Module Manual

Master of Science (M.Sc.) Mechatronics

Cohort: Winter Term 2020 Updated: 30th April 2020

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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 subdisciplines. Based on personal interest, students are able to adapt their study programs within a broad catalogue of elective courses.

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.

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.

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)

Core qualification

Module M0523: B	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 Responsible	Dagmar Richter			
Admission Requirements	None			
Recommended Previous Knowledge	None			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional				
competence	The Nontechnical Academic Programms (NTA)			
	imparts skills that, in view of the TUHH's training profile, professional engineering studies require l are not able to cover fully. Self-reliance, self-management, collaboration and professional a personnel management competences. The department implements these training objectives in teaching architecture , in its teaching and learning arrangements , in teaching areas and means of teaching offerings in which students can qualify by opting for specific competences are competence level at the Bachelor's or Master's level. The teaching offerings are pooled in t different catalogues for nontechnical complementary courses.			
	The Learning Architecture			
	consists of a cross-disciplinarily study offering. The centrally designed teaching offering ensures t courses in the nontechnical academic programms follow the specific profiling of TUHH degree courses			
	The learning architecture demands and trains independent educational planning as regards individual development of competences. It also provides orientation knowledge in the form "profiles".			
	The subjects that can be studied in parallel throughout the student's entire study program - if need it can be studied in one to two semesters. In view of the adaptation problems that individu commonly face in their first semesters after making the transition from school to university and order to encourage individually planned semesters abroad, there is no obligation to study th subjects in one or two specific semesters during the course of studies.			
	Teaching and Learning Arrangements provide for students, separated into B.Sc. and M.Sc., to learn with and from each oth semesters. The challenge of dealing with interdisciplinarity and a variety of stages of le courses are part of the learning architecture and are deliberately encouraged in specific courses			
	Fields of Teaching			
Knowledge	are based on research findings from the academic disciplines cultural studies, social studies, a historical studies, communication studies, migration studies and sustainability research, and fr engineering didactics. In addition, from the winter semester 2014/15 students on all Bachele courses will have the opportunity to learn about business management and start-ups in a goal-orien way.			
	The fields of teaching are augmented by soft skills offers and a foreign language offer. Here, the fo is on encouraging goal-oriented communication skills, e.g. the skills required by outgoing engineers international and intercultural situations.			
	The Competence Level			
	of the courses offered in this area is different as regards the basic training objective in the Bachele and Master's fields. These differences are reflected in the practical examples used, in content top that refer to different professional application contexts, and in the higher scientific and theoret level of abstraction in the B.Sc.			
	This is also reflected in the different quality of soft skills, which relate to the different team position and different group leadership functions of Bachelor's and Master's graduates in their future work life.			
	Specialized Competence (Knowledge)			
	Students can			
	 explain specialized areas in context of the relevant non-technical disciplines, outline basic theories, categories, terminology, models, concepts or artistic techniques in disciplines represented in the learning area, different specialist disciplines relate to their own discipline and differentiate it as well as ma connections, sketch the basic outlines of how scientific disciplines, paradigms, models, instruments, metha and forms of representation in the specialized sciences are subject to individual and some set of the set of th			

In selected sub-areas students can	
 apply basic and specific methods of the said scientific disciplines, aquestion a specific technical phenomena, models, theories from the viewpoint of a aforementioned specialist discipline, to handle simple and advanced questions in aforementioned scientific disciplines in a successful manner, justify their decisions on forms of organization and application in practical questions in contrast go beyond the technical relationship to the subject. 	nother, sessful ntexts
Personal Competence	
Personal Competences (Social Skills)	
 Students will be able to learn to collaborate in different manner, to present and analyze problems in the abovementioned fields in a partner or group situate a manner appropriate to the addressees, to express themselves competently, in a culturally appropriate and gender-sensitive mather language of the country (as far as this study-focus would be chosen), to explain nontechnical items to auditorium with technical background knowledge. 	tion in iner in
Personal Competences (Self-reliance)	
Students are able in selected areas • to reflect on their own profession and professionalism in the context of real-life fi application • to organize themselves and their own learning processes • to reflect and decide questions in front of a broad education background • to communicate a nontechnical item in a competent way in writen form or verbaly • to organize themselves as an entrepreneurial subject country (as far as this study-focus be chosen)	elds of
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: R	Robotics			
Courses				
Title Robotics: Modelling and Col Robotics: Modelling and Col	ntrol (L0168) ntrol (L1305)	Typ Lecture Recitation Section (small)	Hrs/wk 3 2	CP 3 3
Module Responsible	Prof. Uwe Weltin			
Admission Requirements	None			
	Fundamentals of electrical engineering			
Recommended Previous Knowledge	Broad knowledge of mechanics			
	Fundamentals of control theory			
Educational Objectives	After taking part successfully, students have reac	ned the following learning	results	
Professional Competence				
Knowledge	Students are able to describe fundamental prope problems in robotics.	Students are able to describe fundamental properties of robots and solution approaches for multiple problems in robotics.		
	Students are able to derive and solve equations of	f motion for various manip	oulators.	
Skills	Students can generate trajectories in various coor	dinate 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.			
	Students are able to recognize and improve know	ledge deficits independent	tly.	
Autonomy	With instructor assistance, students are able to evaluate their own knowledge level and define a further course of study.			
Workload in Hours	Independent Study Time 110, Study Time in Lectu	ire 70		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	120 min			
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: 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 Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory			

Course 10168: Pobotic	s: Modelling and Control
Course Loros. Robotics	
Тур	Lecture
Hrs/wk	3
СР	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	WiSe
Content	Fundamental kinematics of rigid body systems 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		
Тур	Recitation Section (small)	
Hrs/wk	2	
СР	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Lecturer	Prof. Uwe Weltin	
Language	EN	
Cycle	WiSe	
Content	See interlocking course	
Literature	See interlocking course	

Module M0808: F	inite Elements	Methods			
Title			Turn		CD
Γιτιe Finite Element Methods (L0	291)		l yp Lecture	Hrs/WK 2	СР 3
Finite Element Methods (L0	804)		Recitation Section (large)	2	3
Module Responsible	Prof. Otto von Estorff				
Admission	None				
Requirements	Machanics I (Statics, N	lochanics of Materials) and	Machanica II (Hydractatica	Kinomotics	
Recommended Previous Knowledge	Mathematics I, II, III (in	particular differential equa	ations)	, Kinematics	, Dynamics)
Educational Objectives	After taking part succe	essfully, students have reac	hed the following learning	results	
Professional					
Competence	The students possess :	an in-denth knowledge rega	arding the derivation of the	finite elem	ent method and
	are able to give an ove	erview of the theoretical and	d methodical basis of the r	nethod.	
Knowledge	2				
	The students are cap	able to handle engineering	g problems by formulatin and solving the resulting sy	g suitable f stem of equ	inite elements, ations
Skille		bonding system matrices, a	and solving the resulting sy	stem of equ	
SKIIIS					
Personal Competence					
Social Competence	Students can work in s	mall groups on specific pro	blems to arrive at joint sol	utions.	
	The students are able	to independently solve ch	nallenging computational	problems an	id develop own
	finite element routines	. Problems can be identified	d and the results are critic	ally scrutiniz	ed.
Autonomy					
Credit points	Independent Study Tim	ne 124, Study Time in Lecti	ure 56		
	CompulsorBonus	Form	Description		
Course achievement	No 20 %	Midterm	Description		
Examination	Written exam				
Examination duration and scale	120 min				
	Civil Engineering: Core	qualification: Compulsory			
	Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory				
	Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory				
	International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production				
	Elective Compulsory				
Assignment for the	Mechatronics: Core qualification: Compulsory				
Following Curricula	a 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: Compute	sory	
	Theoretical Mechanica	pecialisation III. Engineerin l Engineering: Core qualific	ig Science: Elective Compu ation: Compulsory	lisory	

Course L0291: Finite El	ement Methods
Тур	Lecture
Hrs/wk	2
СР	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 Applications
Literature	Bathe, KJ. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin

Course L0804: Finite Element Methods		
Тур	Recitation Section (large)	
Hrs/wk	2	
СР	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: C	Control Systems Theory a	nd Design		
Courses				
Title Control Systems Theory and Control Systems Theory and	d Design (L0656) d Design (L0657)	Typ Lecture Recitation Section (small)	Hrs/wk 2 2	CP 4 2
Module Responsible	Prof. Herbert Werner			
Admission Requirements	None			
Recommended Previous Knowledge	Introduction to Control Systems			
Educational Objectives	After taking part successfully, studen	ts have reached the following learning	results	
Professional Competence				
Knowledge	 Students can explain how line can interpret the system response space They can explain the system prestate feedback and state estim They can explain the significar They can explain observer-base disturbance rejection They can extend all of the aboo They can explain the z-transfo They can explain the z-transfo They can explain the experimentation of the state space resplain the experimentation of the state space response 	ar dynamic systems are represented a onse to initial states or external excita roperties controllability and observabil hation, respectively nee of a minimal realisation sed state feedback and how it can be us we to multi-input multi-output systems rm and its relationship with the Laplace nodels and transfer function models of ental identification of ARX models of be solved by solving a normal equation a space model can be constructed from	s state spac tion as traje ity, and thei sed to achie e Transform discrete-tim dynamic sys n m a discret	ce models; they ectories in state r relationship to ve tracking and he systems stems, and how te-time impulse
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 or	specific problems to arrive at joint sol	utions.	
Autonomy	Students can obtain information fr experiment guides) and use it when s They can assess their knowledge in v	rom provided sources (lecture notes, solving given problems. veekly on-line tests and thereby contro	, software I their learni	documentation, ing progress.
Workload in Hours	Independent Study Time 124, Study	Time in Lecture 56		
Credit points	6			
Course achievement	Written exam			
Examination				
and scale	120 min			
Assignment for the Following Curricula	Electrical Engineering: Core qualificat Energy Systems: Core qualification: E Aircraft Systems Engineering: Specia Aircraft Systems Engineering: Specia Computational Science and Engineer International Management and Ei Compulsory International Management and Engin Mechanical Engineering and Manager Mechatronics: Core qualification: Con Biomedical Engineering: Specialisa Compulsory	tion: Compulsory Elective Compulsory lisation Aircraft Systems: Compulsory lisation Avionic Systems: Elective Comp ing: Specialisation II. Engineering Scien ngineering: Specialisation II. Electri eering: Specialisation II. Mechatronics: ment: Specialisation Mechatronics: Elec npulsory ation Artificial Organs and Regene	oulsory ice: Elective cal Engine Elective Con ctive Compu rative Med	Compulsory ering: Elective mpulsory llsory licine: Elective

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		
Тур	Lecture	
Hrs/wk	2	
СР	4	
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28	
Lecturer	Prof. Herbert Werner	
Language	EN	
Cycle	WiSe	
	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-100p Stability Pole placement for multivariable systems. LOB design, Kalman filter	
Content	role placement for mativaliable systems, Eqit design, Raman meet	
	Digital Control	
	Discrete-time systems: difference equations and z-transform	
	 Discrete-time state space models, sampled data systems, poles and zeros Eroquency response of sampled data systems, choice of sampling rate 	
	· rrequency response of sampled data systems, choice of sampling face	
	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	
	Werner H. Lecture Notes, Control Systems Theory and Design"	
	 T. Kailath "Linear Systems", Prentice Hall, 1980 	
Literature	• 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		
Тур	Recitation Section (small)	
Hrs/wk	2	
СР	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	

E

Module M1222: D	esign and Implementation	n of Softwar	e Systems		
Courses					
Title Design and Implementation Design and Implementation	of Software Systems (L1657) of Software Systems (L1658)	Typ Lectr Prac	ure tical Course	Hrs/wk 2 2	CP 3 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 T	ime in Lecture 56			
Credit points	6				
Course achievement	None				
Examination	Written exam				
and scale	90 min				
Assignment for the Following Curricula	Mechatronics: Core qualification: Com Theoretical Mechanical Engineering: T Theoretical Mechanical Engineering Compulsory	pulsory echnical Compler g: Specialisation	nentary Course: Elec Robotics and Co	ctive Compul mputer Sci	sory ence: Elective

Course L1657: Design and Implementation of Software Systems		
Тур	Lecture	
Hrs/wk	2	
СР	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		
Тур	Practical Course	
Hrs/wk	2	
СР	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: V	/ibration Theory			
Courses				
Title Vibration Theory (L0701)		Typ Integrated Lecture	Hrs/wk 4	CP 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 r	eached the following learn	ing results	
Professional Competence				
Knowledge	Students are able to denote terms and concer	ots of Vibration Theory and	develop them	further.
Skills	Students are able to denote methods of Vibra	tion Theory and develop th	em further.	
Personal Competence	Ctudents can reach working regults also in ar			
Social Competence	Students are able to approach individually res	oups. Jearch tasks in Vibration Th	eory	
Workload in Hours	Independent Study Time 124, Study Time in L	ecture 56	cory.	
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 Theoretical Mechanical Engineering: Core qualification: Elective Compulsory			

Course L0701: Vibratio	n Theory
Тур	Integrated Lecture
Hrs/wk	4
СР	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 Oscillations and Waves.
Literature	K. Magnus, K. Popp, W. Sextro: Schwingungen. Physikalische Grundlagen und mathematische Behandlung von Schwingungen. Springer Verlag, 2013.

Module M0565: M	lechatronic Sys	tems			
Courses					
Title			Тур	Hrs/wk	СР
Electro- and Contromechan	ics (L0174)		Lecture	2	2
Electro- and Contromechan	ics (L1300)		Recitation Section (small)	T	2
Mechatronics Laboratory (L	0196)		Learning	2	2
Module Responsible	Prof. Uwe Weltin				
Admission Requirements	None				
Recommended Previous Knowledge	Fundamentals of mech	anics, electromechanics	and control theory		
Educational Objectives	After taking part succe	essfully, students have rea	iched the following learning	results	
Professional Competence					
Knowledge	Students are able to describe methods and calculations to design, model, simulate and optimize mechatronic systems and can repeat methods to verify and validate models.				
Skills	Students are able to plan and execute mechatronic experiments. Students are able to model mechatronic systems and derive simulations and optimizations.				
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.				
	Students are able to so	olve individually exercises	related to this lecture with	instructiona	al direction.
Autonomy	Students are able to plan, execute and summarize a mechatronic experiment.				
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70				
Credit points	6				
	Compulsor B onus	Form	Description		
Course achievement	Yes None	Subject theoretical practical work	and		
Examination	Written exam				
Examination duration and scale	90 min				
Assignment for the Following Curricula	Electrical Engineering: Aircraft Systems Engin Aircraft Systems Engin Mechatronics: Core qua	Specialisation Control an eering: Specialisation Avi eering: Specialisation Air alification: Compulsory	d Power Systems Engineerir onic Systems: Elective Com craft Systems: Elective Com	ng: Elective pulsory pulsory	Compulsory

Course L0174: Electro- and Contromechanics		
Тур	Lecture	
Hrs/wk	2	
СР	2	
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28	
Lecturer	Prof. Uwe Weltin	
Language	EN	
Cycle	SoSe	
Content	Introduction to methodical design of mechatronic systems: Modelling System identification Simulation Optimization 	
Literature	Denny Miu: Mechatronics, Springer 1992 Rolf Isermann: Mechatronic systems : fundamentals, Springer 2003	

Course L1300: Electro-	Course L1300: Electro- and Contromechanics		
Тур	Recitation Section (small)		
Hrs/wk	1		
СР	2		
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14		
Lecturer	Prof. Uwe Weltin		
Language	EN		
Cycle	SoSe		
Content	See interlocking course		
Literature	See interlocking course		

Course L0196: Mechatronics Laboratory		
Тур	Project-/problem-based Learning	
Hrs/wk	2	
СР	2	
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28	
Lecturer	Prof. Uwe Weltin	
Language	DE/EN	
Cycle	SoSe	
	Modeling in MATLAB $^{ extsf{@}}$ und Simulink $^{ extsf{@}}$	
	Controller Design (Linear, Nonlinear, Observer)	
Content	Parameter identification	
	Control of a real system with a realtimeboard and Simulink $^{ extsf{B}}$ RTW	
	- Abhängig vom Versuchsaufbau	
Literature	- Depends on the experiment	

Module M1211: R	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			
	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.		
Knowledge	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 newes 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	It. FSPO		
Assignment for the Following Curricula	Mechatronics: Core qualification: Compulsory		

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: A	Approximation and Stability			
Courses				
Title Approximation and Stability Approximation and Stability	/ (L0487) / (L0488)	Typ Lecture Recitation Section (small)	Hrs/wk 3 1	CP 4 2
Module Responsible	Prof. Marko Lindner			
Admission Requirements	None			
Recommended Previous Knowledge	 Linear Algebra: systems of linear equavalues Analysis: sequences, series, differentiation 	tions, least squares probl n, integration	ems, eigenv	'alues, singular
Educational Objectives	After taking part successfully, students have rea	ched the following learning	results	
Professional				
competence	Students are able to			
Knowledge	 sketch and interrelate basic concepts of full name and understand concrete approximations name and explain basic stability theorems discuss spectral quantities, conditions nur 	unctional analysis (Hilbert s ation methods, s, nbers and methods of regu	pace, operat larisation	:ors),
Skills	 Students are able to apply basic results from functional analysi apply approximation methods, apply stability theorems, compute spectral quantities, apply regularisation methods. 	is,		
Personal Competence				ĺ
Social Competence	Students are able to solve specific problems in as a seminar presentation).	groups and to present thei	r results app	propriately (e.g.
Autonomy	 Students are capable of checking their u can specify open questions precisely and Students have developed sufficient persis oriented manner on hard problems. 	nderstanding of complex c know where to get help in s stence to be able to work f	oncepts on t olving them or longer pe	:heir own. They riods in a goal-
Workload in Hours	Independent Study Time 124, Study Time in Lec	ture 56		
Credit points	6			
Course achievement	CompulsorBonusFormYesNonePresentation	Description		
Examination	Oral exam			
Examination duration and scale	20 min			
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Mathematical Modelling in Engineering: Theory (TUHH): Elective Compulsory Mechatronics: Specialisation Intelligent Systems Technomathematics: Specialisation I. Mathemati Theoretical Mechanical Engineering: Technical C Theoretical Mechanical Engineering: Specialis Compulsory	d Power Systems Engineerir y, Numerics, Applications: and Robotics: Elective Com ics: Elective Compulsory omplementary Course: Elec isation Robotics and Co	ng: Elective (Specialisati npulsory tive Compul mputer Sci	Compulsory on I. Numerics Isory ence: Elective

Course L0487: Approxi	mation and Stability
Тур	Lecture
Hrs/wk	3
СР	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 convergence of condition numbers convergence of spectral quantities: spectrum, eigen values, singular values, pseudospectra
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		
Тур	Recitation Section (small)	
Hrs/wk	1	
СР	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	

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Module M0714: N	lumerical Treatment of Ordina	ary Differential Equati	ions	
Courses				
Title Numerical Treatment of Orc Numerical Treatment of Orc	dinary Differential Equations (L0576) dinary Differential Equations (L0582)	Typ Lecture Recitation Section (small)	Hrs/wk 2 2	CP 3 3
Module Responsible	Prof. Daniel Ruprecht			
Admission	None			
Requirements				
Recommended Previous Knowledge	 Mathematik I, II, III für Ingenieurstu Algebra I + II sowie Analysis III für Te Basic MATLAB knowledge 	idierende (deutsch oder englisc ichnomathematiker	h) oder Ana	alysis & Lineare
Educational Objectives	After taking part successfully, students hav	e reached the following learning	results	
Professional Competence				
•	Students are able to			
Knowledge	 list numerical methods for the solutideas, repeat convergence statements for tied to the underlying problem), explain aspects regarding the practice select the appropriate numerical rangorithms efficiently and interpret the select the sele	on of ordinary differential equat the treated numerical methods cal execution of a method. nethod for concrete problems, ne numerical results	ions and ex (including t implement	xplain their core he prerequisites the numerica
Skills	 Students are able to implement (MATLAB), apply and compare numerical methods for the solution of ordinary differential equations, to justify the convergence behaviour of numerical methods with respect to the posed problem and selected algorithm, for a given problem, develop a suitable solution approach, if necessary by the composition of several algorithms, to execute this approach and to critically evaluate the results. 			
Personal Competence	Students are able to			
Social Competence	 work together in heterogeneously c and background knowledge), expla practical aspects regarding the imple 	omposed teams (i.e., teams from in theoretical foundations and ementation of algorithms.	m different support e	study programs ach other with
	Students are capable			
Autonomy	 to assess whether the supporting individually or in a team, to assess their individual progress ar 	theoretical and practical exc nd, if necessary, to ask questions	ercises are and seek h	e better solved elp.
Workload in Hours	Independent Study Time 124, Study Time in	n Lecture 56		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration	90 min			
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - C Chemical and Bioprocess Engineering: Compulsory Chemical and Bioprocess Engineering: Compulsory Computer Science: Specialisation III. Mathe Electrical Engineering: Specialisation Contro Energy Systems: Core qualification: Elective Aircraft Systems Engineering: Specialisation Mathematical Modelling in Engineering: T (TUHH): Compulsory Mechatronics: Specialisation Intelligent Sys Technomathematics: Specialisation I. Mathe Theoretical Mechanical Engineering: Core q Process Engineering: Specialisation Chemic	Seneral Bioprocess Engineering: Specialisation Chemical Proce Specialisation General Proce matics: Elective Compulsory of and Power Systems Engineering e Compulsory n Aircraft Systems: Elective Com heory, Numerics, Applications: tems and Robotics: Elective Com ematics: Elective Compulsory ualification: Compulsory al Process Engineering: Elective	Elective Con ess Engine ess Engine ng: Elective pulsory Specialisat npulsory Compulsory	mpulsory eering: Elective Compulsory ion I. Numerics

Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0576: Numerical Treatment of Ordinary Differential Equations			
Тур	Lecture		
Hrs/wk	2		
СР	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 variational 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 		

Course L0582: Numerical Treatment of Ordinary Differential Equations		
Тур	Recitation Section (small)	
Hrs/wk	2	
СР	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 M0752: N	Ionlinear Dynamics			
Courses				
Title Nonlinear Dynamics (L0702	2)	Typ Integrated Lecture	Hrs/wk 4	CP 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 reac	hed the following learning	results	
Professional Competence				
Knowledge	Students are able to reflect existing terms and research new terms and concepts.	concepts in Nonlinear Dyr	namics and	to develop and
Skills	Students are able to apply existing methods an novel methods and procedures.	d procesures of Nonlinea	r Dynamics	and to develop
Personal Competence	•			
Social Competence	Students can reach working results also in groups	5.		
Autonomy	Students are able to approach given research ta research tasks by themselves.	asks individually and to id	dentify and	follow up novel
Workload in Hours	Independent Study Time 124, Study Time in Lectu	ure 56		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	2 Hours			
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Aircr International Management and Engineering: Special Mechanical Engineering and Management: Special Mechatronics: Specialisation System Design: Elect Mechatronics: Specialisation Intelligent Systems a Biomedical Engineering: Specialisation Artificit Compulsory Biomedical Engineering: Specialisation Implants a Biomedical Engineering: Specialisation Medical Te Biomedical Engineering: Specialisation Medical Te Biomedical Engineering: Specialisation Manageme Product Development, Materials and Production: C Theoretical Mechanical Engineering: Core qualific	aft Systems: Elective Com ialisation II. Mechatronics: ilisation Mechatronics: Elec tive Compulsory and Robotics: Elective Com ial Organs and Regene and Endoprostheses: Elective chnology and Control The ent and Business Administ Core qualification: Elective mplementary Course: Elec ation: Elective Compulsory	pulsory Elective Compu ctive Compu erative Med ve Compulsory ration: Elect Compulsory ctive Compulsory	mpulsory lsory icine: Elective ory Compulsory ive Compulsory sory

Course L0702: Nonlinear Dynamics		
Тур	Integrated Lecture	
Hrs/wk	4	
СР	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.	
Literature	S. Strogatz: Nonlinear Dynamics and Chaos. Perseus, 2013.	
Literature	S. Strogatz: Nonlinear Dynamics and Chaos. Perseus, 2013.	

Module M0840: C	Optimal and Robust Contro	bl		
Courses				
Title Optimal and Robust Control Optimal and Robust Control	l (L0658) l (L0659)	Typ Lecture Recitation Section (small)	Hrs/wk 2 2	CP 3 3
Module Responsible	Prof. Herbert Werner	· ·		
Admission Requirements	None			
Recommended Previous Knowledge	 Classical control (frequency res State space methods Linear algebra, singular value d 	sponse, root locus) lecomposition		
Educational Objectives	After taking part successfully, student	s have reached the following learning	results	
Professional Competence				
Knowledge	 Students can explain the sign problems. They can explain the duality be They can explain how the H performance constraints. They can explain how an LQG d problem. They can explain how model u controller design They can explain how - based stability and performance for an They understand how analysis as linear matrix inequalities. 	nificance of the matrix Riccati equat etween optimal state feedback and opt 12 and H-infinity norms are used to design problem can be formulated as s uncertainty can be represented in a wa on the small gain theorem - a robus n uncertain plant. and synthesis conditions on feedback	ion for the imal state e to represer pecial case y that lends t controller c loops can	solution of LQ estimation. It stability and of an H2 design s itself to robust can guarantee be represented
Skills	 Students are capable of designi They are capable of representing plant, and of using standard softeness. They are capable of translating constraints on closed-loop sensions. They are capable of construct designing a mixed-objective role. They are capable of formulating (LMI), and of using standard LM. They can carry out all of the toolbox). 	ing and tuning LQG controllers for mul ng a H2 or H-infinity design problem in ftware tools for solving it. g time and frequency domain specifica itivity functions, and of carrying out a ting an LFT uncertainty model for an bust controller. ng analysis and synthesis conditions a II-solvers for solving them. e above using standard software to	tivariable p n the form of ations for co mixed-sens uncertain s linear ma ols (Matlab	lant models. of a generalized ontrol loops into itivity design. system, and of trix inequalities robust control
Personal Competence				
Social Competence	Students can work in small groups on	specific problems to arrive at joint sol	utions.	
-	Students are able to find required inf	formation in sources provided (lecture	notes, lite	rature, software
Autonomy	documentation) and use it to solve giv	ven problems.		
Workload in Hours	I Independent Study Time 124. Study T	ime 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 of Energy Systems: Core qualification: El Aircraft Systems Engineering: Specialis Mechatronics: Specialisation Intelliger Mechatronics: Specialisation System E Biomedical Engineering: Specialisation Compulsory Biomedical Engineering: Specialisation Biomedical Engineering: Specialisation Biomedical Engineering: Specialisation Biomedical Engineering: Specialisation Product Development, Materials and F Product Development, Materials and F	Control and Power Systems Engineerin lective Compulsory isation Aircraft Systems: Elective Comp nt Systems and Robotics: Elective Com Design: Elective Compulsory tion Artificial Organs and Regene n Implants and Endoprostheses: Electiv n Medical Technology and Control The n Management and Business Administi and Production: Specialisation Production: R	g: Elective pulsory pulsory rative Meo ve Compuls ory: Elective ration: Elect ct Develop Elective Cor	Compulsory licine: Elective ory e Compulsory ive Compulsory oment: Elective npulsory

Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory

Course L0658: Optimal	and Robust Control
Тур	Lecture
Hrs/wk	2
СР	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		
Тур	Recitation Section (small)	
Hrs/wk	2	
СР	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: S	Systems Engineering			
Courses				
Title Systems Engineering (L154 Systems Engineering (L154	7) 8)	Typ Lecture Recitation Section (large)	Hrs/wk 3 1	CP 4 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 reac	hed 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 comple • organize the development phases and developm • assign required business activities and technica • apply systems engineering methods and tools	ex Systems nent Tasks I Tasks		
Personal Competence				
Social Competence	Students are able to: • understand their responsibilities within a develo in the overall process	opment team and integrate	e themselves	; with their role
Autonomy	Students are able to: • interact and communicate in a development tea	am which has distributed t	asks	
Workload in Hours	Independent Study Time 124, Study Time in Lectu	ure 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: O International Management and Engineering: Spec International Management and Engineering: Spec Elective Compulsory Mechatronics: Specialisation System Design: Elect Mechatronics: Specialisation Intelligent Systems a Product Development, Materials and Production: S Product Development, Materials and Production: S Product Development, Materials and Production: S Product Development, Materials and Production: S Theoretical Mechanical Engineering: Technical Co Theoretical Mechanical Engineering: Specialisation	Compulsory ialisation II. Aviation Syste ecialisation II. Product De tive Compulsory and Robotics: Elective Com Specialisation Product Dev Specialisation Production: Specialisation Materials: El mplementary Course: Elec n Aircraft Systems Engined	ms: Elective velopment a ipulsory elopment: Co Elective Comp ective Compuls trive Compuls ering: Electiv	Compulsory nd Production: ompulsory pulsory ulsory sory e Compulsory

Course L1547: Systems Engineering		
Тур	Lecture	
Hrs/wk	3	
СР	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	
Тур	Recitation Section (large)
Hrs/wk	1
СР	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

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Module M1212: Technical Complementary Course for IMPMEC (according to Subjec Specific Regulations)		
Courses		
Title	Typ Hrs/wk	СР
Module Responsible	Prof. Uwe Weltin	
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	see selected module according to FSPO	
Social Competence	see selected module according to FSPO	
Autonomy		
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		Тур	Hrs/wk	СР
Applied Automation (L1592)	Project-/problem-based	3	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 Engir	neering (MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Process Measurement Engi	neering (L1077)	Lecture	2	3
Process Measurement Engi	neering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medica	l Technology (L0664)	Lecture	2	3
Six Sigma (L1130)		Lecture	2	3
Applied Dynamics (L1630)		Lecture	2	3
Reliability in Engineering D	ynamics (L0176)	Lecture	2	2
Reliability in Engineering D	ynamics (L1303)	Recitation Section (small)	1	2
Module Responsible	Prof. Uwe Weltin			
Admission Requirements	None			
Recommended Previous Knowledge	None			
Educational Objectives	After taking part successfully, students have re	eached the following learning	results	
Professional Competence				
Knowledge	 Students are able to express their extension special fields or application areas of med Students are qualified to connect different 	nded knowledge and discuss chatronics nt special fields with each ot	the connect	tion of different
Skills	 Students can apply specialized solution : Students are able to transfer learned sk solution approaches 	strategies and new scientific ills to new and unknown prol	methods in blems and ca	selected areas an develop own
Personal Competence				
Social Competence	None			
Social Competence	None			
Autonomy	 Students are able to develop their know 	ledge and skills by autonome	ous election (of courses.
Workload in Hours	Depends on choice of courses			
Credit points	12			
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: El Mechatronics: Specialisation Intelligent System	ective Compulsory s and Robotics: Elective Com	npulsory	
-			-	

Course L1592: Applied Automation		
Тур	Project-/problem-based Learning	
Hrs/wk	3	
СР	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 L1512: Development Management for Mechatronics		
Тур	Lecture	
Hrs/wk	2	
СР	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Examination Form	Mündliche Prüfung	
Examination duration and scale	30 Minuten	
Lecturer	Dr. Daniel Steffen	
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 	
 Bender: Embedded Systems - qualitätsorientierte Entwicklung Ehrlenspiel: Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit Gausemeier/Ebbesmeyer/Kallmeyer: Produktinnovation - Strategische Planung und Entwicklur der Produkte von morgen Haberfellner/de Weck/Fricke/Vössner: Systems Engineering: Grundlagen und Anwendung Lindemann: Methodische Entwicklung technischer Produkte: Methoden flexibel ur situationsgerecht anwenden Pahl/Beitz: Konstruktionslehre: Grundlagen erfolgreicher Produktentwicklung. Methoden un Anwendung VDI-Richtlinie 2206: Entwicklungsmethodik für mechatronische Systeme 		

Course L0310: Fatigue & Damage Tolerance		
Тур	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		
Тур	Lecture	
Hrs/wk	2	
СР	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		
Тур	Seminar	
Hrs/wk	2	
СР	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	ge DE	
Cycle	le 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: Microsy	stems Technology
Тур	Lecture
Hrs/wk	2
СР	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, RLF, Bosch process, XreJ zetching) 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; modulating sensors: placeresistive, angular rate sensor: operating principle and fabrication process) Magnetic Sensors (glavanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive, piezoelectric and capacitive; angular rate sensor: metal oxide semiconductor gas sensor, principle of biosensor, Clark electrode, enzyme electrod, 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 pr
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		
Тур	Project-/problem-based Learning	
Hrs/wk	3	
СР	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 L1083: Process Measurement Engineering		
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Тур	Recitation Section (large)	
Hrs/wk	1	
СР	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		
Тур	Lecture	
Hrs/wk	2	
СР	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 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. 	

Course L1130: Six Sigma		
Тур	Lecture	
Hrs/wk	2	
СР	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Examination Form	Klausur	
Examination duration and scale	90 Minuten	
Lecturer	Prof. Claus Emmelmann	
Language	DE	
Cycle	WiSe	
Content	 Introduction and structuring Basic terms of quality management Measuring and inspection equipment Tools of quality management: FMEA, QFD, FTA, etc. Quality management methodology Six Sigma, DMAIC 	
Literature	Pfeifer, T.: Qualitätsmanagement : Strategien, Methoden, Techniken, 4. Aufl., München 2008 Pfeifer, T.: Praxishandbuch Qualitätsmanagement, München 1996 Geiger, W., Kotte, W.: Handbuch Qualität : Grundlagen und Elemente des Qualitätsmanagements: Systeme, Perspektiven, 5. Aufl., Wiesbaden 2008	

Course L1630: Applied Dynamics		
Тур	Lecture	
Hrs/wk	2	
СР	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Examination Form	Klausur	
Examination duration and scale	90 min	
Lecturer	Prof. Robert Seifried	
Language	DE	
Cycle	SoSe	
Content	 Modelling of Multibody Systems Basics from kinematics and kinetics Constraints Multibody systems in minimal coordinates State space, linearization and modal analysis Multibody systems with kinematic constraints Multibody systems as DAE Non-holonomic multibody systems 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.	

Course L0176: Reliability in Engineering Dynamics		
Тур	Lecture	
Hrs/wk	2	
СР	2	
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28	
Examination Form	Klausur	
Examination duration and scale	90 min.	
Lecturer	Prof. Uwe Weltin	
Language	EN	
Cycle	SoSe	
Content	 Method for calculation and testing of reliability of dynamic machine systems Modeling System identification Simulation Processing of measurement data Damage accumulation Test planning and execution 	
Literature	Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540- 33969-4 Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737 Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936. VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412	

Course L1303: Reliability in Engineering Dynamics	
Тур	Recitation Section (small)
Hrs/wk	1
СР	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

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

Courses				
Title		Тур	Hrs/wk	СР
Applied Automation (L1592)		Project-/problem-based Learning	3	3
Development Management for Mechatronics (L1512)		Lecture	2	3
Fatigue & Damage Tolerand	ce (L0310)	Lecture	2	3
Industry 4.0 for engineers (L2012)	Lecture	2	3
Microcontroller Circuits: Imp	plementation in Hardware and Software (L0087)	Seminar	2	2
Microsystems Technology (L0724)	Lecture	2	4
Model-Based Systems Engir	neering (MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Process Measurement Engir	neering (L1077)	Lecture	2	3
Process Measurement Engir	neering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medica	l Technology (L0664)	Lecture	2	3
Six Sigma (L1130)		Lecture	2	3
Applied Dynamics (L1630)		Lecture	2	3
Reliability in Engineering Dy	ynamics (L0176)	Lecture	2	2
Reliability in Engineering Dy	ynamics (L1303)	Recitation Section (small)	1	2
Module Responsible	Prof. Uwe Weltin			
Admission Requirements	None			
Recommended Previous Knowledge	None			
Educational Objectives	After taking part successfully, students have read	hed 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				j
Social Competence	None			
Autonomy	Students are able to develop their knowled	lge and skills by autonomo	us election o	of courses.
Workload in Haura	Depends on choice of courses	-		
Creait points				
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elec Mechatronics: Specialisation Intelligent Systems	tive Compulsory and Robotics: Elective Com	pulsory	

Course L1512: Development Management for Mechatronics		
Тур	Lecture	
Hrs/wk	2	
СР	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Examination Form	Mündliche Prüfung	
Examination duration and scale	30 Minuten	
Lecturer	Dr. Daniel Steffen	
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 Entwicklur der Produkte von morgen Haberfellner/de Weck/Fricke/Vössner: Systems Engineering: Grundlagen und Anwendung Lindemann: Methodische Entwicklung technischer Produkte: Methoden flexibel ur situationsgerecht anwenden Pahl/Beitz: Konstruktionslehre: Grundlagen erfolgreicher Produktentwicklung. Methoden un Anwendung VDI-Richtlinie 2206: Entwicklungsmethodik für mechatronische Systeme 	

Course L0310: Fatigue & Damage Tolerance	
Тур	Lecture
Hrs/wk	2
СР	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	
Тур	Lecture
Hrs/wk	2
СР	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		
Тур	Seminar	
Hrs/wk	2	
СР	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			
Тур	p Lecture		
Hrs/wk	2		
СР	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 Technologues (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) Etching and Bulk Micromachning (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, RLF, Bosch process, Xref 2 etching) Surface Micromachning 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; modulating sensors: pizoresistive, capacitive and fabrication process) Mechanical Sensors (strain based and stress based principle, capacitive readout, 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, principle of biosensor, Clark electrode, enzyme electroda, DNA chip)		
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			
Тур	Project-/problem-based Learning		
Hrs/wk	3		
СР	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 L1083: Process Measurement Engineering	
Тур	Recitation Section (large)
Hrs/wk	1
СР	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		
Тур	Lecture	
Hrs/wk	2	
СР	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. 	

Course L1130: Six Sigma			
Тур	Lecture		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Examination Form	Klausur		
Examination duration and scale	90 Minuten		
Lecturer	Prof. Claus Emmelmann		
Language	DE		
Cycle	WiSe		
Content	 Introduction and structuring Basic terms of quality management Measuring and inspection equipment Tools of quality management: FMEA, QFD, FTA, etc. Quality management methodology Six Sigma, DMAIC 		
Literature	Pfeifer, T.: Qualitätsmanagement : Strategien, Methoden, Techniken, 4. Aufl., München 2008 Pfeifer, T.: Praxishandbuch Qualitätsmanagement, München 1996 Geiger, W., Kotte, W.: Handbuch Qualität : Grundlagen und Elemente des Qualitätsmanagements: Systeme, Perspektiven, 5. Aufl., Wiesbaden 2008		

Course L1630: Applied Dynamics			
Тур	Lecture		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Examination Form	Klausur		
Examination duration and scale	90 min		
Lecturer	Prof. Robert Seifried		
Language	DE		
Cycle	SoSe		
Content	 Modelling of Multibody Systems Basics from kinematics and kinetics Constraints Multibody systems in minimal coordinates State space, linearization and modal analysis Multibody systems with kinematic constraints Multibody systems as DAE Non-holonomic multibody systems 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.		

Course L0176: Reliability in Engineering Dynamics			
Тур	Lecture		
Hrs/wk	2		
СР	2		
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28		
Examination Form	Klausur		
Examination duration and scale	90 min.		
Lecturer	Prof. Uwe Weltin		
Language	EN		
Cycle	SoSe		
Content	 Method for calculation and testing of reliability of dynamic machine systems Modeling System identification Simulation Processing of measurement data Damage accumulation Test planning and execution 		
Literature	Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540- 33969-4 Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737 Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936. VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412		

Course L1303: Reliabili	Course L1303: Reliability in Engineering Dynamics	
Тур	Recitation Section (small)	
Hrs/wk	1	
СР	2	
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14	
Examination Form	Klausur	
Examination duration and scale	90 min	
Lecturer	Prof. Uwe Weltin	
Language	EN	
Cycle	SoSe	
Content	See interlocking course	
Literature	See interlocking course	

Module M1302: Applied Humanoid Robotics				
Courses				
- Title		Тур	Hrs/wk	СР
Applied Humanoid Robotics	5 (L1794)	Project-/problem-based Learning	6	6
Module Responsible	Patrick Göttsch			
Admission Requirements	None			
Recommended Previous Knowledge	 Object oriented programming; algorithms Introduction to control systems Control systems theory and design Mechanics 	and data structures		
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 Lectu	ure 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 Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory			

ourse L1794: Applied Humanoid Robotics			
Тур	roject-/problem-based Learning		
Hrs/wk	6		
СР	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: L	ab Cyber-Physical Systems			
Courses				
Title		Тур	Hrs/wk	СР
Lab Cyber-Physical Systems	s (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 reac	hed the following learning	results	
Professional Competence				
	Cyber-Physical Systems (CPS) are tightly integrai A/D and D/A converters, and actors. Due to ti sensors, processors and actors are common. specification approaches for CPS - in contrast to c Based on practical experiments using robot ki	ted with their surrounding heir particular application Accordingly, there is a classical software engineeri its and computers, the b	environmen areas, hig large varie ing approact	nt, via sensors, hly specialized ty of different nes. ecification and
Knowledge	modelling of CPS are taught. The lab introduces into the area (basic notions, characteristical properties) and their specification techniques (models of computation, hierarchical automata, dat flow models, petri nets, imperative approaches). Since CPS frequently perform control tasks, the lab experiments will base on simple control applications. The experiments will use state-of-the-are 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 a interdependencies between a CPS and its surrour interacts with the environment via sensors, A/E actors. The lab enables students to compare mod limitations, and to decide which technique to use techniques to practical problems. They obtai development, in industry-relevant specification to	are able to develop simple nding processes which ste O converters, digital proce delling approaches, to eva for a concrete task. They in first experiences in pols and in the area of simp	CPS. They m from the essors, D/A luate their a will be able hardware-re ble control a	understand the fact that a CPS converters and advantages and to apply these lated software pplications.
Personal Competence				
Social Competence	Students are able to solve similar problems alone	or in a group and to prese	nt the result	ts accordingly.
Autonomy	Students are able to acquire new knowledge from with other classes.	m specific literature and t	o associate	this knowledge
Workload in Hours	Independent Study Time 124, Study Time in Lectu	ure 56		
Credit points	6			
Course achievement	None			
Examination	Written elaboration			
Examination duration and scale	Execution and documentation of all lab experimen	nts		
Assignment for the Following Curricula	General Engineering Science (German program Elective Compulsory Computer Science: Specialisation Computer and S Computer Science: Specialisation II. Mathematics General Engineering Science (English program, 7 Compulsory Computational Science and Engineering: Specialis Compulsory Computational Science and Engineering: Specialis Mechatronics: Specialisation Intelligent Systems a Mechatronics: Specialisation System Design: Elect	m, 7 semester): Speciali Software Engineering: Elect and Engineering Science: semester): Specialisation sation II. Mathematics & Er sation Computer Science: E and Robotics: Elective Com tive Compulsory Elective Compulsory	sation Com tive Compul: Elective Con Computer So agineering So Elective Com pulsory	puter Science: sory npulsory cience: Elective cience: Elective npulsory

Course L1740: Lab Cyb	er-Physical Systems
Тур	Project-/problem-based Learning
Hrs/wk	4
СР	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. 2nd Edition, Springer, 2012. Begleitende Foliensätze

Module M1306: C	Contr	rol Lab C					
Courses							
Title Control Lab IX (L1836) Control Lab VII (L1834) Control Lab VIII (L1835)					Typ Practical Course Practical Course Practical Course	Hrs/wk 1 1 1	CP 1 1 1
Module Responsible	Prof. I	Herbert Werner					
Admission Requirements	None						
Recommended Previous Knowledge	•	State space me LQG control H2 and H-infinit uncertain plant LPV control	thods y optimal co models and	ontrol I robust control	I		
Educational Objectives	After	taking part succ	essfully, stu	dents have rea	ched the following le	arning results	
Professional Competence							
Knowledge	•	Students can o experimental v	explain the alidation	difference be	tween validation of	a control lop i	n simulation ar
Skills	•	Students are ca Toolbox) to iden They are capat implementation They are capa mixed-sensitivit They are capa robust controlle They are capa design and the	apable of ap ntify a dyna ole of using o of LQG con ble of using cy design an ble of repre- r ble of using implementa	pplying basic sy mic model that standard softw ntrollers g standard sof nd the impleme esenting mode g standard sof ation of LPV gai	estem identification t can be used for con- vare tools (Matlab Co tware tools (Matlab ntation of H-infinity o I uncertainty, and o tware tools (Matlab n-scheduled controllo	ools (Matlab Sys troller synthesis ontrol Toolbox) fo Robust Control optimal controlle of designing and Robust Control ers	tem Identificatio or the design an Toolbox) for th rs I implementing Toolbox) for th
Personal Competence							
Social Competence	•	Students can w	ork in team	s to conduct ex	periments and docu	ment the results	
Autonomy	•	Students can in	dependentl	y carry out sim	ulation studies to de	sign and validate	e control loops
Workload in Hours	Indep	endent Study Tir	ne 48, Stud	y Time in Lectu	ıre 42		
Credit points	3						
Course achievement	None						
Examination	Writte	en elaboration					
Examination duration and scale	1						
Assignment for the Following Curricula	Electr Mecha Mecha Theor Theor	rical Engineering atronics: Special atronics: Special retical Mechanica retical Mechanica	Specialisat sation Intell sation Syste I Engineerir I Engineerir	ion Control and ligent Systems em Design: Ele ng: Core qualifi ng: Technical C	d Power Systems Eng and Robotics: Electiv ctive Compulsory cation: Elective Com omplementary Cours	ineering: Electiv ve Compulsory pulsory se: Elective Comp	e Compulsory pulsory

Course L1836: Control Lab IX			
Тур	Practical Course		
Hrs/wk	1		
СР	1		
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14		
Lecturer	of. Herbert Werner, Patrick Göttsch, Adwait Datar		
Language	EN		
Cycle	WiSe/SoSe		
Content	One of the offered experiments in control theory.		
Literature	Experiment Guides		

Course L1834: Control Lab VII			
Тур	Practical Course		
Hrs/wk	1		
СР	1		
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14		
Lecturer	r Prof. Herbert Werner, Patrick Göttsch		
Language	EN		
Cycle	WiSe/SoSe		
Content	One of the offered experiments in control theory.		
Literature	Experiment Guides		

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Course	L1835:	Control	Lab	VIII

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

Module M1281: A	Advanced Topics in Vibration				
Courses					
Title		Тур	Hrs/wk	СР	
Advanced Topics in Vibratio	on (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 h	ave reached the following learning	g results		
Professional Competence					
Knowledge	Students are able to reflect existing terms and concepts of Advanced Vibrations and to develop and research new terms and concepts.				
Skills	Students are able to apply existing metho methods and procedures.	Students are able to apply existing methods and procesures of Advanced Vibrations and to develop novel methods and procedures.			
Personal Competence					
Social Competence	Students can reach working results also in gr	oups.			
Autonomy	Students are able to approach given resear tasks by themselves.	ch tasks individually and to identify	and follow u	p novel research	
Workload in Hours	Independent Study Time 124, Study Time	e 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 Desi Mechatronics: Specialisation Intelligent S Mechatronics: Technical Complementary Theoretical Mechanical Engineering: Tech Theoretical Mechanical Engineering: Sp Compulsory	gn: Elective Compulsory ystems and Robotics: Elective Cor Course: Elective Compulsory inical Complementary Course: Ele ecialisation Product Developmer	npulsory ctive Compu nt and Prod	lsory uction: Elective	

Course L1743: Advanced Topics in Vibration			
Тур	Project-/problem-based Learning		
Hrs/wk	4		
СР	6		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Lecturer	Prof. Norbert Hoffmann, Merten Tiedemann, Sebastian Kruse		
Language	DE/EN		
Cycle	SoSe		
Content	Research Topics in Vibrations.		
Literature	Aktuelle Veröffentlichungen		

Module M0835: H	lumanoid Robotics
Courses	
Title Humanoid Robotics (L0663)	TypHrs/wkCPSeminar22
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 specific 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 ov results
Autonomy	 Students evaluate advantages and drawbacks of different forms of presentation for specif tasks and select the best solution Students familiarize themselves with a scientific field, are able of introduce it and follo 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L0663: Humano	id Robotics
Тур	Seminar
Hrs/wk	2
СР	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: L	inear and Nonlinear Sy	ystem Identifikation		
Courses				
Title		Тур	Hrs/wk	СР
Linear and Nonlinear Syste	m Identification (L0660)	Lecture	2	3
Module Responsible	Prof. Herbert Werner			
Admission Requirements	None			
Recommended Previous Knowledge	 Classical control (frequence State space methods Discrete-time systems Linear algebra, singular va Basic knowledge about store 	cy response, root locus) alue decomposition ochastic processes		
Educational Objectives	After taking part successfully, stu	udents have reached the following le	arning results	
Professional Competence				
Knowledge	 Students can explain the g a variety of linear and non They can explain how mul They can explain how a network models They can explain the idea 	general framework of the prediction linear model structures tilayer perceptron networks are used n approximate predictive control s of subspace identification and its rel	error method and d to model nonline scheme can be b lation to Kalman re	its application to ar dynamics ased on neura calisation theory
Skills	 Students are capable of a of linear and nonlinear mo They are capable of implet network model They are capable of applemodels for dynamic system They can do the above usin Toolbox) 	pplying the predicition error method dels for dynamic systems lementing a nonlinear predictive co ying subspace algorithms to the ex ms ing standard software tools (includin	to the experiment ontrol scheme bas perimental identif g the Matlab Syste	tal identification ed on a neura ication of linea em Identification
Personal Competence				
Social Competence	Students can work in mixed grou	ips on specific problems to arrive at	joint solutions.	
Autonomy	Students are able to find require documentation) and use it to solv	ed information in sources provided (ve given problems.	lecture notes, lite	rature, software
Workload in Hours	Independent Study Time 62, Stud	dy 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: Specialisa Mechatronics: Specialisation Inter Mechatronics: Specialisation Syst Biomedical Engineering: Speciali Biomedical Engineering: Speciali Biomedical Engineering: Speciali Biomedical Engineering: Speciali Theoretical Mechanical Engineer Theoretical Mechanical Engineer	ation Control and Power Systems Eng elligent Systems and Robotics: Elective tem Design: Elective Compulsory ialisation Artificial Organs and I sation Implants and Endoprostheses sation Medical Technology and Contr sation Management and Business Ac ing: Technical Complementary Cours ing: Core qualification: Elective Com	ineering: Elective ve Compulsory Regenerative Med : Elective Compuls rol Theory: Compu Iministration: Elective se: Elective Compu pulsory	Compulsory dicine: Elective ory Isory cive Compulsory Isory

Course L0660: Linear a	nd Nonlinear System Identification
Тур	Lecture
Hrs/wk	2
СР	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: C	Control Lab A			
Courses				
Title		Түр	Hrs/wk	СР
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 c LPV control 	ontrol		
Educational Objectives	After taking part successfully, students hav	ve reached the following learning	ng results	
Professional				
Competence	 Students can explain the different 	ce between validation of a d	control lop in	simulation and
Knowledge	experimental validation			
Skills	 Students are capable of applying ba Toolbox) to identify a dynamic mode They are capable of using standard implementation of LQG controllers They are capable of using standa mixed-sensitivity design and the im They are capable of representing robust controller They are capable of using standa design and the implementation of LI 	asic system identification tools el that can be used for controll software tools (Matlab Contro rd software tools (Matlab Rol plementation of H-infinity optin model uncertainty, and of d rd software tools (Matlab Rol PV gain-scheduled controllers	(Matlab Syste er synthesis ol Toolbox) for oust Control To nal controllers esigning and i oust Control To	m Identification the design and polbox) for the mplementing a polbox) for the
Personal Competence				
Social Competence	• Students can work in teams to cond	uct experiments and documen	t the results	
Autonomy	Students can independently carry of	ut simulation studies to design	and validate o	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 Contr Mechatronics: Specialisation System Desig Mechatronics: Specialisation Intelligent Sys Theoretical Mechanical Engineering: Techr Theoretical Mechanical Engineering: S Compulsory	ol and Power Systems Engined n: Elective Compulsory stems and Robotics: Elective C ical Complementary Course: E pecialisation Robotics and	ering: Elective ompulsory lective Compu Computer Sci	Compulsory Isory ience: Elective

Course L1093: Control Lab I	
Тур	Practical Course
Hrs/wk	1
СР	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
	Experiment Guides
Literature	

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

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

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

Module M0924: S	oftware for Embedded Systems			
Courses				
Title Software for Embdedded Sy Software for Embdedded Sy	/stems (L1069) /stems (L1070)	Typ Lecture Recitation Section (small)	Hrs/wk 2 3	CP 3 3
Module Responsible	Prof. Bernd-Christian Renner			
Admission Requirements	None			
Recommended Previous Knowledge	 Good knowledge and experience in progr Basis knowledge in software engineering Basic understanding of assembly language 	amming language C e		
Educational Objectives	After taking part successfully, students have rea	iched 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 Leo	ture 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 a Electrical Engineering: Specialisation Informatio Information and Communication Systems: Spe Software and Signal Processing: Elective Compu- Information and Communication Systems: Spe Elective Compulsory International Management and Engineering: Compulsory Mechatronics: Technical Complementary Course Mechatronics: Specialisation Intelligent Systems Mechatronics: Specialisation System Design: Ele Microelectronics and Microsystems: Specialisation	nd Software Engineering: Ele n and Communication Syste cialisation Secure and Dep Isory ecialisation Communication Specialisation II. Informa e: Elective Compulsory and Robotics: Elective Com- ective Compulsory on Embedded Systems: Elect	ective Compo ms: Elective endable IT S Systems, F tion Techno pulsory tive Compuls	ulsory Compulsory ;ystems, Focus ocus Software: logy: Elective sory

Course L1069: Softwar	e for Embdedded Systems		
Тур	Lecture		
Hrs/wk	2		
СР	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	 Embedded System Design, F. Vahid and T. Givargis, John Wiley Programming Embedded Systems: With C and Gnu Development Tools, M. Barr and A. Massa, O'Reilly C und C++ für Embedded Systems, F. Bollow, M. Homann, K. Köhn, MITP The Art of Designing Embedded Systems, J. Ganssle, Newnses Mikrocomputertechnik mit Controllern der Atmel AVR-RISC-Familie, G. Schmitt, Oldenbourg Making Embedded Systems: Design Patterns for Great Software, E. White, O'Reilly 		

Course L1070: Software for Embdedded Systems	
Тур	Recitation Section (small)
Hrs/wk	3
СР	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 M0630: F	Robotics and Nav	vigation in Medici	ne		
Courses					
Title Robotics and Navigation in Robotics and Navigation in Robotics and Navigation in	Medicine (L0335) Medicine (L0338) Medicine (L0336)		Typ Lecture Project Seminar Recitation Section (small)	Hrs/wk 2 2 1	CP 3 2 1
Module Responsible	Prof. Alexander Schlae	fer			
Admission Requirements	None				
Recommended Previous Knowledge	 principles of mail principles of pro solid R or Matlab 	th (algebra, analysis/calcul gramming, e.g., in Java or o skills	lus) C++		
Educational Objectives	After taking part succe	ssfully, students have read	ched the following learning	results	
Professional					
Knowledge	The students can expl and their components safety and regulations.	ain kinematics and trackir in detail. Systems can b Students can assess typic	ng systems in clinical cont e evaluated with respect cal systems regarding desig	exts and illu to collision gn and limit	strate systems detection and ations.
Skills	The students are able applications.	to design and evaluate	navigation systems and ro	obotic syste	ms for medica
Personal Competence					
Social Competence	The students discuss the results of other groups, provide helpful feedback and can incoorporate feedback into their work.				
Autonomy	The students can reflect their knowledge and document the results of their work. They can present the results in an appropriate manner.				
Workload in Hours	Independent Study Tim	ne 110, Study Time in Lect	ure 70		
Credit points	6				
Course achievement	CompulsorBonus Yes 10 % Yes 10 %	Form Written elaboration Presentation	Description		
Examination	Written exam				
Examination duration and scale	90 minutes				
Assignment for the Following Curricula	Computer Science: Spe Electrical Engineering: International Manage Compulsory International Managem Elective Compulsory Mechatronics: Specialis Biomedical Engineering Biomedical Engineering Biomedical Engineering Biomedical Engineering Product Development Compulsory Product Development, Product Development, Product Development, Theoretical Mechanical Theoretical Mechanical	ecialisation II: Intelligence I Specialisation Medical Tec ment and Engineering: Spe sation Intelligent Systems a ng: Specialisation Implants a g: Specialisation Medical Te g: Specialisation Medical Te g: Specialisation Managem , Materials and Production: Materials and Production: Materials and Production: I Engineering: Technical Ce I Engineering: Specialisation	Engineering: Elective Comp Innology: Elective Compuls Specialisation II. Electr Indication II. Process Engin and Robotics: Elective Com- ial Organs and Regene and Endoprostheses: Elective echnology and Control The ent and Business Administ ion: Specialisation Production: Specialisation Materials: Ele- omplementary Course: Election Indication Technology and Medical Technology Specialisation Materials: Ele- Specialisation Material	pulsory ory ical Engine neering and pulsory erative Med ve Compulso ory: Elective ration: Elect ict Develop Elective Comp ective Compu- tive Compul logy: Electiv	ering: Elective Biotechnology: icine: Elective cory Compulsory ive Compulsory ment: Elective npulsory bulsory sory e Compulsory

Course L0335: Robotics	s and Navigation in Medicine
Тур	Lecture
Hrs/wk	2
СР	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	
Тур	Project Seminar
Hrs/wk	2
СР	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			
Тур	Recitation Section (small)		
Hrs/wk	1		
СР	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		

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Module M1248: C	ompilers for Embedded Sy	stems			
Courses					
Title Compilers for Embedded Systems (L1692)		Typ Lecture		Hrs/wk 3	CP 4
Compilers for Embedded Systems (L1693) Project-/problem- Learning			problem-based	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 fo	ollowing learning	g results	
Professional Competence					
Knowledge Skills	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 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. 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.				
	optimizations.				
Personal Competence	Students are able to solve similar prob	lems alone or in a gr	oup and to pres	ent the resul	ts accordingly
Social Competence Autonomy	Students are able to acquire new know with other classes.	wledge from specific	literature and	to associate	this knowledge
Worklood in User	Indopondent Study Time 124 Study Ti	mo in Locture 56			
	naepenaent study rime 124, Study II	me in lecture 56			
Course achievement	Nepe				
Examination 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: Specialisation Avionic Systems: 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory				

Course L1692: Compile	ers for Embedded Systems
Тур	Lecture
Hrs/wk	3
СР	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. 2nd Edition, Springer, 2012. Steven S. Muchnick. Advanced Compiler Design and Implementation. Morgan Kaufmann, 1997. Andrew W. Appel. Modern compiler implementation in C. Oxford University Press, 1998.

Course L1693: Compilers for Embedded Systems			
Тур	Project-/problem-based Learning		
Hrs/wk	1		
СР	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 M0803: E	mbedded Syste	ems				
Courses						
Title Embedded Systems (L0805) Embedded Systems (L0806))			Typ Lecture Recitation Section (sma	Hrs/wk 3 III) 1	CP 4 2
Module Responsible	Prof. Heiko Falk					
Admission Requirements	None					
Recommended Previous Knowledge	Computer Engineering	9				
Educational Objectives	After taking part succ	essfully, students	have reache	ed the following learn	ing results	
Professional Competence						
	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).					
Knowledge	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 s	Students are able to solve similar problems alone or in a group and to present the results accordingly.				
Autonomy	Students are able to with other classes.	acquire new know	wledge from	specific literature ar	d to associat	e this knowledg
Workload in Hours	Independent Study Ti	me 124, Study Ti	me in Lectur	e 56		
Credit points	6					
Course achievement	CompulsorBonus	Form Subject theo	pretical an	Description		
Examination	Written exam					
Examination duration and scale	90 minutes, contents	of course and lab	S			
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Electrical Engineering: Core qualification: Elective Compulsory Engineering Science: Specialisation Mechatronics: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic Systems: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechatronics: Elective Compulsory Computational Science and 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: Embedd	ed Systems
Тур	Lecture
Hrs/wk	3
СР	4
Workload in Hours	Independent Study Time 78, 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. 2nd Edition, Springer, 2012., Springer, 2012.

Course L0806: Embedded Systems			
Тур	Recitation Section (small)		
Hrs/wk	1		
СР	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 M0551: P	attern Recognition and Da	ta Compression		
Courses				
Title Pattern Recognition and Da	ta Compression (L0128)	Typ Lecture	Hrs/wk 4	CP 6
Module Responsible	Prof. Rolf-Rainer Grigat			
Admission Requirements	None			
Recommended Previous Knowledge	Linear algebra (including PCA, unitary t	ransforms), stochastics and s	statistics, binary arit	hmetics
Educational Objectives	After taking part successfully, students	have reached the following l	earning results	
Professional Competence				
	Students can name the basic concepts	of pattern recognition and da	ata compression.	
Knowledge	Students are able to discuss logical connections between the concepts covered in the course and explain them by means of examples.			
Skills	Students can apply statistical metho prediction in data compression. On characteristic value assignments and c coding. They are able to use highly sop are capable of assessing different solut	nds to classification probler a sound theoretical and m classifications and describe of histicated methods and proc ion approaches in multidimen	ns in pattern reco ethodical basis the data compression a esses of the subject nsional decision-ma	ognition and to ay can analyze nd video signa area. Students king areas.
Personal Competence <i>Social Competence</i> <i>Autonomy</i>	k.A. Students are capable of identifying pro the methods they have learnt.	oblems independently and o	of solving them scie	entifically, using
Workload in Hours	Independent Study Time 124, Study Tir	ne in Lecture 56		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	60 Minutes, Content of Lecture and mat	terials in StudIP		
Assignment for the Following Curricula	Computer Science: Specialisation II: Inte Electrical Engineering: Specialisation In Information and Communication Syste Software and Signal Processing: Electiv Information and Communication Syst Processing: Elective Compulsory International Management and Engin Compulsory International Management and Eng Compulsory Mechatronics: Specialisation Intelligent Mechatronics: Technical Complementar Theoretical Mechanical Engineering: Te Theoretical Mechanical Engineering: Compulsory	elligence Engineering: Electiv formation and Communicatio ems: Specialisation Secure a e Compulsory tems: Specialisation Comm neering: Specialisation II. ineering: Specialisation II. Systems and Robotics: Elect ty Course: Elective Compulso chnical Complementary Cour Specialisation Robotics a	ve Compulsory on Systems: Elective nd Dependable IT s nunication Systems Information Techno Electrical Engine ive Compulsory ry rse: Elective Compu and Computer Sci	e Compulsory Systems, Focus , Focus Signa blogy: Elective ering: Elective lsory ence: Elective
Course L0128: Pattern	Recognition and Data Compression			
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Тур	Lecture			
Hrs/wk	4			
СР	6			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Lecturer	Prof. Rolf-Rainer Grigat			
Language	EN			
Cycle	SoSe			
Content	Structure of a pattern recognition system, statistical decision theory, classification based on statistical models, polynomial regression, dimension reduction, multilayer perceptron regression, radial basis functions, support vector machines, unsupervised learning and clustering, algorithm-independent machine learning, mixture models and EM, adaptive basis function models and boosting, Markov random fields Information, entropy, redundancy, mutual information, Markov processes, basic coding schemes (code length, run length coding, prefix-free codes), entropy coding (Huffman, arithmetic coding), dictionary coding (LZ77/Deflate/LZMA2, LZ78/LZW), prediction, DPCM, CALIC, quantization (scalar and vector quantization), transform coding, prediction, decorrelation (DPCM, DCT, hybrid DCT, JPEG, JPEG-LS), motion estimation, subband coding, wavelets, HEVC (H.265,MPEG-H)			
Literature	Schürmann: Pattern Classification, Wiley 1996 Murphy, Machine Learning, MIT Press, 2012 Barber, Bayesian Reasoning and Machine Learning, Cambridge, 2012 Duda, Hart, Stork: Pattern Classification, Wiley, 2001 Bishop: Pattern Recognition and Machine Learning, Springer 2006 Salomon, Data Compression, the Complete Reference, Springer, 2000 Sayood, Introduction to Data Compression, Morgan Kaufmann, 2006 Ohm, Multimedia Communication Technology, Springer, 2004 Solari, Digital video and audio compression, McGraw-Hill, 1997 Tekalp, Digital Video Processing, Prentice Hall, 1995			

Module M0627: N	lachine Learning and Dat	a Mining		
Courses Title Machine Learning and Data	Mining (L0340)	Typ Lecture Desitation Section (ampli)	Hrs/wk	CP 4
Machine Learning and Data		Recitation Section (small)	Z	Ζ
Module Responsible	NN			
Admission Requirements	None			
Recommended Previous Knowledge	CalculusStochastics			
Educational Objectives	After taking part successfully, studer	nts 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, i and are able to name and explain ba of first-order inductive leaning. Stu parameters of Bayesian networks ar out Gaussian mixture learning. They machines, and name their basic ap basic clustering techniques and exp related machine learning technique They can distinguish various ensem techniques.	n turn, propositional rule sets from sin sic optimization techniques. They pres dents apply the BME, MAP, ML, and nd compare the different algorithms. T can contrast kNN classifiers, neural ne plication areas and algorithmic proper lain the basic components of those tec es, e.g., k-means clustering and near ble learning techniques and compare	mple and st. ent and app EM algorith hey also kno etworks, and ties. Studen chniques. Stu rest neighbo the different	atic data tables by the basic ide ms for learning ow how to carry support vecto ts can describe udents compare or classification t goals of those
Personal Competence				
Social Competence	Ì			
Autonomy	1			
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: International Management and Er Compulsory Mechatronics: Technical Complemen Mechatronics: Specialisation Intellige Mechatronics: Specialisation System Theoretical Mechanical Engineering: Theoretical Mechanical Engineering	Intelligence Engineering: Elective Comp ngineering: Specialisation II. Informatory tary Course: Elective Compulsory ent Systems and Robotics: Elective Com- Design: Elective Compulsory Technical Complementary Course: Electing og: Specialisation Robotics and Comp	oulsory ation Techno npulsory ctive Compu mputer Sci	ology: Elective Isory ence: Elective

Course L0340: Machine	Learning and Data Mining		
Тур	Lecture		
Hrs/wk	2		
СР	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 Theory 		
Literature	 Artificial Intelligence: A Modern Approach (Third Edition), Stuart Russel, Peter Norvig, Prentice Hall, 2010, Chapters 13, 14, 18-21 Machine Learning: A Probabilistic Perspective, Kevin Murphy, MIT Press 2012 		

ction (small)
Study Time 32, Study Time in Lecture 28
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ing course
ing course

Module M0550: D	vigital Image Analysis		
Courses			
Title	 Typ Hrs/wk CP		
Digital Image Analysis (L012	26) Lecture 4 6		
Module Responsible	Prof. Rolf-Rainer Grigat		
Admission Requirements	None		
Recommended Previous Knowledge	System theory of one-dimensional signals (convolution and correlation, sampling theory, interpolatio and decimation, Fourier transform, linear time-invariant systems), linear algebra (Eigenvalu decomposition, SVD), basic stochastics and statistics (expectation values, influence of sample size correlation and covariance, normal distribution and its parameters), basics of Matlab, basics in optics		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional			
Competence			
Knowledge	 Describe imaging processes Depict the physics of sensorics Explain linear and non-linear filtering of signals Establish interdisciplinary connections in the subject area and arrange them in their context Interpret effects of the most important classes of imaging sensors and displays us mathematical methods and physical models. 		
	Students are able to		
	 Use highly sophisticated methods and procedures of the subject area Identify problems and develop and implement creative solutions. 		
Skills	Students can solve simple arithmetical problems relating to the specification and design of ima processing and image analysis systems.		
	Students are able to assess different solution approaches in multidimensional decision-making areas		
	Students can undertake a prototypical analysis of processes in Matlab.		
Personal Competence			
Social Competence	k.A.		
Autonomy	Students can solve image analysis tasks independently using the relevant literature.		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Course achievement	None		
Examination	Written exam		
Examination duration and scale	60 Minutes, Content of Lecture and materials in StudIP		
Assignment for the Following Curricula	Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Sig Processing: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Electi Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elect Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elect Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elect Compulsory		

Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory

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

Module M0623: Intelligent Systems in Medicine					
Courses					
TitleTypHrs/wlIntelligent Systems in Medicine (L0331)Lecture2Intelligent Systems in Medicine (L0334)Project Seminar2Intelligent Systems in Medicine (L0333)Recitation Section (small)1			Hrs/wk 2 2 1	CP 3 2 1	
Module Responsible	Prof. Alexander Schlaef	fer			
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 succe	ssfully, students have read	ched the following learning	results	
Professional Competence					
Knowledge	The students are able to analyze and solve clinical treatment planning and decision support problems using methods for search, optimization, and planning. They are able to explain methods for classification and their respective advantages and disadvantages in clinical contexts. The students can compare different methods for representing medical knowledge. They can evaluate methods in the context of clinical data and explain challenges due to the clinical nature of the data and its acquisition and due to privacy and safety requirements.				
Skills	The students can give reasons for selecting and adapting methods for classification, regression, and prediction. They can assess the methods based on actual patient data and evaluate the implemented methods.				
Personal Competence Social Competence	The students discuss the results of other groups, provide helpful feedback and can incoorporate feedback into their work.				
Autonomy	The students can reflect their knowledge and document the results of their work. They can present the results in an appropriate manner.				
Workload in Hours	Independent Study Tim	ne 110, Study Time in Lect	ure 70		
Credit points	6				
Course achievement	CompulsorBonusYes10 %Yes10 %	Form Written elaboration Presentation	Description		
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 Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory				

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Course L0331: Intellige	ent Systems in Medicine
Тур	Lecture
Hrs/wk	2
СР	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		
Тур	Project Seminar	
Hrs/wk	2	
СР	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		
Тур	Recitation Section (small)	
Hrs/wk	1	
СР	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 M0552: 3	D Computer Vision
Courses	
Title	Typ Hrs/wk CP
3D Computer Vision (L0129) Lecture 2 3
3D Computer Vision (L0130) Recitation Section (small) 2 3
Module Responsible	Prof. Rolf-Rainer Grigat
Admission Requirements	None
Recommended Previous Knowledge	 Knowlege of the modules Digital Image Analysis and Pattern Recognition and Data Compression are used in the practical task Linear Algebra (including PCA, SVD), nonlinear optimization (Levenberg-Marquardt), basics of stochastics and basics of Matlab are required and cannot be explained in detail during the lecture.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain and describe the field of projective geometry.
	Students are capable of
	 Implementing an exemplary 3D or volumetric analysis task Using highly sophisticated methods and procedures of the subject area Identifying problems and Developing and implementing creative solution suggestions.
Skills	With assistance from the teacher students are able to link the contents of the three subject area (modules)
	 Digital Image Analysis Pattern Recognition and Data Compression and 3D Computer Vision
	in practical assignments.
Personal Competence	
Social Competence	Students can collaborate in a small team on the practical realization and testing of a system t reconstruct a three-dimensional scene or to evaluate volume data sets.
	Students are able to solve simple tasks independently with reference to the contents of the lecture and the exercise sets.
Autonomy	Students are able to solve detailed problems independently with the aid of the tutorial's programmin task.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None Written even
Examination	
and scale	60 Minutes, Content of Lecture and materials in StudIP
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signa Processing: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

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

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

Module M0633: II	ndustrial Proces	s Automation			
Courses					
Title Industrial Process Automation (L0344) Industrial Process Automation (L0345)			Typ Lecture Recitation Section (small)	Hrs/wk 2 2	CP 3 3
Module Responsible	Prof. Alexander Schlaef	er			
Admission Requirements	None				
Recommended Previous Knowledge	mathematics and optin principles of automata principles of algorithms programming skills	mathematics and optimization methods principles of automata principles of algorithms and data structures programming skills			
Educational Objectives	After taking part succe	ssfully, students have	e 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 work in teams to solve problems.				
Autonomy	The students can reflec	t their knowledge an	d document the results of their	work.	
Workload in Hours	Independent Study Tim	e 124. Study Time in	Lecture 56		
Credit points	6				
Course achievement	CompulsorBonus No 10 %	Form Excercises	Description		
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: Specialisation Control and Power Systems: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory				

Course L0344: Industri	al Process Automation
Тур	Lecture
Hrs/wk	2
СР	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			
Тур	Recitation Section (small)		
Hrs/wk	2		
СР	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 M0677: D	Digital Signal Processing and	Digital Filters			
Courses					
Title Digital Signal Processing ar Digital Signal Processing ar	nd Digital Filters (L0446) nd Digital Filters (L0447)	Typ Lecture Recitation Section (large)	Hrs/wk 3 2	CP 4 2	
Module Responsible	Prof. Gerhard Bauch				
Admission Requirements	None				
Recommended Previous Knowledge	 Mathematics 1-3 Signals and Systems Fundamentals of signal and system Fundamentals of spectral transform 	n theory as well as random process ns (Fourier series, Fourier transforr	ses. n, Laplace	transform)	
Educational Objectives	After taking part successfully, students h	ave 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				
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 o spectrum estimation and to take the effects of a limited observation window into account.				ose g to ion, s of
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	e 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 Computational Science and Engineering: Specialisation II. Engineering Science: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Sig Processing: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elec Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elec Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elec Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elec				, jnal tive tive tive

Course L0446: Digital S	Signal Processing and Digital Filters			
Тур	Lecture			
Hrs/wk	3			
СР	4			
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42			
Lecturer	Prof. Gerhard Bauch			
Language	EN			
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 			
	KD. Kammeyer, K. Kroschel: Digitale Signalverarbeitung. Vieweg Teubner.			
Literature	W. Hess: Digitale Filter. Teubner. Oppenheim, R. W. Schafer: Digital signal processing. Prentice Hall.			
	S. Haykin: Adaptive flter 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			
Тур	Recitation Section (large)		
Hrs/wk	2		
СР	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 M0832: A	dvanced Topics in Control					
Courses						
Title		Түр	Hrs/wk	СР		
Advanced Topics in Control	(L0661)	Lecture	2	3		
Advanced Topics in Control	(L0662)	Recitation Section (small)	2	3		
Module Responsible	Prof. Herbert Werner					
Requirements	None					
Recommended Previous Knowledge	H-infinity optimal control, mixed-sensitivity	design, linear matrix inequalities	5			
Educational Objectives	After taking part successfully, students hav	e reached the following learning	results			
Professional Competence						
	 Students can explain the advanta approach They can explain the representation They can explain how stability and p as LMI conditions They can explain how gridding techn for LPV systems They are familiar with polytopic and synthesis techniques associated with 	ges and shortcomings of the of nonlinear systems in the form performance conditions for LPV s iques can be used to solve analy LFT representations of LPV syst a each of these model structures	classical of quasi-Lf systems ca rsis and syr ems and so	gain scheduling PV systems n be formulated othesis problems ome of the basic		
Knowledge	 Students can explain how graph theoretic concepts are used to represent the topology of multiagent systems They can explain the convergence properties of first order consensus protocol They can explain analysis and synthesis conditions for formation control loop LTI or LPV agent models 					
	 Students can explain the state space representation of spatially invariant distributed systems that are discretized according to an actuator/sensor array They can explain (in outline) the extension of the bounded real lemma to such distributed systems and the associated synthesis conditions for distributed controllers 					
	 Students are capable of constructir sensitivity design of gain-scheduled LPV models They are able to use standard softwate 	ng LPV models of nonlinear plar controllers; they can do this usir are tools (Matlab robust control to	nts and car ng polytopic polbox) for	ry out a mixed c, LFT or genera these tasks		
Skills	 Students are able to design distributed formation controllers for groups of agents w or LPV dynamics, using Matlab tools provided 					
	 Students are able to design distributed controllers for spatially interconnected systems, the Matlab MD-toolbox 					
Personal Competence						
Social Competence	Students can work in small groups and arriv	ve at joint results.	notos lita	rature coffwor		
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	a Lecture 56				
Credit points	6					
Course achievement	None					
Examination	Urai exam					
Examination duration and scale	30 min					
	Computer Science: Specialisation Intelligen	ce Engineering: Elective Comput	sory			

Course L0661: Advance	ed Topics in Control			
Тур	Lecture			
Hrs/wk				
СР	3			
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28			
Lecturer	Prof. Herbert Werner			
Language	1			
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 Controller synthesis based on input/output models Applications: LPV torque vectoring for electric vehicles, LPV control of a robotic manipulator Control of Multi-Agent Systems Communication graphs Spectral properties of the graph Laplacian First and second order consensus protocols Formation control, stability and performance LPV models for agents subject to nonholonomic constraints Application: formation control for a team of quadrotor helicopters Control of Spatially Interconnected Systems Multidimensional signals, I2 and L2 signal norm Extension of real-bounded lemma to spatially interconnected systems LMI-based synthesis of distributed controllers Spatial LPV control of spatially varying systems Applications: control of spatially varying systems Applications: control of temperature profiles, vibration damping for an actuated beam 			
Literature	 Werner, H., Lecture Notes "Advanced Topics in Control" Selection of relevant research papers made available as pdf documents via StudIP 			

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

Module M1173: A	pplied Statistic	cs			
Courses					
Title			Typ	Hrs/wk	СР 3
Applied Statistics (L1586)			Project-/problem-based	2	2
Applied Statistics (L1585)			Learning Recitation Section (small)	1	1
Module Responsible	Prof. Michael Morlock			_	_
Admission Requirements	None				
Recommended Previous Knowledge	Basic knowledge of st	tatistical methods			
Educational Objectives	After taking part succ	essfully, students have read	ched the following learning	results	
Professional Competence Knowledge Skills Personal Competence	Students can explain Students are able to the results Team Work, joined pr	the statistical methods and use the statistics program t resentation of results	the conditions of their use o solve statistics problems	and to inte	rpret and depict
Social Competence Autonomy	To understand and interpret the question and solve				
Workload in Hours	Independent Study Ti	me 110, Study Time in Lect	ure 70		
Credit points	6				
Course achievement	CompulsorBonus Yes None	Form Written elaboration	Description		
Examination	Written exam				
Examination duration and scale	90 minutes, 28 quest	ions			
Assignment for the Following Curricula	Aechanical Engineering and Management: Specialisation Management: Elective Compulsory Aechatronics: Specialisation System Design: Elective Compulsory Aechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Core qualification: Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Fheoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Fheoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory				

Course L1584: Applied	Statistics
Тур	Lecture
Hrs/wk	2
СР	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
Тур	Project-/problem-based Learning
Hrs/wk	2
СР	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
Тур	Recitation Section (small)
Hrs/wk	1
СР	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 M1204: N	lodelling and Optimization in	n Dynamics		
Courses				
Title Flexible Multibody Systems Optimization of dynamical s	(L1632) systems (L1633)	Typ Lecture Lecture	Hrs/wk 2 2	CP 3 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 ha	ave reached the following h	earning results	
Professional Competence				
Knowledge	Students demonstrate basic knowledge complex rigid and flexible multibody sy successful completion of the module.	and understanding of mo stems and methods for o	deling, simulation optimizing dynami	and analysis o c systems after
Skills	 + to think holistically + to independently, securly and critically and flexible multibody systems + to describe dynamics problems mathen + to optimize dynamics problems 	analyze and optimize basi	c problems of the c	lynamics of rigic
Personal Competence Social Competence	Students are able to + solve problems in heterogeneous group	os and to document the cor	responding results	
Autonomy	Students are able to + assess their knowledge by means of ex + acquaint themselves with the necessar	ercises. y knowledge to solve resea	arch oriented tasks	
Workload in Hours	Independent Study Time 124, Study Time	in Lecture 56		
Credit points	6			
Course achievement	None			
Examination Examination duration	Oral exam 30 min			
Assignment for the Following Curricula	Energy Systems: Core qualification: Electi Aircraft Systems Engineering: Specialisati Mechatronics: Specialisation System Desi Mechatronics: Specialisation Intelligent Sy Product Development, Materials and Prod Theoretical Mechanical Engineering: Core Theoretical Mechanical Engineering: Tech	ve Compulsory on Aircraft Systems: Electi gn: Elective Compulsory /stems and Robotics: Electi uction: Core qualification: I qualification: Elective Com nical Complementary Cour	ve Compulsory ive Compulsory Elective Compulsor Ipulsory se: Elective Compu	y Ilsory

Course L1632: Flexible	Multibody Systems
Тур	Lecture
Hrs/wk	2
СР	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	 Basics of Multibody Systems Basics of Continuum Mechanics Linear finite element modelles and modell reduction Nonlinear finite element Modelles: absolute nodal coordinate formulation Kinematics of an elastic body Kinetics of an elastic body 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: Optimiz	ation of dynamical systems					
Тур	Lecture					
Hrs/wk	2					
СР	3					
Workload in Hours	ependent Study Time 62, Study Time in Lecture 28					
Lecturer	Prof. Robert Seifried					
Language	DE					
Cycle	WiSe					
Content	 Formulation and classification of optimization problems Scalar Optimization Sensitivity Analysis Unconstrained Parameter Optimization Constrained Parameter Optimization Stochastic optimization Multicriteria Optimization 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 M1229: C	Contr	rol Lab	В						
Courses									
Title						Тур		Hrs/wk	СР
Control Lab V (L1667)						Practical C	Course	1	1
	1					Plactical C	Jourse	1	1
Module Responsible	Prof.	Herbert We	erner						
Admission Requirements	None	None							
Recommended Previous Knowledge	•	State spa LQG cont H2 and H uncertain LPV cont	ce method rol -infinity op plant moc rol	ls otimal con dels and ro	trol obust contr	ol			
Educational Objectives	After	taking par	t successfu	ılly, stude	ents have re	ached the fol	lowing lear	ning results	
Professional Competence	9								
Knowledge	•	Students experime	can expla ntal valida	ain the d tion	lifference b	etween valid	ation of a	control lop in	simulation ar
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 H-infinity optimal controllers 							
Personal Competence									
Social Competence	•	Students	can work i	n teams t	o conduct e	experiments a	nd docume	ent the results	
Autonomy	•	Students	can indepe	endently o	carry out si	nulation stud	ies to desig	gn and validate	control loops
Workload in Hours	Indep	endent Stu	udy Time 3	2, Study	Time in Lec	ture 28			
Credit points	2								
Course achievement	None								
Examination	Writte	en elabora	tion						
Examination duration and scale	1								
Assignment for the Following Curricula	Electr Mech Mech	rical Engine atronics: S atronics: S	eering: Spe pecialisatio pecialisatio	ecialisatio on Intellig on System	n Control ar ent System n Design: El	nd Power Syst s and Robotic ective Compu	ems Engin s: Elective Ilsory	eering: Elective Compulsory	Compulsory
Course L1667: Control	Lab V	1							

Course L1007. Control	
Тур	Practical Course
Hrs/wk	1
СР	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1668: Control	Course L1668: Control Lab VI				
Тур	Practical Course				
Hrs/wk	1				
СР	1				
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14				
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar				
Language	EN				
Cycle	WiSe/SoSe				
Content	One of the offered experiments in control theory.				
Literature	Experiment Guides				

Module M1305: S	eminar Advanc	ed Topics in (Control			
Courses						
Title Advanced Topics in Control	(L1803)		Typ Seminar	Hrs/wk 2	CP 2	
Module Responsible	Prof. Herbert Werner					
Admission Requirements	None					
Recommended Previous Knowledge	 Introduction to a Control theory a optimal and rob 	control systems and design ust control				
Educational Objectives	After taking part succe	essfully, students ha	ave reached the following le	arning 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 ca They are able t results 	pable of developing to provide appropri	g solutions and present then ate feedback and handle c	n onstructive criticis	m of their own	
Autonomy	 Students evaluation tasks and select Students famili presentations or 	ate advantages an t the best solution arize themselves f other students, su	d drawbacks of different for with a scientific field, are ch that a scientific discussio	orms of presentat able of introduce on develops	ion for specific e it and follow	
Workload in Hours	Independent Study Tin	ne 32, Study Time i	n Lecture 28			
Credit points	2					
Course achievement	None					
Examination Examination duration	Presentation					
and scale	90 min					
Assignment for the Following Curricula	Mechatronics: Speciali Mechatronics: Speciali	sation System Desi sation Intelligent Sy	gn: Elective Compulsory ystems and Robotics: Electiv	ve Compulsory		

Course L1803: Advance	ed Topics in Control
Тур	Seminar
Hrs/wk	2
СР	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	Seminar on selected topics in modern control
Literature	To be specified

Module M1398: S	Selected Topics in Multibody Dyna	amics and Robotics	5					
Courses								
Title Formulas and Vehicles - Ma (L1981)	thematics and Mechanics in Autonomous Driving	Typ Project-/problem-based Learning	Hrs/wk	CP 6				
Module Responsible	Prof. Robert Seifried	rof. Robert Seifried						
Admission Requirements	None							
	Mechanics IV, Applied Dynamics or Robotics							
Recommended	Numerical Treatment of Ordinary Differential Eq	uations						
Previous Knowledge	Control Systems Theory and Design							
Educational Objectives	After taking part successfully, students have rea	ched the following learning	results					
Professional Competence								
Knowledge	After successful completion of the module stude in selected application areas of multibody dynar	nts demonstrate deeper kno nics and robotics	owledge and	l understanding				
	Students are able							
	+ to think holistically							
Skills	+ 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 hardwar	re la						
Personal Competence								
	Students are able to							
Social Competence	+ solve problems in heterogeneous groups and to document the corresponding results and present them							
	Students are able to							
Autonomv	+ assess their knowledge by means of exercises and projects.							
	+ acquaint themselves with the necessary know	ledge to solve research orie	nted tasks.					
Workload in Hours	Independent Study Time 152, Study Time in Lec	ture 28						
Credit points	6							
Course achievement	None							
Examination	Presentation							
Examination duration and scale	ТВА							
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems Mechatronics: Specialisation System Design: Ele Theoretical Mechanical Engineering: Technical C Theoretical Mechanical Engineering: Core qualifi	and Robotics: Elective Com ctive Compulsory complementary Course: Elec cation: Elective Compulsory	pulsory tive Compu	sory				

Course L1981: Formula	is and Vehicles - Mathematics and Mechanics in Autonomous Driving
Тур	Project-/problem-based Learning
Hrs/wk	2
СР	6
Workload in Hours	Independent Study Time 152, Study Time in Lecture 28
Lecturer	Prof. Robert Seifried
Language	DE
Cycle	WiSe
Content	
	Seifried, R.: Dynamics of underactuated multibody systems, Springer, 2014
Literature	Popp, K.; Schiehlen, W.: Ground vehicle dynamics, Springer, 2010

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Module M1336: S	oft Computing - Introd	uction to Mach	ine Learnin	g	
Courses					
Title Soft Computing - Introduction	on to Machine Learning (L1869)	Typ Lect	ure	Hrs/wk 4	CP 6
Module Responsible	Prof. Karl-Heinz Zimmermann				
Admission Requirements	None				
	Bachelor in Computer Science.				
Recommended Previous Knowledge	Basics in higher mathematics optimization.	are inevitable, like	calculus, linear	algebra, graj	ph theory, an
Educational Objectives	After taking part successfully, stu	idents have reached th	ne following learr	ning results	
Professional Competence					
Knowledge	Students are able to formalize, hidden Markov models, phyloger networks, and fuzzy controllers.	Students are able to formalize, compute, and analyze belief networks, alignments of sequences, hidden Markov models, phylogenetic tree models, classical regression and clustering methods, neural networks, and fuzzy controllers.			
Skills	Students can apply the relevant the statistics language R.	algorithms and determ	nine their comple	xity, and they o	can make use c
Personal Competence					
Social Competence	Students are able to solve specifi	ic problems alone or in	a group and to p	present the resu	ults accordingly
Autonomy	Students are able to acquire ne knowledge to other fields.	ew knowledge from n	ewer literature	and to associa	te the acquire
Workload in Hours	Independent Study Time 124, Stu	udy 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 International Management and Compulsory Mechatronics: Specialisation Inte Mechatronics: Specialisation Syst Mechatronics: Technical Compler Theoretical Mechanical Engineeri Theoretical Mechanical Engine Compulsory Theoretical Mechanical Engine Compulsory	a II: Intelligence Engine Engineering: Specia Iligent Systems and Ro tem Design: Elective C mentary Course: Electiv ng: Technical Compler tering: Specialisation ering: Specialisation	ering: Elective C alisation II. Info obotics: Elective (ompulsory ve Compulsory nentary Course: Robotics and Numerics and	ompulsory rmation Techn Compulsory Elective Compu Computer Sc Computer Sc	ology: Elective Ilsory ience: Elective :ience: Elective

Course L1869: Soft Con	nputing - Introduction to Machine Learning
Тур	Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Karl-Heinz Zimmermann, Dr. Mehwish Saleemi
Language	DE/EN
Cycle	WiSe
Content	Students are able to formalize, compute, and analyze belief networks, alignments of sequences, hidden Markov models, phylogenetic tree models, neural networks, and fuzzy controllers. In particular, inference and learning in belief networks are important topics that the students should be able to master. Students can apply the relevant algorithms and determine their complexity, and they can make use of the statistics language R.
Literature	 David Barber, Bayes Reasoning and Machine Learning, Cambridge Univ. Press, Cambridge, 2012. Volker Claus, Stochastische Automaten, Teubner, Stuttgart, 1971. Ernst Klement, Radko Mesiar, Endre Pap, Triangular Norms, Kluwer, Dordrecht, 2000. Timo Koski, John M. Noble, Bayesian Networks, Wiley, New York, 2009. Dimitris Margaritis, Learning Bayesian Network Model Structure from Data, PhD thesis, Carnegie Mellon University, Pittsburgh, 2003. Hidetoshi Nishimori, Statistical Physics of Spin Glasses and Information Processing, Oxford Univ. Press, London, 2001. James R. Norris, Markov Chains, Cambridge Univ. Press, Cambridge, 1996. Maria Rizzo, Statistical Computing with R, Chapman & Hall/CRC, Boca Raton, 2008. Peter Sprites, Clark Glymour, Richard Scheines, Causation, Prediction, and Search, Springer, New York, 1993. Raul Royas, Neural Networks, Springer, Berlin, 1996. Lior Pachter, Bernd Sturmfels, Algebraic Statistics for Computational Biology, Cambridge Univ. Press, Cambridge, 2005. David A. Sprecher, From Algebra to Computational Algorithms, Docent Press, Boston, 2017. Karl-Heinz Zimmermann, Algebraic Statistics, TubDok, Hamburg, 2016.

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ntelligent Autonomous Agents	s and Cognitive Rob	otics		
	Тур	Hrs/wk	СР	
ents and Cognitive Robotics (L0341)	Lecture	2	4	
ents and Cognitive Robotics (L0512)	Recitation Section (sma	ill) 2	2	
Rainer Marrone				
None				
Vectors, matrices, Calculus				
After taking part successfully, students hav	e reached the following learn	ing results		
Students can explain the agent abstraction details about agent design (goals, utilities environments. The notion of adversarial problems and algorithms for solving the scenarios, students can summarize how representation and reasoning formalism in decision making procedures in simple and state of the environment. In this contex observable) Markov decision problems, ar information. Students can identify technic explain planning techniques for achieving and decision making in a multi-agent set functions, voting protocol, and mechanism	a, define intelligence in terms b, environments). They can agent cooperation can be d se problems. For dealing v Bayesian networks can be static and dynamic settings. I sequential settings, with an t, students can describe tech ad they can recall technique ques for simultaneous localis desired states. Students can ting in term of different typ design techniques.	of rational bel describe the m iscussed in ter vith uncertaint e employed a n addition, stud d with complet chniques for se s for measurin zation and ma explain coordin es of equilibria	navior, and give nain features of rms of decision y in real-world s a knowledge dents can define e access to the olving (partially ng the value of pping, and can nation problems a, social choice	
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 echniques. 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 echniques 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 echniques 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.				
Students are able to discuss their solutions	to problems with others. The	y communicate	in English	
Students are able of checking their understanding of complex concepts by solving varaints of concrete problems				
Independent Study Time 124, Study Time in	n Lecture 56			
6				
None				
Written exam				
90 minutes				
Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory nternational Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory				
	ntelligent Autonomous Agents Ints and Cognitive Robotics (L0341) Ints and Cognitive Robotics (L0512) Rainer Marrone None Vectors, matrices, Calculus After taking part successfully, students hav Students can explain the agent abstraction details about agent design (goals, utilities environments. The notion of adversarial a problems and algorithms for solving the scenarios, students can summarize how representation and reasoning formalism in decision making procedures in simple and state of the environment. In this context observable) Markov decision problems, ari decision making in a multi-agent set functions, voting protocol, and mechanism Students can select an appropriate agent simplified agent applications they can and apply bayesian reasoning for simple qu techniques for simplified agent scenarios compute the best action or policies for con techniques for finding different equilibria s students are able to discuss their solutions Students are able of checking their underst problems Independent Study Time 124, Study Time ir 6 None Written exam 90 minutes Computer Science: Specialisation II: Intellign International Management and Engineer Compulsory Mechatronics: Technical Complementary Co Mechatronics: Specialisation II: Intellign International Management and Engineer Compulsory Theoretical Mechanical Engineering: Specialisation Man Theoretical Mechanical Engin	Students and Cognitive Robotics (L0341) Lecture Rainer Marrone Recitation Section (sma None Vectors, matrices, Calculus After taking part successfully, students have reached the following learn Students can explain the agent abstraction, define intelligence in terms details about agent design (goals, utilities, environments). They can environments. The notion of adversarial agent cooperation can be d problems and algorithms for solving these problems. For dealing v scenarios, students can summarize how Bayesian networks can be representation and reasoning formalism in static and dynamic settings. Indexision and reasoning formalism is static and dynamic settings. Information. Students can identify techniques for simultaneous locali: explain planning techniques for achieving desired states. Students can and decision making in a multi-agent setting in term of different typ functions, voting protocol, and mechanism design techniques. Students can select an appropriate agent architecture for concrete ag simplified agent application students can derive decision trees a techniques. For those applications tuy can also create Bayesian networi and apply bayesian reasoning for simple queries. Students can also nam techniques for simple and complex concepts is problems. Students are able to discuss their solutions to problems with others. The Students are able of checking their understanding of complex concepts is problems. Independent Study Time 124, Study Time in Lecture 56 6 None Written ex	Students can explain the agent abstraction, define intelligence in terms of rational beformation of adversarial agent constraints and adversarial agent constraints agent age	

Course L0341: Intellige	ent Autonomous Agents and Cognitive Robotics
Тур	Lecture
Hrs/wk	2
СР	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: POMDPs, reduction to multidimensional continuous MDPs, dynamic decision networks Simultaneous Localization and Mapping Planning Game theory (Golden Balls: Split or Share) Decision with multiple agents, Nash equilibrium, Bayes-Nash equilibrium Social Choice Voting protocols, preferences, paradoxes, Arrow's Theorem, Mechanism Design Fundamentals, dominant strategy implementation, Revelation
Literature	 Artificial Intelligence: A Modern Approach (Third Edition), Stuart Russell, Peter Norvig, Prentice Hall, 2010, Chapters 2-5, 10-11, 13-17 Probabilistic Robotics, Thrun, S., Burgard, W., Fox, D. MIT Press 2005 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		
Тур	Recitation Section (small)	
Hrs/wk	2	
СР	2	
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28	
Lecturer	Rainer Marrone	
Language	EN	
Cycle	WiSe	
Content	See interlocking course	
Literature	See interlocking course	

Module M0881: N	Aathematical Image Processing				
Courses					
Title Mathematical Image Proces Mathematical Image Proces	ssing (L0991) ssing (L0992)	Typ Lecture Recitation Section (small)	Hrs/wk 3 1	CP 4 2	
Module Responsible	Prof. Marko Lindner				
Admission Requirements	None				
Recommended Previous Knowledge	 Analysis: partial derivatives, gradient, d Linear Algebra: eigenvalues, least squar 	irectional derivative res solution of a linear system			
Educational Objectives	After taking part successfully, students have re	eached the following learning	results		
Professional Competence					
Knowledge	 Students are able to characterize and compare diffusion equal explain elementary methods of image p explain methods of image segmentation sketch and interrelate basic concepts of 	 tudents 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 method explain and apply modern methods of ir 	ods of image processing mage processing			
Personal Competence					
Social Competence	Students are able to work together in hetero study programs and background knowledge) a	ogeneously composed teams ind to explain theoretical foun	(i.e., team: dations.	s from differer	
Autonomy	 Students are capable of checking their can specify open questions precisely an Students have developed sufficient per oriented manner on hard problems. 	understanding of complex co d know where to get help in s sistence to be able to work fo	oncepts on olving them or longer pe	their own. The ۱. eriods in a goa	
Workload in Hours	Independent Study Time 124, Study Time in Le	ecture 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 - Gen Computer Science: Specialisation III. Mathemai Computational Science and Engineering: Speci Mechatronics: Technical Complementary Cours Mechatronics: Specialisation Intelligent System Mechatronics: Specialisation System Design: E Technomathematics: Specialisation I. Mathema Theoretical Mechanical Engineering: Technical Theoretical Mechanical Engineering: Specia Compulsory Theoretical Mechanical Engineering: Specia Compulsory Process Engineering: Specialisation Process Pr	eral Bioprocess Engineering: I tics: Elective Compulsory ialisation III. Mathematics: Ele se: Elective Compulsory ns and Robotics: Elective Com Elective Compulsory atics: Elective Compulsory Complementary Course: Elec alisation Robotics and Co alisation Numerics and Co	Elective Cor ctive Comp pulsory tive Compu mputer Sc mputer Sc	npulsory ulsory lsory ience: Electiv ience: Electiv	

Course L0991: Mathem	atical Image Processing
Тур	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: Mathem	ourse L0992: Mathematical Image Processing		
Тур	Recitation Section (small)		
Hrs/wk	1		
СР	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		

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: N	Ionlinear Dynamics				
Courses					
Title Nonlinear Dynamics (L0702)	Typ Integrated Lecture	Hrs/wk 4	CP 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 read	ched the following learning	g 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.				
Skills	Students are able to apply existing methods ar novel methods and procedures.	nd procesures of Nonlinea	ar Dynamics	and to develop	
Personal Competence					
Social Competence	Students can reach working results also in groups	S.			
Autonomy	Students are able to approach given research t research tasks by themselves.	Students are able to approach given research tasks individually and to identify and follow up novel research tasks by themselves.			
Workload in Hours	Independent Study Time 124, Study Time in Lect	ure 56			
Credit points	6				
Course achievement	None				
Examination	Written exam				
Examination duration and scale	2 Hours				
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Aircr International Management and Engineering: Special Mechanical Engineering and Management: Special Mechatronics: Specialisation System Design: Elec Mechatronics: Specialisation Intelligent Systems a Biomedical Engineering: Specialisation Artific Compulsory Biomedical Engineering: Specialisation Implants a Biomedical Engineering: Specialisation Medical To Biomedical Engineering: Specialisation Medical To Biomedical Engineering: Specialisation Managem Product Development, Materials and Production: Theoretical Mechanical Engineering: Core qualific	raft Systems: Elective Con cialisation II. Mechatronics alisation Mechatronics: Ele trive Compulsory and Robotics: Elective Cor cial Organs and Regen and Endoprostheses: Elect echnology and Control The ent and Business Adminis Core qualification: Elective complementary Course: Ele cation: Elective Compulsor	npulsory : Elective Compu ective Compu erative Med erative Compulse eory: Elective tration: Elect e Compulsory ctive Compu y	mpulsory Ilsory licine: Elective ory e Compulsory ive Compulsory / lsory	

Course L0702: Nonline	ar Dynamics
Тур	Integrated Lecture
Hrs/wk	4
СР	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.
Literature	S. Strogatz: Nonlinear Dynamics and Chaos. Perseus, 2013.

Module M0803: E	mbedded Syste	ems						
Courses								
Title Embedded Systems (L0805 Embedded Systems (L0806)			Typ Lecture Recitation Section (sr	mall)	Hrs/wk 3 1	CP 4 2	
Module Responsible	Prof. Heiko Falk				-			
Admission Requirements	None							
Recommended Previous Knowledge	Computer Engineering	9						
Educational Objectives	After taking part succ	essfully, student	s have react	ned the following lea	rning I	results		
Professional Competence								
	Embedded systems of products. This course introduction into these (models of computat specification of real-ti	can be defined e teaches the se systems (not ion, hierarchica me applications,	as informa foundations ions, commo l automata, translations	tion processing sys of such systems. on characteristics) a specification of dis between different n	tems In pa nd the stribut nodels	embeddeo rticular, i eir specific ed systen ;).	d into e t deals ation la ns, task	enclosing with an inguages graphs,
Knowledge	Another part covers t capable communica reconfigurable logic a systems, middleware using hardware/softw specifications, energy	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, econfigurable 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 s	olve similar prol	olems alone	or in a group and to	presei	nt the resu	ilts acco	rdingly.
Autonomy	Students are able to with other classes.	acquire new kno	owledge fror	n specific literature	and to	o associate	e this kn	iowledge
Workload in Hours	Independent Study Tir	me 124, Study T	ime in Lectu	re 56				
Credit points	6							
	Compulsor₿onus	Form		Description				
Course achievement	Yes 10 %	Subject the practical work	oretical a	nd				
Examination	Written exam							
Examination duration and scale	90 minutes, contents	of course and la	bs					
Assignment for the Following Curricula	General Engineering Elective Compulsory General Engineering Compulsory Computer Science: Sp Computer Science: Sp Electrical Engineering Engineering Science: Sp Aircraft Systems Engin General Engineering S Compulsory General Engineering Compulsory Computational Science Mechatronics: Special Mechatronics: Special	Science (Gern Science (Gern Decialisation Con Decialisation I. Co Core qualification Specialisation M Decering: Specialis Science (English Science (English	nan program nan program nputer and S omputer and ion: Elective echatronics: isation Avion program, 7 h program, 7 h program, ng: Core qua Design: Elect tt Systems a	n, 7 semester): Sp n, 7 semester): Sp oftware Engineering Software Engineerin Compulsory Elective Compulsory ic Systems: Elective semester): Specialisa 7 semester): Speci lification: Compulsor ive Compulsory nd Robotics: Elective	ecialis ecialis : Elect g: Ele / Comp ation C alisati y comp	sation Con sation Con ive Compu- ctive Com ulsory Computer : on Mecha pulsory	nputer nputer Ilsory pulsory Science: tronics:	Science: Science: Elective Elective

Course L0805: Embedded Systems			
Тур	Lecture		
Hrs/wk	3		
СР	4		
Workload in Hours	Independent Study Time 78, 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. 2nd Edition, Springer, 2012., Springer, 2012. 		

Course L0806: Embedded Systems		
Тур	Recitation Section (small)	
Hrs/wk	1	
СР	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			СР	
Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics) (L0516) Lecture			3	
Markala Bases and the		2	5	
Requirements	None			
	Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics	, Kinematics,	Dynamics)	
Recommended Previous Knowledge	Mathematics I, II, III (in particular differential equations)			
Educational Objectives	After taking part successfully, students have reached the following learning	results		
Professional				
Competence	The students persons on in denth knowledge in acoustics regarding acoust	ic wayor no	ico protoction	
Knowledge	and psycho acoustics and are able to give an overview of the corresponding basis.	theoretical a	nd methodical	
Skills	The students are capable to handle engineering problems in acoustics by the demanding methodologies and measurement procedures treated within	theory-based the module.	application of	
Personal Competence				
Social Competence	Students can work in small groups on specific problems to arrive at joint sol	utions.		
Autonomy	The students are able to independently solve challenging acoustical problems in the areas treat within the module. Possible conflicting issues and limitations can be identified and the results a 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: Specialisation Cabin Systems: 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory			

Course L0516: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)			
Тур	Lecture		
Hrs/wk			
СР			
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Lecturer	Prof. Otto von Estorff		
Language	je 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)		
Тур	Recitation Section (large)	
Hrs/wk	2	
СР	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 M0807: Boundary Element Methods					
Courses					
Title	(10522)		Тур	Hrs/wk	CP
Boundary Element Methods	s (L0523) s (L0524)		Recitation Section (lar	2 ge) 2	3
Module Responsible	Prof. Otto von Estorff				
Admission Requirements	None				
Recommended Previous Knowledge	Mechanics I (Statics, M Mathematics I, II, III (ir	lechanics of Mater particular differer	ials) and Mechanics II (Hydrostantial equations)	atics, Kinematic	s, Dynamics)
Educational Objectives	After taking part succe	essfully, students h	nave reached the following learn	ning results	
Professional Competence					
	The students possess and are able to give an	an in-depth knowle n overview of the t	edge regarding the derivation o heoretical and methodical basis	f the boundary s of the method	element method
Knowledge					
Skills	The students are capa assembling the corres	ble to handle eng ponding system m	ineering problems by formulati atrices, and solving the resultir	ng suitable bou 1g system of eq	ndary elements, uations.
Personal Competence Social Competence	Students can work in s	mall groups on sp	ecific problems to arrive at join	t solutions. nal problems a	nd develop own
Autonomy	boundary element rou	tines. Problems ca	n be identified and the results a	are critically scr	utinized.
Workload in Hours	Independent Study Tin	ne 124, Study Tim	e in Lecture 56		
Credit points	6				
Course achievement	CompulsorBonus	Form Midterm	Description		
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: Technical Complementary Course: Elective Compulsory				

Course L0523: Boundary Element Methods			
Тур	Lecture		
Hrs/wk	2		
СР	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, KJ. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin		

Course L0524: Boundary Element Methods				
Тур	Recitation Section (large)			
Hrs/wk	2			
СР	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 M1143: A	opplied Design Methodology in M	echatronics		
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Courses				
Title Applied Design Methodolog	y in Mechatronics (L1523)	Typ Lecture	Hrs/wk 2	CP 2
Applied Design Methodolog	y 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 proc product design techniques	uct design considering tar	geted applica	ation of specific
Skills	Creative handling of processes used for scien design problems / Application of various product	tific preparation and form design techniques followir	ulation of cong theoretica	omplex product l 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			
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 Anagement and Engineering: Specialisation System Design: Elective Compulsory Mechanical Engineering and Management: Specialisation System Design: Ele Biomedical Engineering: Specialisation Artific Compulsory Biomedical Engineering: Specialisation Implants Biomedical Engineering: Specialisation Medical Biomedical Engineering: Specialisation Manager Theoretical Mechanical Engineering: Specialisation Manager Theoretical Mechanical Engineering: Specialisation Manager Theoretical Mechanical Engineering: Technical Compulsory	pecialisation II. Product De cialisation II. Mechatronics pecialisation Product Dev ctive Compulsory cial Organs and Regene and Endoprostheses: Elect Fechnology and Control The nent and Business Administ ation Product Developmer omplementary Course: Fle	evelopment a : Elective Convelopment a erative Med ive Compulse eory: Elective tration: Elect int and Productive Compute	and Production: mpulsory nd Production: icine: Elective ory compulsory ive Compulsory uction: Elective

Course L1523: Applied Design Methodology in Mechatronics		
Тур	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, preferencematrix, 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) Prosentation-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, KH.: Konstruktionslehre: Grundlage erfolgreicher Produktentwicklung, Methoden und Anwendung, 7. Auflage, Springer Verlag, Berlin 2007 VDI-Richtlinien: 2206; 2221ff 	
	l	

Course L1524: Applied Design Methodology in Mechatronics	
Тур	Project-/problem-based Learning
Hrs/wk	3
СР	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 M1156: S	Systems Engineering			
Courses				
Title Systems Engineering (L154 Systems Engineering (L154	7) 8)	Typ Lecture Recitation Section (large)	Hrs/wk 3 1	CP 4 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 reac	hed 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 comple • organize the development phases and developm • assign required business activities and technica • apply systems engineering methods and tools	x Systems nent Tasks I Tasks		
Personal Competence				
Social Competence	Students are able to: • understand their responsibilities within a develo in the overall process	pment team and integrate	e themselves	with their role
Autonomy	Students are able to: • interact and communicate in a development tea	m which has distributed to	asks	
Workload in Hours	Independent Study Time 124, Study Time in Lectu	ıre 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: O International Management and Engineering: Speci International Management and Engineering: Speci Elective Compulsory Mechatronics: Specialisation System Design: Elect Mechatronics: Specialisation Intelligent Systems a Product Development, Materials and Production: S Product Development, Materials and Production: S Product Development, Materials and Production: S Product Development, Materials and Production: S Theoretical Mechanical Engineering: Technical Co Theoretical Mechanical Engineering: Specialisation	Compulsory ialisation II. Aviation Syste ecialisation II. Product De- tive Compulsory and Robotics: Elective Com Specialisation Product Dev Specialisation Production: I Specialisation Materials: El mplementary Course: Elec n Aircraft Systems Engined	ms: Elective velopment a elopment: Co Elective Compo ective Compus ering: Elective	Compulsory nd Production: ompulsory pulsory ulsory sory e Compulsory

Course L1547: Systems Engineering		
Тур	Lecture	
Hrs/wk	3	
СР	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 (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	
Тур	Recitation Section (large)
Hrs/wk	1
СР	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

Specific Regulation	ons)	
Courses		
Title	Typ Hrs/wk	СР
Module Responsible	Prof. Uwe Weltin	
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	see selected module according to FSPO	
Social Competence 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		Тур	Hrs/wk	СР
Applied Automation (L1592)	Project-/problem-based	3	3
Development Management	for Mechatronics (L1512)	Lecture	2	3
Fatigue & Damage Tolerand	ce (L0310)	Lecture	2	3
Industry 4.0 for engineers (L2012)	Lecture	2	3
Microcontroller Circuits: Imp	plementation in Hardware and Software (L0087)	Seminar	2	2
Microsystems Technology (L0724)	Lecture	2	4
Model-Based Systems Engir	neering (MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Process Measurement Engin	neering (L1077)	Lecture	2	3
Process Measurement Engin	neering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medica	l Technology (L0664)	Lecture	2	3
Six Sigma (L1130)		Lecture	2	3
Applied Dynamics (L1630)		Lecture	2	3
Reliability in Engineering D	ynamics (L0176)	Lecture	2	2
Reliability in Engineering D	ynamics (L1303)	Recitation Section (small)	1	2
Module Responsible	Prof. Uwe Weltin			
Admission Requirements	None			
Recommended Previous Knowledge	None			
Educational Objectives	After taking part successfully, students have re	eached the following learning	results	
Professional Competence				
Knowledge	 Students are able to express their exter special fields or application areas of med Students are qualified to connect differe 	nded knowledge and discuss chatronics nt special fields with each ot	the connec her	tion of different
Skills	 Students can apply specialized solution s Students are able to transfer learned sk solution approaches 	strategies and new scientific ills to new and unknown prol	methods in blems and c	selected areas an develop own
Personal Competence				
Social Competence	None			
Jocial Competence				
Autonomy	 Students are able to develop their knowledge 	ledge and skills by autonome	ous election	of courses.
Workload in Hours	Depends on choice of courses			
Credit points	12			
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: El Mechatronics: Specialisation Intelligent System	lective Compulsory is and Robotics: Elective Com	npulsorv	

Course L1592: Applied Automation		
Тур	Project-/problem-based Learning	
Hrs/wk	3	
СР	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 L1512: Develop	ment Management for Mechatronics	
Тур	Lecture	
Hrs/wk	2	
СР	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Examination Form	Mündliche Prüfung	
Examination duration and scale	30 Minuten	
Lecturer	Dr. Daniel Steffen	
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
Тур	Lecture
Hrs/wk	2
СР	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	
Тур	Lecture
Hrs/wk	2
СР	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		
Тур	Seminar	
Hrs/wk	2	
СР	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		
ATmega16A 8-bit Microcontroller with 16K Bytes In-System Programmable Flash - DATASH Literature Atmel AVR 8-bit Instruction Set Instruction Set Manual, Atmel Corporation 2016		

Course L0724: Microsy	stems Technology				
Тур	Lecture				
Hrs/wk	2				
СР	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 Technologues (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) Etching and Bulk Micromachning (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, RLF, Bosch process, Xref 2 etching) Surface Micromachning 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; modulating sensors: pizoresistive, capacitive and fabrication process) Mechanical Sensors (strain based and stress based principle, capacitive readout, 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, principle of biosensor, Clark electrode, enzyme electroda, DNA chip)				
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		
Тур	Project-/problem-based Learning	
Hrs/wk	3	
СР	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 L1083: Process Measurement Engineering		
Тур	Recitation Section (large)	
Hrs/wk	1	
СР	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: Feedbac	ck Control in Medical Technology			
Тур	Lecture			
Hrs/wk	2			
СР	3			
Workload in Hours	ndependent 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 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. 			

Course L1130: Six Sigma					
Тур	Lecture				
Hrs/wk	2				
СР	3				
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28				
Examination Form	Klausur				
Examination duration and scale	90 Minuten				
Lecturer	Prof. Claus Emmelmann				
Language	DE				
Cycle	WiSe				
Content	 Introduction and structuring Basic terms of quality management Measuring and inspection equipment Tools of quality management: FMEA, QFD, FTA, etc. Quality management methodology Six Sigma, DMAIC 				
Literature	Pfeifer, T.: Qualitätsmanagement : Strategien, Methoden, Techniken, 4. Aufl., München 2008 Pfeifer, T.: Praxishandbuch Qualitätsmanagement, München 1996 Geiger, W., Kotte, W.: Handbuch Qualität : Grundlagen und Elemente des Qualitätsmanagements: Systeme, Perspektiven, 5. Aufl., Wiesbaden 2008				

Course L1630: Applied Dynamics				
Тур	Lecture			
Hrs/wk	2			
СР	3			
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28			
Examination Form	Klausur			
Examination duration and scale	90 min			
Lecturer	Prof. Robert Seifried			
Language	DE			
Cycle	SoSe			
Content	 Modelling of Multibody Systems Basics from kinematics and kinetics Constraints Multibody systems in minimal coordinates State space, linearization and modal analysis Multibody systems with kinematic constraints Multibody systems as DAE Non-holonomic multibody systems 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.			

Course L0176: Reliability in Engineering Dynamics		
Тур	Lecture	
Hrs/wk	2	
СР	2	
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28	
Examination Form	Klausur	
Examination duration and scale	90 min.	
Lecturer	Prof. Uwe Weltin	
Language	EN	
Cycle	SoSe	
Content	 Method for calculation and testing of reliability of dynamic machine systems Modeling System identification Simulation Processing of measurement data Damage accumulation Test planning and execution 	
Literature	Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540- 33969-4 Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737 Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936. VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412	

Course L1303: Reliability in Engineering Dynamics		
Тур	Recitation Section (small)	
Hrs/wk	1	
СР	2	
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14	
Examination Form	Klausur	
Examination duration and scale	90 min	
Lecturer	Prof. Uwe Weltin	
Language	EN	
Cycle	SoSe	
Content	See interlocking course	
Literature	See interlocking course	

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

Courses				
Title		Тур	Hrs/wk	СР
Applied Automation (L1592)		Project-/problem-based Learning	3	3
Development Management for Mechatronics (L1512)		Lecture	2	3
Fatigue & Damage Tolerand	ce (L0310)	Lecture	2	3
Industry 4.0 for engineers (L2012)	Lecture	2	3
Microcontroller Circuits: Imp	plementation in Hardware and Software (L0087)	Seminar	2	2
Microsystems Technology (L0724)		Lecture	2	4
Model-Based Systems Engir	neering (MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Process Measurement Engin	neering (L1077)	Lecture	2	3
Process Measurement Engir	neering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medica	ıl Technology (L0664)	Lecture	2	3
Six Sigma (L1130)		Lecture	2	3
Applied Dynamics (L1630)		Lecture	2	3
Reliability in Engineering Dy	ynamics (L0176)	Lecture	2	2
Reliability in Engineering Dy	ynamics (L1303)	Recitation Section (small)	1	2
Module Responsible	Prof. Uwe Weltin			
Admission Requirements	ssion _{None}			
Recommended Previous Knowledge	mended owledge			
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: Ele Mechatronics: Specialisation Intelligent Systems	ective Compulsory and Robotics: Elective Com	pulsory	

Course L1512: Develop	ment Management for Mechatronics
Тур	Lecture
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 Minuten
Lecturer	Dr. Daniel Steffen
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	
Тур	Lecture
Hrs/wk	2
СР	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	
Тур	Lecture
Hrs/wk	2
СР	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	
Тур	Seminar
Hrs/wk	2
СР	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: Microsy	stems Technology
Tvp	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 Technologues (thermal oxidation, opitaxy, 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 undercuting, measures for compensation and etch-stop techniques; plasma processes, dry etching: back sputtering, plasma etching, RE, 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, SUB, arpid 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, NIC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, R sensor: thermopile and bolometer) Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistive, piezoresistive, capacitive; angular rate sensor: operating principle and fabrication process) Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transitor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer) Chemical and Bio Sensors (thermal gas sensors; pellistor and thermal conductivity sensor; metal axide semiconductor gas sensor, principle of biosensor, Clark electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, mi
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	
Тур	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 L1077: Process	s Measurement Engineering
Тур	Lecture
Hrs/wk	¢2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 Minuten
Lecturer	r Prof. Roland Harig
Language	DE/EN
Cycle	a 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	
Тур	Recitation Section (large)
Hrs/wk	1
СР	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	
Тур	Lecture
Hrs/wk	2
СР	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.

Course L1130: Six Sigma	
Тур	Lecture
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Prof. Claus Emmelmann
Language	DE
Cycle	WiSe
Content	 Introduction and structuring Basic terms of quality management Measuring and inspection equipment Tools of quality management: FMEA, QFD, FTA, etc. Quality management methodology Six Sigma, DMAIC
Literature	Pfeifer, T.: Qualitätsmanagement : Strategien, Methoden, Techniken, 4. Aufl., München 2008 Pfeifer, T.: Praxishandbuch Qualitätsmanagement, München 1996 Geiger, W., Kotte, W.: Handbuch Qualität : Grundlagen und Elemente des Qualitätsmanagements: Systeme, Perspektiven, 5. Aufl., Wiesbaden 2008

Course L1630: Applied Dynamics	
Тур	Lecture
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Robert Seifried
Language	DE
Cycle	SoSe
Content	 Modelling of Multibody Systems Basics from kinematics and kinetics Constraints Multibody systems in minimal coordinates State space, linearization and modal analysis Multibody systems with kinematic constraints Multibody systems as DAE Non-holonomic multibody systems 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.

Course L0176: Reliability in Engineering Dynamics	
Тур	Lecture
Hrs/wk	2
СР	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 min.
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	 Method for calculation and testing of reliability of dynamic machine systems Modeling System identification Simulation Processing of measurement data Damage accumulation Test planning and execution
Literature	Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540- 33969-4 Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737 Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936. VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412

Course L1303: Reliabili	ourse L1303: Reliability in Engineering Dynamics				
Тур	Recitation Section (small)				
Hrs/wk	1				
СР	2				
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14				
Examination Form	Klausur				
Examination duration and scale	90 min				
Lecturer	Prof. Uwe Weltin				
Language	EN				
Cycle	SoSe				
Content	See interlocking course				
Literature	See interlocking course				

Module M1306: C	Conti	rol Lab C							
Courses									
Title Control Lab IX (L1836) Control Lab VII (L1834) Control Lab VIII (L1835)					Typ Practical Course Practical Course Practical Course	Hrs 1 1 1	5/wk	CP 1 1 1	
Module Responsible	Prof.	Herbert Werner							
Admission Requirements	None								
Recommended Previous Knowledge	•	State space m LQG control H2 and H-infin uncertain plan LPV control	ethods ity optimal o t models an	control d robust contr	ol				
Educational Objectives	After	taking part suc	cessfully, stu	udents have re	eached the following le	earning resu	ılts		
Professional Competence									
Knowledge	•	Students can experimental	explain the validation	e difference b	etween validation of	f a control	lop in	simulation	and
Skills	•	Students are of Toolbox) to ide They are capa implementation They are cap mixed-sensitiv They are cap robust control They are cap design and the	capable of a entify a dyna ible of using in of LQG co able of usir ity design a able of repu ler able of usir e implement	pplying basic s amic model that standard soft introllers ing standard soft resenting mod ing standard so tation of LPV ga	system identification at can be used for cor tware tools (Matlab C oftware tools (Matlab entation of H-infinity lel uncertainty, and oftware tools (Matlab ain-scheduled control	tools (Matla ntroller syntl ontrol Toolb Robust Co optimal con of designing Robust Co lers	b Systenesis ox) for ontrol Tr trollers g and i ontrol Tr	m Identifica the design bolbox) for implementir bolbox) for	ation and the ng a the
Personal Competence									
Social Competence	•	Students can	work in tean	ns to conduct e	experiments and docu	iment the re	sults		
Autonomy	•	Students can i	ndependent	tly carry out si	mulation studies to de	esign and va	lidate o	control loops	5
Workload in Hours	Indep	endent Study T	ime 48, Stu	dy Time in Lec	ture 42				
Credit points	3								
Course achievement	None								
Examination	Writte	en elaboration							
Examination duration and scale	1								
Assignment for the Following Curricula	Electr Mech Mech Theor Theor	ical Engineering atronics: Specia atronics: Specia retical Mechanic retical Mechanic	g: Specialisa Ilisation Inte Ilisation Syst al Engineer al Engineer	ation Control an elligent System tem Design: El ing: Core quali ing: Technical	nd Power Systems Eng s and Robotics: Electi ective Compulsory fication: Elective Com Complementary Cour	gineering: E ve Compuls pulsory se: Elective	lective ory Compu	Compulsory Isory	,

Course L1836: Control Lab IX				
Тур	Practical Course			
Hrs/wk	1			
СР	1			
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14			
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar			
Language	EN			
Cycle	WiSe/SoSe			
Content	One of the offered experiments in control theory.			
Literature	Experiment Guides			

Course L1834: Control	ourse L1834: Control Lab VII				
Тур	Practical Course				
Hrs/wk	1				
СР	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	Course	L1835:	Control	Lab VIII	
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Тур	Practical Course
Hrs/wk	1
СР	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

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Module M1269: L	ab Cyber-Physical Systems			
Courses				
Title		Тур	Hrs/wk	СР
Lab Cyber-Physical Systems	s (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 reac	hed the following learning	results	
Professional				
competence	Cyber-Physical Systems (CPS) are tightly integrat A/D and D/A converters, and actors. Due to the sensors, processors and actors are common. specification approaches for CPS - in contrast to classed on practical experiments using robot king modelling of CPS are taught. The lab introdu	ted with their surrounding neir particular application Accordingly, there is a lassical software engineering ts and computers, the burges into the area (basi	environmer areas, higi large variet ing approact pasics of sp	nt, via sensors, hly specialized ty of different nes. ecification and characteristical
Knowledge	^e properties) and their specification techniques (models of computation, hierarchical automata, da flow models, petri nets, imperative approaches). Since CPS frequently perform control tasks, the lal experiments will base on simple control applications. The experiments will use state-of-the- industrial specification tools (MATLAB/Simulink, LabVIEW, NXC) in order to model cyber-physic models that interact with the environment via sensors and actors.			
Skills	After successful attendance of the lab, students a interdependencies between a CPS and its surrour interacts with the environment via sensors, A/D actors. The lab enables students to compare moc limitations, and to decide which technique to use techniques to practical problems. They obtai development, in industry-relevant specification to	are able to develop simple nding processes which ste converters, digital proce delling approaches, to eva for a concrete task. They n first experiences in ols and in the area of simp	CPS. They of m from the essors, D/A of luate their a will be able hardware-re ole control ap	understand the fact that a CPS converters and idvantages and to apply these lated software pplications.
Personal Competence				
Social Competence	Students are able to solve similar problems alone	or in a group and to prese	nt the result	s accordingly.
Autonomy	Students are able to acquire new knowledge fror with other classes.	n specific literature and to	o associate i	this knowledge
Workload in Hours	Independent Study Time 124, Study Time in Lectu	ire 56		
Credit points	6			
Course achievement	None			
Examination	Written elaboration			
Examination duration and scale	Execution and documentation of all lab experimer	nts		
Assignment for the Following Curricula	General Engineering Science (German program Elective Compulsory Computer Science: Specialisation Computer and S Computer Science: Specialisation II. Mathematics General Engineering Science (English program, 7 Compulsory Computational Science and Engineering: Specialis Compulsory Computational Science and Engineering: Specialis Mechatronics: Specialisation Intelligent Systems a Mechatronics: Specialisation System Design: Elect Mechatronics: Technical Complementary Course	n, 7 semester): Speciali ioftware Engineering: Elect and Engineering Science: semester): Specialisation (vation II. Mathematics & En vation Computer Science: E nd Robotics: Elective Com Live Compulsory Elective Compulsory	sation Com tive Compute Elective Com Computer So igineering So Elective Com pulsory	puter Science: sory npulsory cience: Elective cience: Elective ipulsory

Course L1740: Lab Cyb	er-Physical Systems
Тур	Project-/problem-based Learning
Hrs/wk	4
СР	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. 2nd Edition, Springer, 2012. Begleitende Foliensätze

Module M1281: A	Advanced Topics in Vibration	I			
Courses					
Title		Тур	Hrs/wk	СР	
Advanced Topics in Vibration (L1743)Project-/problem-based Learning46			6		
Module Responsible	Prof. Norbert Hoffmann				
Admission Requirements	None				
Recommended Previous Knowledge	Vibration Theory				
Educational Objectives	After taking part successfully, students h	ave reached the following learning	g results		
Professional Competence					
Knowledge	Students are able to reflect existing terms and concepts of Advanced Vibrations and to develop and research new terms and concepts.				
Skills	Students are able to apply existing methods and procesures of Advanced Vibrations and to develop novel methods and procedures.				
Personal Competence					
Social Competence	Students can reach working results also in gr	oups.			
Autonomy	Students are able to approach given research tasks individually and to identify and follow up novel research tasks by themselves.				
Workload in Hours	Independent Study Time 124, Study Time	e 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory				

Course L1743: Advanced Topics in Vibration				
Тур	Project-/problem-based Learning			
Hrs/wk	4			
СР	6			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Lecturer	ecturer Prof. Norbert Hoffmann, Merten Tiedemann, Sebastian Kruse			
Language	Language DE/EN			
Cycle	SoSe			
Content	Research Topics in Vibrations.			
Literature	Aktuelle Veröffentlichungen			

Module M0835: H	lumanoid R	lobotics				
Courses						
Title Humanoid Robotics (L0663)				Typ Seminar	Hrs/wk 2	CP 2
Module Responsible	Patrick Göttsch					
Admission Requirements	None					
Recommended Previous Knowledge	IntroductControl t	tion to control s heory and desi	systems ign			
Educational Objectives	After taking pa	rt successfully,	students ha	we reached the following	learning results	
Professional Competence						
Knowledge	StudentsStudents	s can explain hu s learn to apply	umanoid rot v basic contr	oots. ol concepts for different t	asks in humanoid r	obotics.
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 St	udy Time 32, S	Study Time i	n Lecture 28		
Credit points	2					
Course achievement	None					
Examination	Presentation					
examination duration and scale	30 min					
Assignment for the Following Curricula	Mechatronics: S Mechatronics: S Biomedical Err Compulsory Biomedical Eng Biomedical Eng Biomedical Eng Theoretical Mec Theoretical Mec Compulsory	Iechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Iechatronics: Specialisation System Design: Elective Compulsory iomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective compulsory iomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory iomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory iomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory heoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory heoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory				

Course L0663: Humand	id Robotics
Тур	Seminar
Hrs/wk	2
СР	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: L	inear and Nonlinear S	ystem Identifikation		
Courses				
Title		Тур	Hrs/wk	СР
Linear and Nonlinear System	m Identification (L0660)	Lecture	2	3
Module Responsible	Prof. Herbert Werner			
Admission Requirements	None			
Recommended Previous Knowledge	 Classical control (frequence State space methods Discrete-time systems Linear algebra, singular va Basic knowledge about state 	cy response, root locus) alue decomposition ochastic processes		
Educational Objectives	After taking part successfully, st	udents have reached the following le	arning 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 a of linear and nonlinear mo They are capable of imp network model They are capable of appl models for dynamic syste They can do the above us Toolbox) 	pplying the predicition error method odels for dynamic systems lementing a nonlinear predictive co lying subspace algorithms to the ex ms ing standard software tools (includin	to the experiment ontrol scheme bas perimental identif g the Matlab Syste	al identificatior ed on a neura ication of linea m Identificatior
Personal Competence				
Social Competence	Students can work in mixed grou	ups on specific problems to arrive at j	joint solutions.	
Autonomy	Students are able to find requir documentation) and use it to sol	ed information in sources provided (ve given problems.	lecture notes, lite	rature, software
Workload in Hours	Independent Study Time 62, Stu	dy 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: Specialisa Mechatronics: Specialisation Inter Mechatronics: Specialisation Sys Biomedical Engineering: Speciali Biomedical Engineering: Speciali Biomedical Engineering: Speciali Biomedical Engineering: Speciali Theoretical Mechanical Engineer Theoretical Mechanical Engineer	ation Control and Power Systems Eng elligent Systems and Robotics: Electiv tem Design: Elective Compulsory ialisation Artificial Organs and F isation Implants and Endoprostheses isation Medical Technology and Contri isation Management and Business Ac ing: Technical Complementary Cours ing: Core gualification: Elective Comp	ineering: Elective ve Compulsory Regenerative Mec : Elective Compuls rol Theory: Compul iministration: Elect se: Elective Compu pulsory	Compulsory licine: Elective ory lsory ive Compulsory lsory

Course L0660: Linear and Nonlinear System Identification		
Тур	Lecture	
Hrs/wk	2	
СР	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: C	Control Lab A			
Courses				
Title		Тур	Hrs/wk	СР
Control Lab I (L1093)		Practical Course	1	1
Control Lab II (L1291)		Practical Course	1	1
Control Lab III (L1665)		Practical Course	1	1
		Practical Course	T	T
Module Responsible	Prof. Herbert Werner			
Requirements	None			
Recommended Previous Knowledge	 State space methods LQG control H2 and H-infinity optimal control uncertain plant models and robust co LPV control 	ntrol		
Educational Objectives	After taking part successfully, students have	e reached the following learn	ing results	
Professional				
Competence				
Knowledge	 Students can explain the difference experimental validation 	e between validation of a	control lop in	simulation and
Skills	 Students are capable of applying bas Toolbox) to identify a dynamic model They are capable of using standard s implementation of LQG controllers They are capable of using standard mixed-sensitivity design and the impl They are capable of representing m robust controller They are capable of using standard design and the implementation of LPN 	ic system identification tools that can be used for controll software tools (Matlab Contr I software tools (Matlab Rol ementation of H-infinity option hodel uncertainty, and of d I software tools (Matlab Rol / gain-scheduled controllers	6 (Matlab Syste ler synthesis ol Toolbox) for bust Control Tr mal controllers esigning and i bust Control Tr	m Identification the design and polbox) for the mplementing a polbox) for the
Personal Competence	1			
Social Competence	• Students can work in teams to conduc	ct experiments and documer	nt the results	
Autonomy	Students can independently carry out	simulation studies to design	and validate o	control loops
Workload in Hours	Independent Study Time 64, Study Time in L	ecture 56		
Credit points	4			
Course achievement	None			
Examination	Written elaboration			
Examination duration and scale	1			
Assignment for the Following Curricula	Electrical Engineering: Specialisation Contro Mechatronics: Specialisation System Design Mechatronics: Specialisation Intelligent Syste Theoretical Mechanical Engineering: Technic Theoretical Mechanical Engineering: Spe Compulsory	I and Power Systems Engine : Elective Compulsory ems and Robotics: Elective C :al Complementary Course: E ecialisation Robotics and	ering: Elective Compulsory Elective Compu Computer Sc	Compulsory Isory ience: Elective

Course L1093: Control Lab I	
Тур	Practical Course
Hrs/wk	1
СР	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
	Experiment Guides
Literature	

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

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

Course L1666: Control	Course L1666: Control Lab IV			
Тур	Practical Course			
Hrs/wk	1			
СР	1			
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14			
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar			
Language	EN			
Cycle	WiSe/SoSe			
Content	One of the offered experiments in control theory.			
Literature	Experiment Guides			
Module M0924: S	oftware for Embedded Systems			
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Courses				
Title Software for Embdedded Sy Software for Embdedded Sy	/stems (L1069) /stems (L1070)	Typ Lecture Recitation Section (small)	Hrs/wk 2 3	CP 3 3
Module Responsible	Prof. Bernd-Christian Renner			
Admission Requirements	None			
Recommended Previous Knowledge	 Good knowledge and experience in programming language C Basis knowledge in software engineering Basic understanding of assembly language 			
Educational Objectives	After taking part successfully, students have rea	iched 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	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 Information and Communication Systems: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: 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: Softwar	e for Embdedded Systems
Тур	Lecture
Hrs/wk	2
СР	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	 Embedded System Design, F. Vahid and T. Givargis, John Wiley Programming Embedded Systems: With C and Gnu Development Tools, M. Barr and A. Massa, O'Reilly C und C++ für Embedded Systems, F. Bollow, M. Homann, K. Köhn, MITP The Art of Designing Embedded Systems, J. Ganssle, Newnses Mikrocomputertechnik mit Controllern der Atmel AVR-RISC-Familie, G. Schmitt, Oldenbourg Making Embedded Systems: Design Patterns for Great Software, E. White, O'Reilly

Course L1070: Software for Embdedded Systems		
Тур	Recitation Section (small)	
Hrs/wk	3	
СР	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 M0840: C	Optimal and Robust Control			
Courses				
Title Optimal and Robust Control	I (L0658)	Typ Lecture Recitation Section (small)	Hrs/wk 2 2	CP 3
Medule Responsible	Prof. Harbort Warper	Recitation Section (Smail)	2	5
Admission	None			
Recommended Previous Knowledge	 Classical control (frequency response, State space methods Linear algebra, singular value decomp 	root locus) osition		
Educational Objectives	After taking part successfully, students have	reached the following learning	results	
Professional Competence				
Knowledge	 Students can explain the significance problems. They can explain the duality between They can explain how the H2 and performance constraints. They can explain how an LQG design performance. They can explain how model uncertai controller design They can explain how - based on the stability and performance for an uncer They understand how analysis and sy as linear matrix inequalities. 	e of the matrix Riccati equat optimal state feedback and opt H-infinity norms are used problem can be formulated as s nty can be represented in a wa e small gain theorem - a robus tain plant. nthesis conditions on feedback	tion for the timal state e to represer special case ay that lends st controller k loops can	solution of LQ estimation. It stability and of an H2 design itself to robust can guarantee be represented
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	c problems to arrive at joint sol	utions.	
	Students are able to find required information	on in sources provided (lecture	e notes, liter	rature, software
Autonomy	documentation) and use it to solve given pro	blems.		
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: Specialisation Aircraft Systems: 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory

Course L0658: Optimal	and Robust Control
Тур	Lecture
Hrs/wk	2
СР	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		
Тур	Recitation Section (small)	
Hrs/wk	2	
СР	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 M1248: C	Compilers for Embedded Systems			
Courses				
Title Compilers for Embedded Sy	vstems (L1692)	Typ Lecture	Hrs/wk 3	CP 4
Compilers for Embedded Sy	vstems (L1693)	Project-/problem-based Learning	1	2
Module Responsible	Prof. Heiko Falk			
Admission Requirements	None			
 	Module "Embedded Systems"			
Recommended Previous Knowledge	C/C++ Programming skills			
Educational Objectives	After taking part successfully, students have reach	ned the following learning	results	
Professional Competence				
	The relevance of embedded systems increases fro software to be executed on embedded process higher flexibility. Because of the particular applic and application-specific processors are deployed demands on compilers which have to generate co of this course, the students are able • to illustrate the structure and organization of	om year to year. Within su ors grows continuously of ation areas of embedded d. Such highly specialize de of highest quality. Afte of such compilers,	uch systems, due to its lo systems, hi ed processor or the succes	the amount of ower costs and ghly optimized rs impose high sful attendance
	 to distinguish and explain intermediate representations of various abstraction levels, and to assess optimizations and their underlying problems in all compiler phases. 			
Knowledge	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 worst-case execution time, energy dissipation, co of optimizations on these different criteria.	e to optimize for multiple (de size), the students lea	objectives (e rn to evaluat	.g., average- or e the influence
Skills	After successful completion of the course, studen into machine code. They will be enabled to asses most effectively at which abstraction level (e.g., s	ts shall be able to transla s which kind of code opt ource or assembly code) v	ate high-leve imization sho within a com	l program code ould be applied piler.
	While attending the labs, the students will learn optimizations.	n to implement a fully fu	nctional con	npiler including
Personal Competence				
Social Competence	Students are able to solve similar problems alone	or in a group and to prese	ent the result	ts accordingly.
Autonomy	Students are able to acquire new knowledge fror with other classes.	n specific literature and t	o associate	this knowledge
Workload in Hours	Independent Study Time 124, Study Time in Lectu	re 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: Specialisation Avionic Systems: 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory		ulsory Compulsory sory ence: Elective	

Course L1692: Compile	ers for Embedded Systems
Тур	Lecture
Hrs/wk	3
СР	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. 2nd Edition, Springer, 2012. Steven S. Muchnick. Advanced Compiler Design and Implementation. Morgan Kaufmann, 1997. Andrew W. Appel. Modern compiler implementation in C. Oxford University Press, 1998.

Course L1693: Compilers for Embedded Systems		
Тур	Project-/problem-based Learning	
Hrs/wk	1	
СР	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	

E

Module M1400: D	Design of Depen	dable Systems			
Courses					
Title			Тур	Hrs/wk	СР
Designing Dependable Syst Designing Dependable Syst	ems (L2000) ems (L2001)		Lecture Recitation Section (small)	2 2	3 3
Module Responsible	Prof. Görschwin Fey				
Admission Requirements	None				
Recommended Previous Knowledge	Basic knowledge about	data structures and alg	orithms		
Educational Objectives	After taking part succe	ssfully, students have re	ached the following learning	results	
Professional Competence					
	In the following "deper and Security.	ndable" summarizes the	concepts Reliability, Availab	ility, Mainta	inability, Safety
	Knowledge about appro	oaches for designing dep	pendable systems, e.g.,		
Knowledge	 Structural solutions like modular redundancy Algorithmic solutions like handling byzantine faults or checkpointing 				
	Knowledge about meth	ods for the analysis of d	ependable 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					
	Students				
Social Competence	 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 Tim	ne 124, Study Time in Le	cture 56		
Credit points	6				
Course achievement	Compulsor B onus Yes None	Form Subject theoretical practical work	Description Die Lösung of Zuslassungsvoraussetz Aufgabe wird in Vorles	einer A zung für di ung und Üb	Aufgabe ist e Prüfung. Die ung definiert.
Examination	Oral exam				
Examination duration and scale	30 min				
Assignment for the Following Curricula	Computer Science: Spe Computational Science Information and Comm Compulsory Mechatronics: Specialis Microelectronics and M	ecialisation I. Computer a and Engineering: Specia nunication Systems: Spe sation System Design: El icrosystems: Specialisat	and Software Engineering: Ele alisation I. Computer Science cialisation Secure and Deper ective Compulsory ion Embedded Systems: Flec	ective Comp : Elective C ndable IT Sy	oulsory ompulsory ystems: Elective lsory

Course L2000: Designin	ng Dependable Systems
Тур	Lecture
Hrs/wk	2
СР	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	Analysis Techniques

Course L2001: Designing Dependable Systems		
Тур	Recitation Section (small)	
Hrs/wk	2	
СР	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	

E.

Module M1340: Compatibility	Introduction to Waveguides, Antennas, and Electromagnetic	
Courses		
Title Introduction to Waveguides Introduction to Waveguides	TypHrs/wkCP5, Antennas, and Electromagnetic Compatibility (L1669)Lecture346, Antennas, and Electromagnetic Compatibility (L1877)Recitation Section (small)22	
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 Skills	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 - Steady-state sinusoidal description 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 - 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 Compatibility to the	
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	b None	
Evamination		
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 Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory	

Course L1669: Introduc	ction to Waveguides, Antennas, and Electromagnetic Compatibility	
Тур	Lecture	
Hrs/wk	3	
СР	4	
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42	
Lecturer	Prof. Christian Schuster	
Language	E/EN	
Cycle	SoSe	
	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.	
Content	 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 Nost 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		
Тур	Recitation Section (small)	
Hrs/wk	2	
СР	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: M	lachine Learning and Data Mi	ning		
Courses				
Title	Mining (10240)	Typ	Hrs/wk	CP 4
Machine Learning and Data	Mining (L0540) Mining (L0510)	Recitation Section (small)	2	4 2
Module Responsible	NN			
Admission	Nana			
Requirements				
Recommended Previous Knowledge	CalculusStochastics			
Educational Objectives	After taking part successfully, students hav	e reached the following learning	results	
Professional Competence				
Knowledge	Students can explain the difference betwee and they can enumerate basic machine leither on the basis of static data, or on the uncertainty, students can describe suitable features, parameters, or structures used different algorithms. Students are also able the performance of learned classifiers of summarize how this influences computation can also be explained by students.	een instance-based and model-t learning technique for each of ne basis of incrementally incom e representation formalisms, and in these formalisms can be to sketch different clustering te can be improved by ensembli- onal learning theory. Algorithms	based learni the two bas ing data . F d they expla learned aut echniques. T e learning, for reinforc	ng approaches sic approaches or dealing with in how axioms omatically with hey depict how and they car ement learning
Skills	Student derive decision trees and, in turn, and are able to name and explain basic opt of first-order inductive leaning. Students parameters of Bayesian networks and com out Gaussian mixture learning. They can co machines, and name their basic application basic clustering techniques and explain the related machine learning techniques, e.g They can distinguish various ensemble leas techniques.	, propositional rule sets from sir imization techniques. They prese apply the BME, MAP, ML, and pare the different algorithms. The ontrast kNN classifiers, neural ne on areas and algorithmic proper e basic components of those tec ., k-means clustering and near irning techniques and compare	mple and sta ent and appl EM algorithin ney also kno etworks, and ties. Studen hniques. Stu est neighbo the different	atic data tables y the basic ide ms for learning w how to carry support vecto ts can describe idents compare r classification goals of those
Personal Competence				
Social Competence				
Autonomy				
Workload in Hours	Independent Study Time 124, Study Time in	n 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: Intellig International Management and Engineer Compulsory Mechatronics: Technical Complementary Co Mechatronics: Specialisation Intelligent Sys Mechatronics: Specialisation System Design Theoretical Mechanical Engineering: Techni Theoretical Mechanical Engineering: Sp Compulsory	ence Engineering: Elective Comp ring: Specialisation II. Informa purse: Elective Compulsory tems and Robotics: Elective Com 1: Elective Compulsory ical Complementary Course: Elec pecialisation Robotics and Co	oulsory tion Techno apulsory tive Compu mputer Sci	ology: Elective Isory ence: Elective

Course L0340: Machine	Learning and Data Mining
Тур	Lecture
Hrs/wk	2
СР	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 Theory
Literature	 Artificial Intelligence: A Modern Approach (Third Edition), Stuart Russel, Peter Norvig, Prentice Hall, 2010, Chapters 13, 14, 18-21 Machine Learning: A Probabilistic Perspective, Kevin Murphy, MIT Press 2012

ourse L0510: Machine Learning and Data Mining		
Recitation Section (small)		
2		
ndependent Study Time 32, Study Time in Lecture 28		
lainer Marrone		
EN		
SoSe		
See interlocking course		
See interlocking course		

Module M0603: N	Ionlinear Structural Analysi	5		
Courses				
Title Nonlinear Structural Analys Nonlinear Structural Analys	is (L0277) is (L0279)	Typ Lecture Recitation Section (small)	Hrs/wk 3 1	CP 4 2
Module Responsible	Prof. Alexander Düster			
Admission Requirements	None			
Recommended Previous Knowledge	Knowledge of partial differential equation	ns is recommended.		
Educational Objectives	After taking part successfully, students h	nave reached the following learning	results	
Professional Competence				
Knowledge	Students are able to + give an overview of the different nonli + explain the mechanical background of + to specify problems of nonlinear stru explain their mathematical and mechani	near phenomena in structural mech nonlinear phenomena in structural uctural analysis, to identify them in cal background.	anics. mechanics. n a given s	ituation and to
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 grou + share new knowledge with group mem	ps and to document the correspond bers.	ing results.	
Autonomy	Students are able to + acquire independently knowledge to s	olve complex problems.		
Workload in Hours	Independent Study Time 124, Study Tim	e 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 International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory Materials Science: Specialisation Modeling: Elective Compulsory Mechatronics: Specialisation System Design: 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory			

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

Course L0279: Nonlinear Structural Analysis		
Тур	Recitation Section (small)	
Hrs/wk	1	
СР	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 M0746: M	licrosystem Eng	ineering			
Courses					
Title			Тур	Hrs/wk	СР
Microsystem Engineering (L	.0680)		Lecture Project-/problem-based	2	4
Microsystem Engineering (L	.0682)		Learning	2	2
Module Responsible	Prof. Manfred Kasper				
Admission Requirements	None				
Recommended Previous Knowledge	Basic courses in physic	s, mathematics and electric	c engineering		
Educational Objectives	After taking part succe	ssfully, students have reacl	ned the following learning	results	
Professional					
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 so	olve specific problems alone	e or in a group and to pres	sent the resu	ults accordingly.
Autonomy	Students are able to a associate this knowledge	acquire particular knowledg ge with other fields.	ge using specialized liter	ature and t	o integrate and
Workload in Hours	Independent Study Tim	ne 124, Study Time in Lectu	ire 56		
Credit points	6				
Course achievement	CompulsorBonus No 10 %	Form Presentation	Description		
Examination	Written exam				
Examination duration and scale	2h				
Assignment for the Following Curricula	Electrical Engineering: International Manager Compulsory International Manager Mechanical Engineering Mechatronics: Specialis Biomedical Engineering Biomedical Engineering Biomedical Engineering Biomedical Engineering Microelectronics and M Theoretical Mechanical	Core qualification: Compuls ment and Engineering: g and Management: Specia sation System Design: Elect ng: Specialisation Artifici g: Specialisation Implants a g: Specialisation Medical Te g: Specialisation Manageme icrosystems: Core qualifica Engineering: Technical Cor Engineering: Specialisation	sory Specialisation II. Electr lisation Mechatronics: lisation Mechatronics: Ele tive Compulsory al Organs and Regene nd Endoprostheses: Electi chnology and Control The ent and Business Administ tion: Elective Compulsory mplementary Course: Elec n Bio- and Medical Techno	ical Engine Elective Co ctive Compu- erative Mec ive Compuls eory: Elective cration: Elective ctive Compu- blogy: Elective	eering: Elective mpulsory ilsory licine: Elective ory e Compulsory ive Compulsory lsory re Compulsory

Course L0680: Microsystem Engineering		
Тур	Lecture	
Hrs/wk		
СР	4	
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28	
Lecturer	Prof. Manfred Kasper	
Language	EN	
Cycle	WiSe	
	Object and goal of MEMS	
	Scaling Rules	
	Lithography	
	Film deposition	
	Structuring and etching	
	Energy conversion and force generation	
	Electromagnetic Actuators	
- · · ·	Reluctance motors	
Content	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	
	M. Kasper: Mikrosystementwurf, Springer (2000)	
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press (1997)	
l		

Course L0682: Microsy	stem Engineering
Тур	Project-/problem-based Learning
Hrs/wk	2
СР	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Manfred Kasper
Language	EN
Cycle	WiSe
	Examples of MEMS components
	Layout consideration
Content	Electric, thermal and mechanical behaviour
	Design aspects
Literature	Wird in der Veranstaltung bekannt gegeben

Module M0806: T	echnical Acoustics II (Room A	coustics, Computation	nal Meth	nods)
Courses				
Title Technical Acoustics II (Roon Technical Acoustics II (Roon	n Acoustics, Computational Methods) (L0519) n Acoustics, Computational Methods) (L0521)	Typ Lecture Recitation Section (large)	Hrs/wk 2 2	CP 3 3
Module Responsible	Prof. Otto von Estorff			
Admission Requirements	None			
	Technical Acoustics I (Acoustic Waves, Nois	e Protection, Psycho Acoustics)		
Recommended	Mechanics I (Statics, Mechanics of Materials	s) and Mechanics II (Hydrostatics	, Kinematic	s, Dynamics)
Previous Knowledge	Mathematics I, II, III (in particular differentia	al equations)		
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional				
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	n Lecture 56		
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and scale	20-30 Minuten			
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory			

Course L0519: Technical Acoustics II (Room Acoustics, Computational Methods)		
Тур	Lecture	
Hrs/wk	2	
СР	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Lecturer	Prof. Otto von Estorff	
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, KJ. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin	

Course L0521: Technica	ourse L0521: Technical Acoustics II (Room Acoustics, Computational Methods)		
Тур	Recitation Section (large)		
Hrs/wk	2		
СР	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 M0832: A	dvanced Topics in Control			
Courses				
Title		Тур	Hrs/wk	CP
Advanced Topics in Control	(L0661)	Lecture	2	3
Advanced Topics in Control	(L0662)	Recitation Section (small)	2	3
Module Responsible	Prof. Herbert Werner			
Admission Requirements	None			
Recommended Previous Knowledge	H-infinity optimal control, mixed-sensitiv	ity design, linear matrix inequalities	5	
Educational Objectives	After taking part successfully, students h	ave reached the following learning	results	
Professional Competence				
	 Students can explain the advantapproach They can explain the representation They can explain how stability and as LMI conditions They can explain how gridding tect for LPV systems They are familiar with polytopic a synthesis techniques associated with a stability and synthesis techniques associated with a synthesis techniq	ntages and shortcomings of the on of nonlinear systems in the form d performance conditions for LPV s inniques can be used to solve analy nd LFT representations of LPV syst with each of these model structures	classical of of quasi-LF systems ca vsis and syn ems and so	gain scheduling PV systems n be formulated othesis problem ome of the basi
Knowledge	 Students can explain how graph topology of multiagent systems They can explain the convergence They can explain analysis and sy LTI or LPV agent models 	theoretic concepts are used to rep properties of first order consensu nthesis conditions for formation co	present the s protocols ntrol loops	communicatio involving eithe
	 Students can explain the state sp that are discretized according to a They can explain (in outline) the systems and the associated synth 	bace representation of spatially inv n actuator/sensor array e extension of the bounded real esis conditions for distributed contr	variant dist lemma to s ollers	ributed system such distribute
	 Students are capable of construct sensitivity design of gain-schedule LPV models They are able to use standard soft 	ting LPV models of nonlinear plar ed controllers; they can do this usir ware tools (Matlab robust control to	nts and car ng polytopic polbox) for	ry out a mixed :, LFT or genera these tasks
Skills	 Students are able to design distrib or LPV dynamics, using Matlab too 	outed formation controllers for grou Is provided	ps of agent	s with either LT
	 Students are able to design distr the Matlab MD-toolbox 	ibuted controllers for spatially inte	rconnected	systems, usin
Personal Competence				
Social Competence	Students can work in small groups and a	rrive at joint results.	notos lita	rature coffwor
Autonomy	documentation) and use it to solve given	problems.	. notes, nte	Tature, soltwall
Workload in Hours	Independent Study Time 124, Study Time	e in Lecture 56		
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration	30 min			
and scale	Computer Sciences Create Parties Lat. W	ance Engineering Elective Comercia		
	Computer Science: Specialisation Intellig	ence Engineering: Elective Compul	sory	

Course L0661: Advanced Topics in Control			
Тур	Lecture		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Lecturer	Prof. Herbert Werner		
Language	EN		
Cycle	WiSe		
Content	 Linear Parameter-Varying (LPV) Gain Scheduling Linearizing gain scheduling, hidden coupling Jacobian linearization vs. quasi-LPV models Stability and induced L2 norm of LPV systems Synthesis of LPV controllers based on the two-sided projection lemma Simplifications: controller synthesis for polytopic and LFT models Experimental identification of LPV models Controller synthesis based on input/output models Controller synthesis based on input/output models Applications: LPV torque vectoring for electric vehicles, LPV control of a robotic manipulator Control of Multi-Agent Systems Communication graphs Spectral properties of the graph Laplacian First and second order consensus protocols Formation control, stability and performance LPV models for agents subject to nonholonomic constraints Application: formation control for a team of quadrotor helicopters Control of Spatially Interconnected Systems Multidimensional signals, I2 and L2 signal norm Multidimensional signals, I2 and L2 signal norm Extension of real-bounded lemma to spatially interconnected systems LMI-based synthesis of distributed controllers Spatial LPV control of spatially varying systems Applications: control of spatially varying systems Applications: control of temperature profiles, vibration damping for an actuated beam 		
Literature	 Werner, H., Lecture Notes "Advanced Topics in Control" Selection of relevant research papers made available as pdf documents via StudIP 		

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

E.

Module M1024: M	lethods of Integrated Produc	t Development		
Courses				
Title	ment II (I 1254)	Typ	Hrs/wk	CP
Integrated Product Develop	ment II (L1255)	Project-/problem-based Learning	2	3
Module Responsible	Prof. Dieter Krause			
Admission Requirements	None			
Recommended Previous Knowledge	Basic knowledge of Integrated product dev	elopment and applying CAE syst	tems	
Educational Objectives	After taking part successfully, students hav	e reached the following learning	g 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	After passing the module students are able	to		
Social Competence	 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 i	n 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: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Specialisation System Design: 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 Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory			

Course L1254: Integrat	ed Product Development II
Тур	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
	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.
	 Methods of product development, Presentation techniques, Industrial Design, Design for variety Modularization methods, Design catalogs, Adapted QFD matrix, Systematic material selection, Assembly oriented design,
Content	 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: Integrated Product Development II		
Тур	Project-/problem-based Learning	
Hrs/wk	2	
СР	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 M1173: A	pplied Statisti	ics			
Courses					
Title			Тур	Hrs/wk	СР
Applied Statistics (L1584)			Lecture Project-/problem-based	2	3
Applied Statistics (L1586)			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 s	statistical methods			
Educational Objectives	After taking part suc	cessfully, students have rea	ched the following learning	results	
Professional Competence Knowledge Skills	Students can explair Students are able to	the statistical methods and use the statistics program t	l the conditions of their use to solve statistics problems	and to inte	rpret and depict
Personal Competence	the results				
Social Competence	Team Work, joined p	resentation of results			
Autonomy	To understand and ir	nterpret the question and so	lve		
Workload in Hours	Independent Study T	ime 110, Study Time in Lec	ture 70		
Credit points	6				
Course achievement	CompulsorBonus Yes None	Form Written elaboration	Description		
Examination	Written exam				
Examination duration and scale	90 minutes, 28 ques	tions			
Assignment for the Following Curricula	Mechanical Engineering and Management: Specialisation Management: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Core qualification: Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory				

Course L1584: Applied	Statistics
Тур	Lecture
Hrs/wk	2
СР	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
Тур	Project-/problem-based Learning
Hrs/wk	2
СР	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
Тур	Recitation Section (small)
Hrs/wk	1
СР	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 M1204: N	lodelling and Optimization i	n Dynamics				
Courses						
Title Flexible Multibody Systems Optimization of dynamical s	(L1632) systems (L1633)	Typ Lecture Lecture	Hrs/wk 2 2	CP 3 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 h	ave reached the following l	earning results			
Professional Competence						
Knowledge	Students demonstrate basic knowledge complex rigid and flexible multibody s successful completion of the module.	and understanding of mo ystems and methods for	deling, simulation optimizing dynami	and analysis o c systems after		
Skills	 + 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 grou	ps and to document the cor	responding 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	e in Lecture 56				
Credit points	6					
Course achievement	None					
Examination Examination duration	Oral exam 30 min					
Assignment for the Following Curricula	Energy Systems: Core qualification: Elect Aircraft Systems Engineering: Specialisat Mechatronics: Specialisation System Des Mechatronics: Specialisation Intelligent S Product Development, Materials and Proo Theoretical Mechanical Engineering: Core Theoretical Mechanical Engineering: Tech	ive Compulsory ion Aircraft Systems: Electi ign: Elective Compulsory ystems and Robotics: Elect duction: Core qualification: e qualification: Elective Com nnical Complementary Cour	ve Compulsory ive Compulsory Elective Compulsor Ipulsory se: Elective Compu	y Ilsory		

Course L1632: Flexible	Multibody Systems				
Тур	Lecture				
Hrs/wk	2				
СР					
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28				
Lecturer	Prof. Robert Seifried, Dr. Alexander Held				
Language	DE				
Cycle	WiSe				
Content	 Basics of Multibody Systems Basics of Continuum Mechanics Linear finite element modelles and modell reduction Nonlinear finite element Modelles: absolute nodal coordinate formulation Kinematics of an elastic body Kinetics of an elastic body 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: Optimiz	ourse L1633: Optimization of dynamical systems					
Тур	Lecture					
Hrs/wk						
СР						
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28					
Lecturer	Prof. Robert Seifried					
Language	DE					
Cycle	WiSe					
Content	 Formulation and classification of optimization problems Scalar Optimization Sensitivity Analysis Unconstrained Parameter Optimization Constrained Parameter Optimization Stochastic optimization Multicriteria Optimization Topology Optimization 					
Literature	Bestle, D.: Analyse und Optimierung von Mehrkörpersystemen. Springer, Berlin, 1994. Nocedal, J. , Wright , S.J. : Numerical Optimization. New York: Springer, 2006.					

Courses					
Title		Тур	Hrs/wk	СР	
Linear and Nonlinear Wave	s (L1737)	Project-/problem-base Learning	d 4	6	
Module Responsible	Prof. Norbert Hoffmann				
Admission Requirements	None				
Recommended Previous Knowledge	Good Knowledge in Mathemat	ics, Mechanics and Dynamics.			
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 and to develop and research new terms and concepts.				
Skills	Students are able to apply existing methods and procesures of Wave Mechanics and to develop novel methods and procedures.				
Personal Competence	1				
Social Competence	Students can reach working results also in groups.				
Autonomy	Students are able to approach given research tasks individually and 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	Mechatronics: Specialisation System Design: Elective Compulsory Naval Architecture and Ocean Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Maritime Technology: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory				

course E17571 Enicul u						
Тур	Project-/problem-based Learning					
Hrs/wk						
СР						
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56					
Lecturer	f. Norbert Hoffmann, Dr. Antonio Papangelo					
Language	E/EN					
Cycle	iSe					
Content	Introduction into the Dynamics of Linear and Nonlinear Waves.					
G.B. Witham, Linear and Nonlinear Waves. Wiley 1999.						
Literature	C.C. Mei, Theory and Applications of Ocean Surface Waves. World Scientific 2004.					

Module M1229: C	Contr	ol Lab I	В						
Courses									
Title						Τνρ		Hrs/wk	СР
Control Lab V (L1667)						Practical Cou	ırse	1	1
Control Lab VI (L1668)						Practical Cou	ırse	1	1
Module Responsible	Prof. H	Herbert We	rner						
Admission Requirements	None								
Recommended Previous Knowledge	•	State space LQG contre H2 and H- uncertain LPV contre	ce methods ol infinity opt plant mode ol	s timal cont els and rc	trol obust contro	I			
Educational Objectives	After t	taking part	successful	lly, studei	nts have rea	ached the follow	wing learnin	ig results	
Professional Competence									
Knowledge	•	Students experimer	can explaintal validat	in the di tion	ifference be	etween validat	ion of a co	ontrol lop in	simulation and
Skills		Students a Toolbox) t They are a implement They are mixed-sen They are robust cor They are design and	are capable o identify a capable of tation of L0 capable o nsitivity des capable o ntroller capable o d the imple	e of apply a dynamic using sta QG contro of using s sign and t of represe of using s ementatio	ying basic s c model tha andard soft ollers standard so the impleme enting mode standard so on of LPV ga	ystem identific t can be used f ware tools (Ma ftware tools (I entation of H-in el uncertainty, ftware tools (I in-scheduled co	ation tools (for controlle tlab Control Matlab Robu finity optim and of des Matlab Robu ontrollers	(Matlab Syste r synthesis I Toolbox) for ust Control Tr al controllers signing and i ust Control Tr	m Identificatior the design and polbox) for the mplementing a polbox) for the
Personal Competence									
Social Competence	•	Students o	can work ir	n teams to	o conduct e	xperiments and	d document	the results	
Autonomy	•	Students o	can indepe	endently c	arry out sim	ulation studies	s to design a	and validate o	ontrol loops
Workload in Hours	Indep	endent Stu	dy Time 32	2, Study T	Time in Lect	ure 28			
Credit points	2								
Course achievement	None								
Examination	Writte	en elaborati	ion						
Examination duration and scale	1								
Assignment for the Following Curricula	Electri Mecha Mecha	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory							
Course L1667: Control	Lab V								

Course L1007. Control					
Тур	Practical Course				
Hrs/wk					
СР					
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14				
Lecturer	rof. Herbert Werner, Patrick Göttsch, Adwait Datar				
Language	١				
Cycle	WiSe/SoSe				
Content	ne of the offered experiments in control theory.				
Literature	xperiment Guides				

Course L1668: Control	Course L1668: Control Lab VI			
Тур	Practical Course			
Hrs/wk	1			
СР	1			
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14			
Lecturer	. Herbert Werner, Patrick Göttsch, Adwait Datar			
Language				
Cycle	WiSe/SoSe			
Content	ne of the offered experiments in control theory.			
Literature	Experiment Guides			

Module M1305: S	eminar Adva	nced Topics ir	n Control		
Courses					
Title Advanced Topics in Control	(L1803)		Typ Seminar	Hrs/wk 2	CP 2
Module Responsible	Prof. Herbert Wern	er			
Admission Requirements	None				
Recommended Previous Knowledge	 Introduction Control theo optimal and 	to control systems bry and design robust control			
Educational Objectives	After taking part su	uccessfully, students	have reached the following	g learning results	
Professional Competence					
Knowledge	Students carStudents lea	n explain modern co arn to apply basic co	ntrol. ntrol 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 They are ab results 	e capable of develop lle to provide appro	ing solutions and present t priate feedback and handl	hem le constructive criticis	sm of their own
Autonomy	 Students ev tasks and se Students fa presentation 	valuate advantages elect the best solutio miliarize themselve as of other students,	and drawbacks of differer n s with a scientific field, s such that a scientific discu	nt forms of presental are able of introduc ssion develops	ion for specific e it and follow
Workload in Hours	Independent Study	Time 32, Study Tim	e in Lecture 28		
Credit points	2				
Course achievement	None				
Examination Examination duration	Presentation				
and scale	90 min				
Assignment for the Following Curricula	Mechatronics: Spec Mechatronics: Spec	cialisation System Do cialisation Intelligent	esign: Elective Compulsory Systems and Robotics: Ele	ctive Compulsory	

Course L1803: Advance	ed Topics in Control			
Тур	eminar			
Hrs/wk				
СР	2			
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28			
Lecturer	Prof. Herbert Werner			
Language	N			
Cycle	NiSe/SoSe			
Content	Seminar on selected topics in modern control			
Literature	To be specified			

Module M1398: S	Selected Topics in Multibody Dyna	amics and Robotics	5		
Courses					
Title Formulas and Vehicles - Ma (L1981)	athematics and Mechanics in Autonomous Driving	Typ Project-/problem-based Learning	Hrs/wk 2	CP 6	
Module Responsible	Prof. Robert Seifried				
Admission Requirements	None				
	Mechanics IV, Applied Dynamics or Robotics				
Recommended	Numerical Treatment of Ordinary Differential Equations				
Previous Knowledge	Control Systems Theory and Design				
Educational Objectives	After taking part successfully, students have rea	ched 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			l understanding	
	Students are able				
	+ to think holistically				
Skills	+ 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 hardwar	e			
Personal Competence	9				
	Students are able to				
Social Competence	tence + solve problems in heterogeneous groups and to document the corresponding results and pre-			lts and present	
	Students are able to				
Autonomy	+ 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 152, Study Time in Lec	ture 28			
Credit points	6				
Course achievement	None				
Examination	Presentation				
Examination duration and scale	тва				
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems Mechatronics: Specialisation System Design: Ele Theoretical Mechanical Engineering: Technical C Theoretical Mechanical Engineering: Core qualifi	and Robotics: Elective Com ctive Compulsory omplementary Course: Elec cation: Elective Compulsory	pulsory tive Compul	sory	

Course L1981: Formulas and Vehicles - Mathematics and Mechanics in Autonomous Driving			
Тур	Project-/problem-based Learning		
Hrs/wk	2		
СР	6		
Workload in Hours	Independent Study Time 152, Study Time in Lecture 28		
Lecturer	Prof. Robert Seifried		
Language	DE		
Cycle	WiSe		
Content			
	Seifried, R.: Dynamics of underactuated multibody systems, Springer, 2014		
Literature	Popp, K.; Schiehlen, W.: Ground vehicle dynamics, Springer, 2010		

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Module M1336: S	Soft Computing - Introduction to Mach	nine Learning	g	
Courses				
Title Soft Computing - Introduction	on to Machine Learning (L1869)) ture	Hrs/wk 4	CP 6
Module Responsible	Prof. Karl-Heinz Zimmermann			
Admission Requirements	None			
Decommended	Bachelor in Computer Science.			
Recommended Previous Knowledge	Basics in higher mathematics are inevitable, like optimization.	calculus, linear	algebra, grap	oh theory, an
Educational Objectives	After taking part successfully, students have reached t	he following learni	ng results	
Professional Competence	9			
Knowledge	Students are able to formalize, compute, and anal hidden Markov models, phylogenetic tree models, cla networks, and fuzzy controllers.	yze belief networ ssical regression a	ks, alignments nd clustering r	s of sequences methods, neura
Skills	Students can apply the relevant algorithms and deterr the statistics language R.	nine their complex	kity, and they c	an make use o
Personal Competence	•			
Social Competence	Students are able to solve specific problems alone or i	n a group and to p	resent the resu	Ilts accordingly
Autonomy	Students are able to acquire new knowledge from the knowledge to other fields.	newer literature a	nd to associat	te the acquire
Workload in Hours	Independent Study Time 124, Study Time in Lecture 5	6		
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and scale	25 min			
Assignment for the Following Curricula	Computer Science: Specialisation II: Intelligence Engin- International Management and Engineering: Speci Compulsory Mechatronics: Specialisation Intelligent Systems and R Mechatronics: Specialisation System Design: Elective C Mechatronics: Technical Complementary Course: Elect Theoretical Mechanical Engineering: Technical Comple Theoretical Mechanical Engineering: Specialisation Compulsory Theoretical Mechanical Engineering: Specialisation Compulsory	eering: Elective Co alisation II. Infor obotics: Elective C Compulsory ive Compulsory mentary Course: E Robotics and Numerics and	mpulsory mation Techno ompulsory Elective Compu Computer Sci Computer Sci	ology: Elective Isory ience: Electiv ience: Electiv

Course L1869: Soft Cor	nputing - Introduction to Machine Learning
Тур	Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Karl-Heinz Zimmermann, Dr. Mehwish Saleemi
Language	DE/EN
Cycle	WiSe
Content	Students are able to formalize, compute, and analyze belief networks, alignments of sequences, hidden Markov models, phylogenetic tree models, neural networks, and fuzzy controllers. In particular, inference and learning in belief networks are important topics that the students should be able to master. Students can apply the relevant algorithms and determine their complexity, and they can make use of the statistics language R.
Literature	 David Barber, Bayes Reasoning and Machine Learning, Cambridge Univ. Press, Cambridge, 2012. Volker Claus, Stochastische Automaten, Teubner, Stuttgart, 1971. Ernst Klement, Radko Mesiar, Endre Pap, Triangular Norms, Kluwer, Dordrecht, 2000. Timo Koski, John M. Noble, Bayesian Networks, Wiley, New York, 2009. Dimitris Margaritis, Learning Bayesian Network Model Structure from Data, PhD thesis, Carnegie Mellon University, Pittsburgh, 2003. Hidetoshi Nishimori, Statistical Physics of Spin Glasses and Information Processing, Oxford Univ. Press, London, 2001. James R. Norris, Markov Chains, Cambridge Univ. Press, Cambridge, 1996. Maria Rizzo, Statistical Computing with R, Chapman & Hall/CRC, Boca Raton, 2008. Peter Sprites, Clark Glymour, Richard Scheines, Causation, Prediction, and Search, Springer, New York, 1993. Raul Royas, Neural Networks, Springer, Berlin, 1996. Lior Pachter, Bernd Sturmfels, Algebraic Statistics for Computational Biology, Cambridge Univ. Press, Cambridge, 2005. David A. Sprecher, From Algebra to Computational Algorithms, Docent Press, Boston, 2017. Karl-Heinz Zimmermann, Algebraic Statistics, TubDok, Hamburg, 2016.

Module M0881: N	Athematical Image Processing	I		
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Courses				
Mathematical Image Proces Mathematical Image Proces	ssing (L0991) ssing (L0992)	l yp Lecture Recitation Section (small)	Hrs/wk 3 1	4 2
Module Responsible	Prof. Marko Lindner			
Admission Requirements	None			
Recommended Previous Knowledge	 Analysis: partial derivatives, gradient, Linear Algebra: eigenvalues, least squa 	directional derivative ares solution of a linear system	I	
Educational Objectives	After taking part successfully, students have	reached the following learning	results	
Professional				
competence	Students are able to			
Knowledge	 characterize and compare diffusion eq explain elementary methods of image explain methods of image segmentation sketch and interrelate basic concepts of 	uations processing on and registration of functional analysis		
	Students are able to			
Skills	 implement and apply elementary meth explain and apply modern methods of 	nods of image processing image processing		
Personal Competence				
Social Competence	Students are able to work together in hete study programs and background knowledge)	rogeneously composed teams and to explain theoretical foun	(i.e., team: idations.	s from differe
Autonomy	 Students are capable of checking their can specify open questions precisely a Students have developed sufficient per oriented manner on hard problems. 	ir understanding of complex condension of complex condension of the set of th	oncepts on olving them or longer pe	their own. The n. eriods in a goa
Workload in Hours	Independent Study Time 124, Study Time in I	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 - Ge Computer Science: Specialisation III. Mathem Computational Science and Engineering: Spe Mechatronics: Technical Complementary Cou Mechatronics: Specialisation Intelligent Syste Mechatronics: Specialisation System Design: Technomathematics: Specialisation I. Mathen Theoretical Mechanical Engineering: Technica Theoretical Mechanical Engineering: Spec Compulsory Theoretical Mechanical Engineering: Spec Compulsory Process Engineering: Specialisation Process Proces	neral Bioprocess Engineering: atics: Elective Compulsory cialisation III. Mathematics: Ele rse: Elective Compulsory ms and Robotics: Elective Com Elective Compulsory natics: Elective Compulsory al Complementary Course: Elec cialisation Robotics and Co cialisation Numerics and Co	Elective Corr ctive Comp pulsory tive Compu mputer Sc mputer Sc	npulsory ulsory isory ience: Electiv ience: Electiv

Course L0991: Mathem	atical Image Processing
Тур	Lecture
Hrs/wk	3
СР	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			
Тур	Recitation Section (small)		
Hrs/wk	1		
СР	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 M1048: lı	ntegrated Circuit Desig	n	
Courses			
Title Integrated Circuit Design (L Integrated Circuit Design (L	0691) 0998)	Typ Lecture Recitation Section (small)	Hrs/wk CP 3 4 1 2
Module Responsible	Prof. Matthias Kuhl		
Admission Bequirements	None		
Recommended Previous Knowledge	Basic knowledge of (solid-state) pl Knowledge in fundamentals of elec	nysics and mathematics. ctrical engineering and electrical networl	<s.< th=""></s.<>
Educational Objectives	After taking part successfully, stuc	lents have reached the following learning	g results
Professional Competence			
Knowledge	 Students can explain basic bands, generation/recombin semiconductor device equa Students are able to explai using energy band diagram Students can present and circuits of these devices. Students can explain the p carrier flow. Students are able to explain circuits Students can explain the p carrier flow. Students can explain the p carrier solution. Students can explain the p circuits Students can exemplify app Students can describe the p analysis. Students can explain character 	c concepts of electron transport in sem nation, carrier concentrations, drift and tions). in functional principles of pn-diodes, MC s. discuss current-voltage relationships ohysics and current-voltage behavior tr n the basic concepts for static and dynar proaches for low power consumption on t potential and limitations of analytical exp cterization techniques for MOS devices.	iconductor devices (energy diffusion current densities, DS capacitors, and MOSFETs and small-signal equivalent ansistors based on charged nic logic gates for integrated he device and circuit level ression for device and circuit
Skills	 Students can qualitatively voltages. Students are able to qualit flow from energy band diag Students can understand sc Students can calculate the of Students can design completed to students who procedure consumption 	construct energy band diagrams of the tatively determine electric field, carrier rams. cientific publications from the field of sen dimensions of MOS devices in dependence ex electronic circuits and anticipate poss of or optimization regarding high pe	devices for varying applied concentrations, and charge niconductor devices. ce of the circuits properties ble problems. rformance and low power
Personal Competence			
Social Competence	 Students can team up with Students are able to work scientific questions. Students have the ability to 	other experts in the field to work out inn by their own or in small groups for so critically question the value of their con	ovative solutions. Iving problems and answer tributions to working groups.
Autonomy	 Students are able to assess Students are able to define 	their knowledge in a realistic manner. their personal approaches to solve challe	enging problems
Workload in Hours	Independent Study Time 124, Stud	dy Time in Lecture 56	
Credit points	6		
Course achievement	None		
Examination	Written exam		
Examination duration and scale	90 min	sation Nanoelectronics and Microsyst	ems Technology: Flective
Assignment for the	Compulsory International Management and	Engineering: Specialisation II. Elect	rical Engineering: Elective
Following Curricula Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Microelectronics and Microsystems: Core qualification: Elective Compulsory

Course L0691: Integrat	ed Circuit Design
Тур	Lecture
Hrs/wk	3
СР	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		
Тур	Recitation Section (small)	
Hrs/wk	1	
СР	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	

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Supplement Modules

Module M0604: H	ligh-Order FEM					
Courses						
Title High-Order FEM (L0280) High-Order FEM (L0281)			Typ Lecture Recitation Section (large)	Hrs/wk 3 1	CP 4 2	
Module Responsible	Prof. Alexander Düster					
Admission Requirements	None					
Recommended Previous Knowledge	Knowledge of partial d	ifferential equations is reco	mmended.			
Educational Objectives	After taking part succe	essfully, students have react	ned the following learning	results		
Professional Competence						
Knowledge	Students are able to + give an overview of + explain high-order fi + specify problems of their mathematical and	the different (h, p, hp) finite nite element procedures. finite element procedures, d mechanical background.	e element procedures. to identify them in a giv	en situation a	and to explain	
Skills	Students are able to + apply high-order finit + select for a given pro + critically judge result + transfer their knowle	 Students are able to + apply high-order finite elements to problems of structural mechanics. + select for a given problem of structural mechanics a suitable finite element procedure. + critically judge results of high-order finite elements. + transfer their knowledge of high-order finite elements to new problems. 				
Personal Competence						
Social Competence	Students are able to + solve problems in he	eterogeneous groups and to	document the correspond	ding results.		
Autonomy	Students are able to + assess their knowled + acquaint themselves	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.				
Workload in Hours	Independent Study Tim	ne 124, Study Time in Lectu	ire 56			
Credit points	6					
Course achievement	CompulsorBonus No 10 %	Form Presentation	Description Forschendes Lernen			
Examination	Written exam					
Examination duration and scale	120 min					
Assignment for the Following Curricula	Energy Systems: Core International Managen Elective Compulsory Materials Science: Spe Mechanical Engineerin Elective Compulsory Mechatronics: Technica Product Development, Naval Architecture and Theoretical Mechanical Theoretical Mechanical	20 min nergy Systems: Core qualification: Elective Compulsory iternational Management and Engineering: Specialisation II. Product Development and Production lective Compulsory laterials Science: Specialisation Modeling: Elective Compulsory lechanical Engineering and Management: Specialisation Product Development and Production lective Compulsory lechatronics: Technical Complementary Course: Elective Compulsory roduct Development, Materials and Production: Core qualification: Elective Compulsory aval Architecture and Ocean Engineering: Core qualification: Elective Compulsory heoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory				

Course L0280: High-Or	der FEM
Тур	Lecture
Hrs/wk	3
СР	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Alexander Düster
Language	EN
Cycle	SoSe
Content	 Introduction Motivation Hierarchic shape functions Mapping functions Computation of element matrices, assembly, constraint enforcement and solution Convergence characteristics Mechanical models and finite elements for thin-walled structures Computation of thin-walled structures Error estimation and hp-adaptivity High-order fictitious domain methods
Literature	 [1] Alexander Düster, High-Order FEM, Lecture Notes, Technische Universität Hamburg-Harburg, 164 pages, 2014 [2] Barna Szabo, Ivo Babuska, Introduction to Finite Element Analysis – Formulation, Verification and Validation, John Wiley & Sons, 2011

Course L0281: High-Order FEM			
Тур	Recitation Section (large)		
Hrs/wk	1		
СР	2		
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14		
Lecturer	Prof. Alexander Düster		
Language	EN		
Cycle	SoSe		
Content	See interlocking course		
Literature	See interlocking course		

Module M0605: C	Computational Structu	ral Dynamics	5		
Courses					
Title			Тур	Hrs/wk	СР
Computational Structural D	ynamics (L0282)		Lecture	3	4
Computational Structural D	ynamics (L0283)		Recitation Section (small)	1	2
Module Responsible	Prof. Alexander Düster				
Admission Requirements	None				
Recommended Previous Knowledge	Knowledge of partial differential	l equations is recor	nmended.		
Educational Objectives	After taking part successfully, st	tudents have reach	ned the following learning	results	
Professional					
Competence					
Knowledge	 Students are able to + give an overview of the computational procedures for problems of structural dynamics. + explain the application of finite element programs to solve problems of structural dynamics. + specify problems of computational structural dynamics, to identify them in a given situation and to explain their mathematical and mechanical background. 				
Skills	 Students are able to + model problems of structural dynamics. + select a suitable solution procedure for a given problem of structural dynamics. + apply computational procedures to solve problems of structural dynamics. + verify and critically judge results of computational structural dynamics. 				
Personal Competence					
Social Competence	Students are able to + solve problems in heterogene	eous groups and to	document the correspond	ling results.	
Autonomy	Students are able to + acquire independently knowledge to solve complex problems.				
Workload in Hours	Independent Study Time 124, S	tudy Time in Lectu	re 56		
Credit points	6				
Course achievement	None				
Examination	Written exam				
Examination duration and scale	2h				
Assignment for the Following Curricula	International Management and I Materials Science: Specialisation Mechatronics: Technical Comple Naval Architecture and Ocean E Theoretical Mechanical Enginee Theoretical Mechanical Enginee	Engineering: Speci n Modeling: Electiv ementary Course: E ingineering: Core q ring: Technical Cor ring: Specialisatior	alisation II. Mechatronics: e Compulsory Elective Compulsory ualification: Elective Com nplementary Course: Elec I Simulation Technology: I	Elective Con pulsory tive Compuls Elective Com	npulsory sory pulsory

Course L0282: Comput	ational Structural Dynamics
Тур	Lecture
Hrs/wk	3
СР	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Alexander Düster
Language	DE
Cycle	SoSe
Content	 Motivation Basics of dynamics Time integration methods Modal analysis Fourier transform Applications
Literature	 KJ. Bathe, Finite-Elemente-Methoden, Springer, 2002. J.L. Humar, Dynamics of Structures, Taylor & Francis, 2012.

Course L0283: Computational Structural Dynamics			
Тур	Recitation Section (small)		
Hrs/wk	1		
СР	2		
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14		
Lecturer	Prof. Alexander Düster		
Language	DE		
Cycle	SoSe		
Content	See interlocking course		
Literature	See interlocking course		

Module M0673: I	nformation Theory and Coding			
Courses				
Title Information Theory and Coo Information Theory and Coo	ding (L0436) ding (L0438)	Typ Lecture Recitation Section (large)	Hrs/wk 3 2	CP 4 2
Module Responsible	Prof. Gerhard Bauch			
Admission Requirements	None			
Recommended Previous Knowledge	 Mathematics 1-3 Probability theory and random processes Basic knowledge of communications er Communications and Random Processes") 	ngineering (e.g. from	lecture "Fur	ndamentals of
Educational Objectives	After taking part successfully, students have reach	ned the following learning	results	
Professional Competence				
Knowledge	The students know the basic definitions for quantification of information in the sense of information theory. They know Shannon's source coding theorem and channel coding theorem and are able to determine theoretical limits of data compression and error-free data transmission over noisy channels. They understand the principles of source coding as well as error-detecting and error-correcting channel coding. They are familiar with the principles of decoding, in particular with modern methods of iterative decoding. They know fundamental coding schemes, their properties and decoding algorithms.			
Skills	The students are able to determine the limits of data compression as well as of data transmission through noisy channels and based on those limits to design basic parameters of a transmission scheme. They can estimate the parameters of an error-detecting or error-correcting channel coding scheme for achieving certain performance targets. They are able to compare the properties of basic channel coding and decoding schemes regarding error correction capabilities, decoding delay, decoding complexity and to decide for a suitable method. They are capable of implementing basic coding and decoding schemes regarding error correction capabilities, decoding delay, decoding complexity and to decide for a suitable method.			
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 Lectu	re 70		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	90 min			
Assignment for the Following Curricula	Electrical Engineering: Specialisation Information a Computational Science and Engineering: Specialisa Information and Communication Systems: Core qu International Management and Engineering: Compulsory Mechatronics: Technical Complementary Course: E	and Communication Syste ation II. Engineering Scier alification: Compulsory Specialisation II. Electr Elective Compulsory	ms: Elective nce: Elective ical Engine	Compulsory Compulsory ering: Elective

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

Course L0438: Information Theory and Coding			
Тур	Recitation Section (large)		
Hrs/wk	2		
СР	2		
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28		
Lecturer	Prof. Gerhard Bauch		
Language	DE/EN		
Cycle	SoSe		
Content	See interlocking course		
Literature	See interlocking course		

Module M0769: E	MC I: Coupling	Mechanisms, (Countermeasures and	Test Pr	ocedures
Courses					
Title EMC I: Coupling Mechanism EMC I: Coupling Mechanism EMC I: Coupling Mechanism	is, Countermeasures, and is, Countermeasures, and is, Countermeasures, and	Test Procedures (L074 Test Procedures (L074 Test Procedures (L074	Typ3)Lecture4)Recitation Section (small)5)Practical Course	Hrs/wk 3 1 1	CP 4 1 1
Module Responsible	Prof. Christian Schuste	r			
Admission Requirements	None				
Recommended Previous Knowledge	Fundamentals of Elect	rical Engineering			
Educational Objectives	After taking part succe	ssfully, students hav	e reached the following learning	results	
Professional Competence					
Knowledge	Students are able to explain the fundamental principles, inter-dependencies, and methods of Electromagnetic Compatibility of electric and electronic systems and to ensure Electromagnetic Compatibility of such systems. They are able to classify and explain the common interference sources and coupling mechanisms. They are capable of explaining the basic principles of shielding and filtering. They are able of giving an overview over measurement and simulation methods for the characterization of Electromagnetic Compatibility in electrical engineering practice.				
Skills	Students are able to apply a series of modeling methods for the Electromagnetic Compatibility of typical electric and electronic systems. They are able to determine the most important effects that these models are predicting in terms of Electromagnetic Compatibility. They can classify these effects and they can quantitatively analyze them. They are capable of deriving problem solving strategies from these predictions and they can adapt them to applications in electrical engineering practice. They can evaluate their problem solving strategies against each other.				
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, during laboratory work and exercises, e.g				
Autonomy	Students are capable to gather necessary information from the references provided 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. Theoretical Electrical Engineering and Communication Theory). They can communicate problems and solutions in the field of Electromagnetic Compatibility in english language.				
Workload in Hours	Independent Study Tin	ne 110, Study Time ir	Lecture 70		
Credit points	6				
Course achievement	CompulsorBonus Yes None	Form Presentation	Description		
Examination	Oral exam				
Examination duration and scale	45 min				
Assignment for the Following Curricula	Electrical Engineerin Compatibility: Elective Mechatronics: Technic Microelectronics and M	g: Specialisation I Compulsory al Complementary Co licrosystems: Special	Aicrowave Engineering, Option urse: Elective Compulsory sation Microelectronics Compler	cs, and ments: Elect	Electromagnetic

Course L0743: EMC I: C	Coupling Mechanisms, Countermeasures, and Test Procedures
Түр	Lecture
Hrs/wk	3
СР	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	SoSe
Content	 Introduction to Electromagnetic Compatibility (EMC) Interference sources in time an frequency domain Coupling mechanisms Transmission lines and coupling to electromagnetic fields Shielding Filters EMC test procedures
Literature	 C.R. Paul: "Introduction to Electromagnetic Compatibility", 2nd ed., (Wiley, New Jersey, 2006). A.J. Schwab und W. Kürner: "Elektromagnetische Verträglichkeit", 6. Auflage, (Springer, Berlin 2010). F.M. Tesche, M.V. Ianoz, and T. Karlsson: "EMC Analysis Methods and Computational Models", (Wiley, New York, 1997).

Course L0744: EMC I: Coupling Mechanisms, Countermeasures, and Test Procedures			
Тур	Recitation Section (small)		
Hrs/wk	1		
СР	1		
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14		
Lecturer	Prof. Christian Schuster		
Language	DE/EN		
Cycle	SoSe		
Content	The exercise sessions serve to deepen the understanding of the concepts of the lecture.		
Literature	 C.R. Paul: "Introduction to Electromagnetic Compatibility", 2nd ed., (Wiley, New Jersey, 2006). A.J. Schwab und W. Kürner: "Elektromagnetische Verträglichkeit", 6. Auflage, (Springer, Berlin 2010). F.M. Tesche, M.V. Ianoz, and T. Karlsson: "EMC Analysis Methods and Computational Models", (Wiley, New York, 1997). Scientific articles and papers 		

Course L0745: EMC I: Coupling Mechanisms, Countermeasures, and Test Procedures		
Тур	Practical Course	
Hrs/wk	1	
СР	1	
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14	
Lecturer	Prof. Christian Schuster	
Language	DE/EN	
Cycle	SoSe	
Content	 Laboratory experiments serve to practically investigate the following EMC topics: Shielding Conducted EMC test procedures The GTEM-cell as an environment for radiated EMC test 	
Literature	Versuchsbeschreibungen und zugehörige Literatur werden innerhalb der Veranstaltung bereit gestellt.	

Module M0924: S	oftware for Embedded Systems					
Courses						
Title Software for Embdedded Sy Software for Embdedded Sy	ystems (L1069) ystems (L1070)	Typ Lecture Recitation Section (small)	Hrs/wk 2 3	CP 3 3		
Module Responsible	Prof. Bernd-Christian Renner					
Admission Requirements	None					
Recommended Previous Knowledge	 Good knowledge and experience in progr Basis knowledge in software engineering Basic understanding of assembly language 	 Good knowledge and experience in programming language C Basis knowledge in software engineering Basic understanding of assembly language 				
Educational Objectives	After taking part successfully, students have re-	ached 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 Le	cture 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 Information and Communication Systems: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: 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: Softwar	e for Embdedded Systems
Тур	Lecture
Hrs/wk	2
СР	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
 Embedded System Design, F. Vahid and T. Givargis, John Wiley Programming Embedded Systems: With C and Gnu Development Tools, M. Ba O'Reilly C und C++ für Embedded Systems, F. Bollow, M. Homann, K. Köhn, MITP The Art of Designing Embedded Systems, J. Ganssle, Newnses Mikrocomputertechnik mit Controllern der Atmel AVR-RISC-Familie, G. Schmitt, Making Embedded Systems: Design Patterns for Great Software, E. White, O'Re 	

Course L1070: Software for Embdedded Systems		
Тур	Recitation Section (small)	
Hrs/wk	3	
СР	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: C	Compilers for Embedded Syst	tems			
Courses					
Title Compilers for Embedded Systems (L1692)		Typ Lecture	Hrs/wk 3	CP 4	
Compilers for Embedded Systems (L1693) Project-/pro 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 ha	ave reached the following learnin	g results		
Professional Competence					
Knowledge Skills	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 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. 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.				
	optimizations.				
Personal Competence	Students are able to solve similar problem	ns alone or in a group and to prov	ont the recu	Its accordingly	
Social Competence	Students are able to acquire new knowle	edge from specific literature and	to associate	this knowledge	
Autonomy	with other classes.				
Workload in Hours	Independent Study Time 124, Study Time	e in Lecture 56			
Credit points	<u>i</u> 6				
Course achievement	None				
Examination Examination duration and scale	JUrai exam 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: Specialisation Avionic Systems: 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory				

Course L1692: Compile	rs for Embedded Systems
Тур	Lecture
Hrs/wk	3
СР	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. 2nd Edition, Springer, 2012. Steven S. Muchnick. Advanced Compiler Design and Implementation. Morgan Kaufmann, 1997. Andrew W. Appel. Modern compiler implementation in C. Oxford University Press, 1998.

Course L1693: Compilers for Embedded Systems		
Тур	Project-/problem-based Learning	
Hrs/wk	1	
СР	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 M1281: A	Advanced Topics in Vibration			
Courses				
Title		Тур	Hrs/wk	СР
Advanced Topics in Vibratio	on (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 h	ave reached the following learning	results	
Professional Competence				
Knowledge	Students are able to reflect existing terms and concepts of Advanced Vibrations and to develop and research new terms and concepts.			
Skills	Students are able to apply existing methods and procesures of Advanced Vibrations and to develop novel methods and procedures.			
Personal Competence				
Social Competence	Students can reach working results also in gr	oups.		
Autonomy	Students are able to approach given resear tasks by themselves.	ch tasks individually and to identify	and follow u	p novel research
Workload in Hours	Independent Study Time 124, Study Time	e 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory			

Course L1743: Advanced Topics in Vibration		
Тур	Project-/problem-based Learning	
Hrs/wk	4	
СР	6	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56	
Lecturer	Prof. Norbert Hoffmann, Merten Tiedemann, Sebastian Kruse	
Language	DE/EN	
Cycle	SoSe	
Content	Research Topics in Vibrations.	
Literature	Aktuelle Veröffentlichungen	

Module M1269: L	ab Cyber-Physical Systems			
Courses				
Title		Тур	Hrs/wk	СР
Lab Cyber-Physical Systems	s (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 reac	hed the following learning	results	
Professional				
competence	Cyber-Physical Systems (CPS) are tightly integrated with their surrounding environment, via sensor A/D and D/A converters, and actors. Due to their particular application areas, highly specialize 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.			
Knowledge	Based on practical experiments using robot kits and computers, the basics of specification an modelling of CPS are taught. The lab introduces into the area (basic notions, characteristical properties) and their specification techniques (models of computation, hierarchical automata, dat flow models, petri nets, imperative approaches). Since CPS frequently perform control tasks, the lab' experiments will base on simple control applications. The experiments will use state-of-the-ar industrial specification tools (MATLAB/Simulink, LabVIEW, NXC) in order to model cyber-physica models that interact with the environment via sensors and actors.			
Skills	After successful attendance of the lab, students a interdependencies between a CPS and its surrour interacts with the environment via sensors, A/D actors. The lab enables students to compare mod limitations, and to decide which technique to use techniques to practical problems. They obtai development, in industry-relevant specification to	are able to develop simple nding processes which ste converters, digital proce delling approaches, to eva for a concrete task. They n first experiences in l ols and in the area of simp	e CPS. They m from the essors, D/A luate their a will be able hardware-re ble control ap	understand the fact that a CPS converters and dvantages and to apply these lated software pplications.
Personal Competence				
Social Competence	Students are able to solve similar problems alone	or in a group and to prese	nt the result	ts accordingly.
Autonomy	Students are able to acquire new knowledge fror with other classes.	m specific literature and to	o associate	this knowledge
Workload in Hours	Independent Study Time 124, Study Time in Lectu	ıre 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 Elective Compulsory Computer Science: Specialisation Computer and S Computer Science: Specialisation II. Mathematics General Engineering Science (English program, 7 Compulsory Computational Science and Engineering: Specialis Compulsory Computational Science and Engineering: Specialis Mechatronics: Specialisation Intelligent Systems a Mechatronics: Specialisation System Design: Elect Mechatronics: Technical Complementary Course	n, 7 semester): Speciali Software Engineering: Elect and Engineering Science: semester): Specialisation sation II. Mathematics & En sation Computer Science: E ind Robotics: Elective Com tive Compulsory Elective Compulsory	sation Com tive Compul: Elective Con Computer So agineering So Elective Com pulsory	puter Science: sory npulsory cience: Elective cience: Elective npulsory

Course L1740: Lab Cyb	er-Physical Systems
Тур	Project-/problem-based Learning
Hrs/wk	4
СР	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. 2nd Edition, Springer, 2012. Begleitende Foliensätze

Module M0551: P	attern Recognition and Dat	a Compression		
Courses				
Title Pattern Recognition and Da	ta Compression (L0128)	Typ Lecture	Hrs/wk 4	CP 6
Module Responsible	Prof. Rolf-Rainer Grigat			
Admission Requirements	None			
Recommended Previous Knowledge	Linear algebra (including PCA, unitary tr	ansforms), stochastics and s	statistics, binary arit	hmetics
Educational Objectives	After taking part successfully, students	have reached the following l	earning results	
Professional Competence				
	Students can name the basic concepts o	of pattern recognition and da	ata compression.	
Knowledge	Students are able to discuss logical con explain them by means of examples.	nnections between the conc	cepts covered in the	e course and to
Skills	Students can apply statistical method prediction in data compression. On a characteristic value assignments and c coding. They are able to use highly soph are capable of assessing different soluti	ds to classification probler sound theoretical and m lassifications and describe on histicated methods and proc on approaches in multidimen	ns in pattern reco ethodical basis the data compression a esses of the subject nsional decision-ma	ognition and to ey can analyzo nd video signa area. Students king areas.
Personal Competence <i>Social Competence</i> <i>Autonomy</i>	k.A. Students are capable of identifying pro the methods they have learnt.	blems independently and o	of solving them scie	entifically, using
Workload in Hours	Independent Study Time 124, Study Tim	ne in Lecture 56		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	60 Minutes, Content of Lecture and mat	erials in StudIP		
Assignment for the Following Curricula	Computer Science: Specialisation II: Inte Electrical Engineering: Specialisation Inf Information and Communication Syster Software and Signal Processing: Elective Information and Communication Syster Processing: Elective Compulsory International Management and Engir Compulsory International Management and Engi Compulsory Mechatronics: Specialisation Intelligent : Mechatronics: Technical Complementary Theoretical Mechanical Engineering: Tec Theoretical Mechanical Engineering: Compulsory	Alligence Engineering: Elective ormation and Communication ms: Specialisation Secure a e Compulsory ems: Specialisation Communication neering: Specialisation II. neering: Specialisation II. Systems and Robotics: Elect y Course: Elective Compulso chnical Complementary Cour Specialisation Robotics a	ve Compulsory on Systems: Elective nd Dependable IT nunication Systems Information Techno Electrical Engine ive Compulsory ry rse: Elective Compu and Computer Sci	e Compulsory Systems, Focus , Focus Signa blogy: Elective ering: Elective lsory ence: Elective

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

Module M0627: M	lachine Learning and Data Mini	ng		
Courses				
Title	Mining (10240)	Typ	Hrs/wk	CP 4
Machine Learning and Data	Mining (L0540) Mining (L0510)	Recitation Section (small)	2	4 2
Module Responsible	NN			
Admission	Nono			
Requirements				
Recommended Previous Knowledge	CalculusStochastics			
Educational Objectives	After taking part successfully, students have re	eached the following learning	results	
Professional Competence				
Knowledge	Students can explain the difference between and they can enumerate basic machine lear either on the basis of static data, or on the b uncertainty, students can describe suitable re features, parameters, or structures used in different algorithms. Students are also able to the performance of learned classifiers can summarize how this influences computational can also be explained by students.	instance-based and model-b ning technique for each of pasis of incrementally incom presentation formalisms, and these formalisms can be a sketch different clustering te be improved by ensemble learning theory. Algorithms	based learni the two bas ing data . F d they expla learned aut echniques. T e learning, for reinforc	ng approaches sic approaches or dealing with in how axioms omatically with hey depict how and they car ement learning
Skills	Student derive decision trees and, in turn, pro and are able to name and explain basic optimiz of first-order inductive leaning. Students app parameters of Bayesian networks and compar out Gaussian mixture learning. They can contr machines, and name their basic application a basic clustering techniques and explain the ba related machine learning techniques, e.g., k They can distinguish various ensemble learnin techniques.	opositional rule sets from sir zation techniques. They prese by the BME, MAP, ML, and e the different algorithms. The ast kNN classifiers, neural neu- reas and algorithmic proper- asic components of those tec- means clustering and near ng techniques and compare to	nple and sta ent and appl EM algorithm ney also kno tworks, and ties. Studen hniques. Stu est neighbo the different	atic data tables y the basic ide ns for learning w how to carry support vecto ts can describe idents compare r classification goals of those
Personal Competence				
Social Competence				
Autonomy				
Workload in Hours	Independent Study Time 124, Study Time in Le	ecture 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 International Management and Engineering Compulsory Mechatronics: Technical Complementary Course Mechatronics: Specialisation Intelligent System Mechatronics: Specialisation System Design: El Theoretical Mechanical Engineering: Technical Theoretical Mechanical Engineering: Special Compulsory	e Engineering: Elective Comp : Specialisation II. Informa :e: Elective Compulsory is and Robotics: Elective Com lective Compulsory Complementary Course: Elec alisation Robotics and Co	oulsory tion Techno pulsory tive Compul mputer Sci	ology: Elective sory ence: Elective

Course L0340: Machine	Learning and Data Mining
Тур	Lecture
Hrs/wk	2
СР	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 Theory
Literature	 Artificial Intelligence: A Modern Approach (Third Edition), Stuart Russel, Peter Norvig, Prentice Hall, 2010, Chapters 13, 14, 18-21 Machine Learning: A Probabilistic Perspective, Kevin Murphy, MIT Press 2012

Course L0510: Machine Learning and Data Mining	
Тур	Recitation Section (small)
Hrs/wk	2
СР	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
Literature	See interlocking course

ntelligent Autonomous Age	nts and Cognitive Ro	botics	
	Тур	Hrs/wk	СР
nts and Cognitive Robotics (L0341)	Lecture	2	4
nts and Cognitive Robotics (L0512)	Recitation Section (sm	nall) 2	2
Rainer Marrone			
None			
Vectors, matrices, Calculus			
After taking part successfully, students	have reached the following lear	ning results	
Students can explain the agent abstract details about agent design (goals, util environments. The notion of adversar problems and algorithms for solving scenarios, students can summarize l representation and reasoning formalisn decision making procedures in simple state of the environment. In this cor observable) Markov decision problems information. Students can identify tec explain planning techniques for achiev and decision making in a multi-agent functions, voting protocol, and mechani	tion, define intelligence in term lities, environments). They can ial agent cooperation can be these problems. For dealing how Bayesian networks can be in static and dynamic settings, and sequential settings, with an text, students can describe te s, and they can recall techniques thniques for simultaneous loca ing desired states. Students car setting in term of different ty ism design techniques.	is of rational be- describe the n discussed in te with uncertaint be employed a In addition, stu nd with complet echniques for s les for measuri- lization and ma n explain coordii pes of equilibri	havior, and give hain features of rms of decision cy in real-world s a knowledge dents can define te access to the olving (partially ng the value of pipping, and can hation problems a, social choice
Students can select an appropriate ag simplified agent application students techniques. For those applications they and apply bayesian reasoning for simpl techniques for simplified agent scena compute the best action or policies for techniques for finding different equilibr students will apply different voting prot	ent architecture for concrete a s can derive decision trees can also create Bayesian netwo e queries. Students can also nar rios. For simple and complex concrete settings. In multi-ager ia states, e.g., Nash equilibria. F ocols and compare and explain	gent application and apply bas irks/dynamic Ba ne and apply dir decision makin nt situations stu or multi-agent the results.	n scenarios. For sic optimization yesian networks fferent sampling g students can dents will apply decision making
Students are able to discuss their soluti	ons to problems with others. Th	ey communicate	e in English
Students are able of checking their und problems	lerstanding of complex concepts	s by solving vara	ints of concrete
Independent Study Time 124, Study Tir	ne in Lecture 56		
6			
None			
Written exam			
90 minutes			
Computer Science: Specialisation II: International Management and Engin Compulsory Mechatronics: Technical Complementar Mechatronics: Specialisation Intelligent Biomedical Engineering: Specialisation Compulsory Biomedical Engineering: Specialisation Biomedical Engineering: Specialisation Biomedical Engineering: Specialisation Biomedical Engineering: Specialisation Theoretical Mechanical Engineering: Te Theoretical Mechanical Engineering: Compulsory Theoretical Mechanical Engineering: Compulsory	elligence Engineering: Elective C neering: Specialisation II. Info y Course: Elective Compulsory Systems and Robotics: Elective on Artificial Organs and Reg Implants and Endoprostheses: E Medical Technology and Control Management and Business Adm chnical Complementary Course: Specialisation Robotics and Specialisation Numerics and	Compulsory prmation Techn Compulsory generative Med lective Compuls Theory: Elective inistration: Elect Elective Compu Computer Sc Computer Sc	ology: Elective dicine: Elective ory e Compulsory tive Compulsory llsory ience: Elective ience: Elective
	Intelligent Autonomous Age Ints and Cognitive Robotics (L0341) Ints and Cognitive Robotics (L0512) Rainer Marrone None Vectors, matrices, Calculus After taking part successfully, students Students can explain the agent abstract details about agent design (goals, util environments. The notion of adversar problems and algorithms for solving scenarios, students can summarize I representation and reasoning formalism decision making procedures in simple state of the environment. In this cor observable) Markov decision problems and algorithms for achiev and decision making in a multi-agent functions, voting protocol, and mechani Students can select an appropriate agsimplified agent application students techniques for simplified agent scena compute the best action or policies for techniques for simplified agent scena compute the best action or policies for students will apply different voting prot Students are able to discuss their soluti Mone Written exam 90 minutes Computer Science: Specialisation II: Intentional Management and Engineering: Specialisation Biomedical Engineering: Specialisation Biomedical Engineering: Specialisation Students are able of checking their und problems	Intelligent Autonomous Agents and Cognitive Rol Typ tts and Cognitive Robotics (L031) tts and Cognitive Robotics (L0512) Rainer Marrone None Vectors, matrices, Calculus After taking part successfully, students have reached the following lear Students can explain the agent abstraction, define intelligence in term details about agent design (goals, utilities, environments). They can environments. The notion of adversarial agent cooperation can be problems and algorithms for solving these problems. For dealing scension making procedures in simple and sequential settings, with a state of the environment. In this context, students can describe tr Students can summarize how Bayesian networks can 1 and decision making in a multi-agent setting in term of different ty functions, students can identify techniques for simultaneous loca and decision making in a multi-agent setting in term of different ty functions, voting protocol, and mechanism design techniques. Students can able to discuss their solutions to problems with others. Th Students are able to discuss their solutions to problems with others. Th Students are able to discuss their solutions to problems with others. Th Students are able to checking their understand	Intelligent Autonomous Agents and Cognitive Robotics Intervention Typ Hrs/wk Action Provide Robotics (L0341) Lecture 2 Rainer Marrone Recitation Section (small) 2 None Sectors, matrices, Calculus Advectors, matrices, Calculus After taking part successfully, students have reached the following learning results Students can explain the agent abstraction, define intelligence in terms of rational ble details about agent design (goals, utilities, environments). They can describe the newironments. The notion of adversarial agent cooperation can be discussed in terpresensation and reasoning formalism in static and dynamic settings, in addition, stute decision making procedures in simple and sequential settings, with and with complet state of the environment. In this context, students can describe techniques for measurin information. Students can identify techniques for simultaneous localization and mexplain planning techniques for achieving desired states. Students can explain coordia and decision problems, and they can recall techniques for equilibri functions, voting protocol, and mechanism design techniques. Students can select an appropriate agent architecture for concrete agent application is simplified agent applications students can also create Bayesian networks/dynamic Ba and apply bayesian reasoning for simple queries. Students can also prove students will apply different equilibria states, e.g., Nash equilibria. For multi-agent students will apply different equilibria states, e.g., Nash equilibria. For multi-agent students will apply different voting protocols and complex concepts by solving vara problems </th

Course L0341: Intelligent Autonomous Agents and Cognitive Robotics		
Тур	Lecture	
Hrs/wk	2	
СР	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 heoretic agents: POMDPs, reduction to multidimensional continuous MDPs, dynamic 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 Impossibi	
Literature	 Artificial Intelligence: A Modern Approach (Third Edition), Stuart Russell, Peter Norvig, Prentice Hall, 2010, Chapters 2-5, 10-11, 13-17 Probabilistic Robotics, Thrun, S., Burgard, W., Fox, D. MIT Press 2005 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	
Тур	Recitation Section (small)
Hrs/wk	2
СР	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

E.

Module M0836: C	Communication Networks			
Courses				
Titlo		Tun	Hrc/wk	CP
Folostod Topics of Commun	vication Notworks (10800)	Project-/problem-based	115/WK	2 2
Selected Topics of Communication		Learning	2	2
Communication Networks (Project-/problem-based	2	2
Communication Networks E		Learning	1	2
Module Responsible	Prof. Andreas Timm-Giel			
Admission Requirements	None			
Recommended Previous Knowledge	 Fundamental stochastics Basic understanding of computer net 	works and/or communication te	chnologies i	s beneficial
Educational Objectives	After taking part successfully, students have	e reached the following learning	g results	
Professional				
Knowledge	Students are able to describe the principles can explain the formal description methods able to explain how current and complex research in these examples.	and structures of communicat of communication networks a communication networks wor	tion network nd their pro k and descu	s in detail. They tocols. They are ribe the current
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 themselve the learned methods. They can present th analyse the solutions.	es in small teams and solve the e obtained results. They are a	ese problem ble to discu	s together using ss and critically
Autonomy	Students are able to obtain the necessary performance capabilities of new communica	expert knowledge for understa ation networks independently.	anding the f	unctionality and
Workload in Hours	Independent Study Time 110, Study Time ir	1 Lecture 70		
Credit points	6			
Course achievement	None			
Examination	Presentation	poroforo about 20 min nor -turi	ont Topics -	f the college inter
examination duration and scale	are the posters from the previous poster set	ssion and the topics of the mod	ule.	i the colloquium
Assignment for the Following Curricula	Electrical Engineering: Specialisation Inform Electrical Engineering: Specialisation Contro Aircraft Systems Engineering: Specialisation Computational Science and Engineering: Sp Information and Communication Systems: Networks: Elective Compulsory Information and Communication Syste Compulsory International Management and Engineer Compulsory Mechatronics: Technical Complementary Co Microelectronics and Microsystems: Speci	ation and Communication Syste of and Power Systems Engineeri Avionic Systems: Elective Com ecialisation I. Computer Science Specialisation Secure and Dep ms: Specialisation Commun ing: Specialisation II. Inform ourse: Elective Compulsory alisation Communication and	ems: Elective ng: Elective pulsory e: Elective C bendable IT ication Sys ation Techn Signal Proc	e Compulsory Compulsory ompulsory Systems, Focus stems: Elective ology: Elective essing: Elective

Course L0899: Selected Topics of Communication Networks		
Тур	Project-/problem-based Learning	
Hrs/wk	2	
СР	2	
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28	
Lecturer	Prof. Andreas Timm-Giel	
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: Commu	nication Networks
Тур	Lecture
Hrs/wk	2
СР	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	WiSe
Content	
Literature	 Skript des Instituts für Kommunikationsnetze Tannenbaum, Computernetzwerke, Pearson-Studium
	Further literature is announced at the beginning of the lecture.

Course L0898: Commu	nication Networks Excercise
Тур	Project-/problem-based Learning
Hrs/wk	1
СР	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Andreas Timm-Giel
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 M0881: N	lathematical Image Processing	I		
-				
Courses				
Title Mathematical Image Proces Mathematical Image Proces	ssing (L0991) ssing (L0992)	Typ Lecture Recitation Section (small)	Hrs/wk 3 1	CP 4 2
Module Responsible	Prof. Marko Lindner			
Admission Requirements	None			
Recommended Previous Knowledge	 Analysis: partial derivatives, gradient, Linear Algebra: eigenvalues, least squ 	directional derivative ares solution of a linear system	I	
Educational Objectives	After taking part successfully, students have	reached the following learning	results	
Professional				
competence	Students are able to			
Knowledge	 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 met	nods of image processing		
SKIIS	 explain and apply modern methods of 	image processing		
Personal Competence				
Social Competence	Students are able to work together in hete study programs and background knowledge)	rogeneously composed teams and to explain theoretical foun	(i.e., team idations.	s from differei
Autonomy	 Students are capable of checking the can specify open questions precisely a Students have developed sufficient per oriented manner on hard problems. 	ir understanding of complex co ind know where to get help in s ersistence to be able to work f	oncepts on olving them or longer pe	their own. The n. eriods in a goa
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 - Ge Computer Science: Specialisation III. Mathem Computational Science and Engineering: Spe Mechatronics: Technical Complementary Cou Mechatronics: Specialisation Intelligent Syste Mechatronics: Specialisation System Design: Technomathematics: Specialisation I. Mather Theoretical Mechanical Engineering: Technic Theoretical Mechanical Engineering: Spe Compulsory Theoretical Mechanical Engineering: Spe Compulsory Process Engineering: Specialisation Process P	eneral Bioprocess Engineering: natics: Elective Compulsory cialisation III. Mathematics: Ele urse: Elective Compulsory ems and Robotics: Elective Com- Elective Compulsory natics: Elective Compulsory al Complementary Course: Elec cialisation Robotics and Co- cialisation Numerics and Co-	Elective Cor ctive Comp pulsory tive Compu mputer Sc mputer Sc	npulsory ulsory isory ience: Electiv ience: Electiv

Course L0991: Mathem	atical Image Processing
Тур	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		
Тур	Recitation Section (small)	
Hrs/wk	1	
СР	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 M0781: E	MC II: Signal Integrity and P	ower Supply of Electro	nic Syste	ems
Courses				
Title EMC II: Signal Integrity and EMC II: Signal Integrity and EMC II: Signal Integrity and	Power Supply of Electronic Systems (L0770) Power Supply of Electronic Systems (L0771) Power Supply of Electronic Systems (L0774)	Typ Lecture Recitation Section (small) Practical Course	Hrs/wk 3 1 1	CP 4 1 1
Module Responsible	Prof. Christian Schuster			
Admission Requirements	None			
Recommended Previous Knowledge	Fundamentals of electrical engineering			
Educational Objectives	After taking part successfully, students h	ave reached the following learning	results	
Professional Competence				
Knowledge	Students are able to explain the fundamental principles, inter-dependencies, and methods of signal and power integrity of electronic systems. They are able to relate signal and power integrity to the context of interference-free design of such systems, i.e. their electromagnetic compatibility. They are capable of explaining the basic behavior of signals and power supply in typical packages and interconnects. They are able to propose and describe problem solving strategies for signal and power integrity issues. They are capable of giving an overview over measurement and simulation methods for characterization of signal and power integrity in electrical engineering practice.			
Skills	Students are able to apply a series of m behavior in packages and interconnect st most important effects that these model can classify these effects and they can problem solving strategies from these pro engineering practice. The can evaluate th	odeling methods for characterization tructure of electronic systems. They are predicting in terms of signal quantitatively analyze them. The edictions and they can adapt them heir problem solving strategies again	on of electro y are able to and power ey are capa to application inst each oth	omagnetic field determine the integrity. They ble of deriving ons in electrical ner.
Personal Competence				
Social Competence	Students are able to work together on su their results effectively in English (e.g. du	ubject related tasks in small group: Iring CAD exercises).	s. They are	able to present
Autonomy	Students are capable to gather necessary information from the references provided 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, communications, and semiconductor circuit design). They can communicate problems and solutions in the field of signal integrity and power supply of interconnect and packages in English.			
Workload in Hours	I Independent Study Time 110, Study Time	e in Lecture 70		
Credit points	6			
Course achievement	CompulsorigonusFormYesNonePresentation	Description		
Examination	Oral exam			
Examination duration and scale	45 min			
Assignment for the Following Curricula	Electrical Engineering: Specialisation Compatibility: Elective Compulsory Electrical Engineering: Specialisation Compulsory Mechatronics: Technical Complementary Microelectronics and Microsystems: Spec	Microwave Engineering, Optic Nanoelectronics and Microsyste Course: Elective Compulsory ialisation Microelectronics Complen	rs, and E ms Techno nents: Electi	lectromagnetic logy: Elective ve Compulsory

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Course L0770: EMC II: Signal Integrity and Power Supply of Electronic Systems		
Тур	Lecture	
Hrs/wk	3	
СР	4	
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42	
Lecturer	Prof. Christian Schuster	
Language	DE/EN	
Cycle	WiSe	
	- The role of packages and interconnects in electronic systems	
	- Components of packages and interconnects in electronic systems	
	- Main goals and concepts of signal and power integrity of electronic systems	
	- Repeat of relevant concepts from the theory electromagnetic fields	
	- Properties of digital signals and systems	
Content	- Design and characterization of signal integrity	
	- Design and characterization of power supply	
	- Techniques and devices for measurements in time- and frequency-domain	
	- CAD tools for electrical analysis and design of packages and interconnects	
	- Connection to overall electromagnetic compatibility of electronic systems	
	- J. Franz, "EMV: Störungssicherer Aufbau elektronischer Schaltungen", Springer (2012)	
	- R. Tummala, "Fundamentals of Microsystems Packaging", McGraw-Hill (2001)	
	- S. Ramo, J. Whinnery, T. Van Duzer, "Fields and Waves in Communication Electronics", Wiley (1994)	
Literature	- S. Thierauf, "Understanding Signal Integrity", Artech House (2010)	
	- M. Swaminathan, A. Engin, "Power Integrity Modeling and Design for Semiconductors and Systems", Prentice-Hall (2007)	

Course L0771: EMC II: Signal Integrity and Power Supply of Electronic Systems		
Тур	Recitation Section (small)	
Hrs/wk	1	
СР	1	
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14	
Lecturer	Prof. Christian Schuster	
Language	DE/EN	
Cycle	WiSe	
Content	See interlocking course	
Literature	See interlocking course	

Course L0774: EMC II: Signal Integrity and Power Supply of Electronic Systems		
Тур	Practical Course	
Hrs/wk	1	
СР	1	
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14	
Lecturer	Prof. Christian Schuster	
Language	DE/EN	
Cycle	WiSe	
	- The role of packages and interconnects in electronic systems	
	- Components of packages and interconnects in electronic systems	
	- Main goals and concepts of signal and power integrity of electronic systems	
	- Repeat of relevant concepts from the theory electromagnetic fields	
	- Properties of digital signals and systems	
Content	- Design and characterization of signal integrity	
	- Design and characterization of power supply	
	- Techniques and devices for measurements in time- and frequency-domain	
	- CAD tools for electrical analysis and design of packages and interconnects	
	- Connection to overall electromagnetic compatibility of electronic systems	
	- J. Franz, "EMV: Störungssicherer Aufbau elektronischer Schaltungen", Springer (2012)	
	- R. Tummala, "Fundamentals of Microsystems Packaging", McGraw-Hill (2001)	
	- S. Ramo, J. Whinnery, T. Van Duzer, "Fields and Waves in Communication Electronics", Wiley (1994)	
Literature	- S. Thierauf, "Understanding Signal Integrity", Artech House (2010)	
	- M. Swaminathan, A. Engin, "Power Integrity Modeling and Design for Semiconductors and Systems", Prentice-Hall (2007)	

Module M1150: C	Continuum Mechanics			
Courses				
Title Continuum Mechanics (L153 Continuum Mechanics Exerc	33) cise (L1534)	Typ Lecture Recitation Section (small)	Hrs/wk 2 2	CP 3 3
Module Responsible	Prof. Christian Cyron			
Admission Requirements	None			
Recommended Previous Knowledge	Basics of linear continuum mechanics as taught, e stress, linear strain, free-body principle, linear-ela	e.g., in the module Mechar stic constitutive laws, stra	nics II (forces in energy).	and moments
Educational Objectives	After taking part successfully, students have reac	hed the following learning	results	
Professional Competence				
Knowledge	The students can explain the fundamental concepts to calculate the mechanical behavior of materials.			
Skills	The students can set up balance laws and apply basics of deformation theory to specific aspects, both in applied contexts as in research contexts.			
Personal Competence				
Social Competence	The students are able to develop solutions, to develop ideas further.	present them to speciali	sts in writter	n form and to
Autonomy	The students are able to assess their own strengths and weaknesses. They can independently and on their own identify and solve problems in the area of continuum mechanics and acquire the knowledge required to this end.			
Workload in Hours	Independent Study Time 124, Study Time in Lectu	ire 56		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	45 min			
Assignment for the Following Curricula	Materials Science: Specialisation Modeling: Elective Compulsory Mechanical Engineering and Management: Specialisation Materials: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory			

Course L1533: Continu	um Mechanics
Тур	Lecture
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christian Cyron
Language	DE
Cycle	WiSe
Content	 kinematics of undeformed and deformed bodies balance equations (balance of mass, balance of energy,) stress states material modelling
Literature	R. Greve: Kontinuumsmechanik: Ein Grundkurs für Ingenieure und Physiker I-S. Liu: Continuum Mechanics, Springer

Course L1534: Continu	um Mechanics Exercise
Тур	Recitation Section (small)
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christian Cyron
Language	DE
Cycle	WiSe
Content	 kinematics of undeformed and deformed bodies balance equations (balance of mass, balance of energy,) stress states material modelling
Literature	R. Greve: Kontinuumsmechanik: Ein Grundkurs für Ingenieure und Physiker I-S. Liu: Continuum Mechanics, Springer

Module M1336: S	Soft Computing - Introduction to Machine	e Learning		
Courses				
Title Soft Computing - Introduction	ion to Machine Learning (L1869) Lecture		Hrs/wk 4	CP 6
Module Responsible	Prof. Karl-Heinz Zimmermann			
Admission Requirements	None			
	Bachelor in Computer Science.			
Recommended Previous Knowledge	Basics in higher mathematics are inevitable, like ca optimization.	lculus, linear alg	ebra, graph	theory, and
Educational Objectives	After taking part successfully, students have reached the f	following learning I	results	
Professional Competence				
Knowledge	Students are able to formalize, compute, and analyze hidden Markov models, phylogenetic tree models, classica networks, and fuzzy controllers.	belief networks, al regression and o	alignments clustering me	of sequences ethods, neura
Skills	Students can apply the relevant algorithms and determine the statistics language R.	e their complexity,	and they ca	n make use of
Personal Competence				
Social Competence	Students are able to solve specific problems alone or in a g	group and to prese	nt the result	s accordingly.
Autonomy	Students are able to acquire new knowledge from new knowledge to other fields.	er literature and	to associate	the acquired
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 II: Intelligence Engineerin International Management and Engineering: Specialisa Compulsory Mechatronics: Specialisation Intelligent Systems and Robot Mechatronics: Specialisation System Design: Elective Comp Mechatronics: Technical Complementary Course: Elective C Theoretical Mechanical Engineering: Technical Complement Theoretical Mechanical Engineering: Specialisation Ro Compulsory Theoretical Mechanical Engineering: Specialisation Nu Compulsory	ng: Elective Compo ation II. Informat tics: Elective Comp pulsory Compulsory ntary Course: Elect obotics and Con umerics and Cor	ulsory ion Technolo pulsory ive Compulso nputer Scien nputer Scien	ogy: Elective ory nce: Elective nce: Elective

Course L1869: Soft Computing - Introduction to Machine Learning			
Тур	Lecture		
Hrs/wk	4		
CP	6		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Lecturer	Prof. Karl-Heinz Zimmermann, Dr. Mehwish Saleemi		
Language	DE/EN		
Cycle	WiSe		
Content	Students are able to formalize, compute, and analyze belief networks, alignments of sequences, hidden Markov models, phylogenetic tree models, neural networks, and fuzzy controllers. In particular, inference and learning in belief networks are important topics that the students should be able to master. Students can apply the relevant algorithms and determine their complexity, and they can make use of the statistics language R.		
Literature	 David Barber, Bayes Reasoning and Machine Learning, Cambridge Univ. Press, Cambridge, 2012. Volker Claus, Stochastische Automaten, Teubner, Stuttgart, 1971. Ernst Klement, Radko Mesiar, Endre Pap, Triangular Norms, Kluwer, Dordrecht, 2000. Timo Koski, John M. Noble, Bayesian Networks, Wiley, New York, 2009. Dimitris Margaritis, Learning Bayesian Network Model Structure from Data, PhD thesis, Carnegie Mellon University, Pittsburgh, 2003. Hidetoshi Nishimori, Statistical Physics of Spin Glasses and Information Processing, Oxford Univ. Press, London, 2001. James R. Norris, Markov Chains, Cambridge Univ. Press, Cambridge, 1996. Maria Rizzo, Statistical Computing with R, Chapman & Hall/CRC, Boca Raton, 2008. Peter Sprites, Clark Glymour, Richard Scheines, Causation, Prediction, and Search, Springer, New York, 1993. Raul Royas, Neural Networks, Springer, Berlin, 1996. Lior Pachter, Bernd Sturmfels, Algebraic Statistics for Computational Biology, Cambridge Univ. Press, Cambridge, 2005. David A. Sprecher, From Algebra to Computational Algorithms, Docent Press, Boston, 2017. Karl-Heinz Zimmermann, Algebraic Statistics, TubDok, Hamburg, 2016. 		

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Thesis

Module M-002: M	aster Thesis
Courses	
Title	Typ Hrs/wk CP
Module Responsible	Professoren der TUHH
Admission Requirements	According to General Regulations §21 (1):
	At least 60 credit points have to be achieved in study programme. The examinations board decides on exceptions.
Recommended Previous Knowledge	
Educational Obiectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	 The students can use specialized knowledge (facts, theories, and methods) of their subject competently on specialized issues. The students can explain in depth the relevant approaches and terminologies in one or more areas of their subject, describing current developments and taking up a critical position on them. The students can place a research task in their subject area in its context and describe and
	critically assess the state of research. The students are able:
Skills	 To select, apply and, if necessary, develop further methods that are suitable for solving the specialized problem in question. To apply knowledge they have acquired and methods they have learnt in the course of their studies to complex and/or incompletely defined problems in a solution-oriented way. To develop new scientific findings in their subject area and subject them to a critical assessment.
Personal Competence	
	Students can
Social Competence	 Both in writing and orally outline a scientific issue for an expert audience accurately, understandably and in a structured way. Deal with issues competently in an expert discussion and answer them in a manner that is appropriate to the addressees while upholding their own assessments and viewpoints convincingly.
	Students are able:
Autonomy	 To structure a project of their own in work packages and to work them off accordingly. To work their way in depth into a largely unknown subject and to access the information required for them to do so. To apply the techniques of scientific work comprehensively in research of their own.
Workload in Hours	Independent Study Time 900, Study Time in Lecture 0
Credit points	30
Course achievement	None
Examination Examination duration and scale	According to General Regulations
	Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy and Environmental Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory
	Aircraft Systems Engineering: Thesis: Compulsory

J Assignment for the Following Curricula I I I I I I I I I I I I I I I I I I I	oint European Master in Environmental Studies - Cities and Sustainability: Thesis: Compulsory _ogistics, Infrastructure and Mobility: Thesis: Compulsory Materials Science: Thesis: Compulsory Mathematical Modelling in Engineering: Theory, Numerics, Applications: Thesis: Compulsory Mechanical Engineering and Management: Thesis: Compulsory Mechatronics: Thesis: Compulsory Biomedical Engineering: Thesis: Compulsory Microelectronics and Microsystems: Thesis: Compulsory Product Development, Materials and Production: Thesis: Compulsory Renewable Energies: Thesis: Compulsory Naval Architecture and Ocean Engineering: Thesis: Compulsory Ship and Offshore Technology: Thesis: Compulsory Teilstudiengang Lehramt Metalltechnik: Thesis: Compulsory Theoretical Mechanical Engineering: Thesis: Compulsory	
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· ·	Water and Environmental Engineering: Thesis: Compulsory Certification in Engineering & Advisory in Aviation: Thesis: Compulsory	
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