycle analytics • Material circularity and service products • Rules and regulations • Processes and production methods • Tools and technologies • Data handling and usage • Design for maintenance • Self-healing technical systems
Literature	-

Course L3161: Fundamentals of Maintenance, Repair and Overhaul (MRO)	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Gerko Wende
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Thesis

Module M1801: Master thesis (dual study program)

Courses

Title	Typ	Hrs/wk	CP

Module Responsible	Professoren der TUHH
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... use the specialised knowledge (facts, theories and methods) from their field of study and the acquired professional knowledge confidently to deal with technical and practical professional issues. • ... can explain the relevant approaches and terminologies in depth in one or more of their subject's specialist areas, describe current developments and take a critical stance. • ... formulate their own research assignment to tackle a professional problem and contextualise it within their subject area. They ascertain the current state of research and critically assess it.
Skills	Dual students ... • ... can select suitable methods for the respective subject-related professional problem, apply them and develop them further as required. • ... assess knowledge and methods acquired during their studies (including practical phases) and apply their expertise to complex and/or incompletely defined problems in a solution- and application-oriented manner. • ... acquire new academic knowledge in their subject area and critically evaluate it.
Personal Competence	
Social Competence	Dual students ... • ... can present a professional problem in the form of an academic question in a structured, comprehensible and factually correct manner, both in writing and orally, for a specialist audience and for professional stakeholders. • ... answer questions as part of a professional discussion in an expert, appropriate manner. They represent their own points of view and assessments convincingly.
Autonomy	Dual students ... • ... can structure their own project into work packages, work through them at an academic level and reflect on them with regard to feasible courses of action for professional practice. • ... work in-depth in a partially unknown area within the discipline and acquire the information required to do so. • ... apply the techniques of academic work comprehensively in their own research work when dealing with an operational problem and question.
Workload in Hours	Independent Study Time 900, Study Time in Lecture 0
Credit points	30
Course achievement	None
Examination	Thesis
Examination duration and scale	According to General Regulations
Assignment for the Following Curricula	Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Aeronautics: Thesis: Compulsory Materials Science and Engineering: 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 Theoretical Mechanical Engineering: Thesis: Compulsory

	Process Engineering: Thesis: Compulsory Water and Environmental Engineering: Thesis: Compulsory