

Module Manual

Master of Science

Mechatronics

Cohort: Winter Term 2018

Updated: 25th October 2018

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Module Manual

Master

Mechatronics

Cohort: Winter Term 2018

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Program description

Content

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

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

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: E	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 studie require but are not able to cover fully. Self-reliance, self-management, collaboration an professional and personnel management competences. The department implements thes training objectives in its teaching architecture , in its teaching and learning arrangements , i teaching areas and by means of teaching offerings in which students can qualify by opting for specific competences and a competence level at the Bachelor's or Master's level. Th teaching offerings are pooled in two different catalogues for nontechnical complementar courses.
	The Learning Architecture
	consists of a cross-disciplinarily study offering. The centrally designed teaching offering ensures that courses in the nontechnical academic programms follow the specific profiling of TUHH degree courses.
	The learning architecture demands and trains independent educational planning as regard the individual development of competences. It also provides orientation knowledge in the form of "profiles".
	The subjects that can be studied in parallel throughout the student's entire study program - need be, it can be studied in one to two semesters. In view of the adaptation problems that individuals commonly face in their first semesters after making the transition from school to university and in order to encourage individually planned semesters abroad, there is no obligation to study these subjects in one or two specific semesters during the course of studies.
	Teaching and Learning Arrangements
	provide for students, separated into B.Sc. and M.Sc., to learn with and from each other across semesters. The challenge of dealing with interdisciplinarity and a variety of stages of learning in courses are part of the learning architecture and are deliberately encouraged in specific courses.
Knowledge	Fields of Teaching
omedge	are based on research findings from the academic disciplines cultural studies, social studies arts, historical studies, communication studies, migration studies and sustainability research and from engineering didactics. In addition, from the winter semester 2014/15 students on a Bachelor's courses will have the opportunity to learn about business management and start ups in a goal-oriented way.
	The fields of teaching are augmented by soft skills offers and a foreign language offer. Here the focus is on encouraging goal-oriented communication skills, e.g. the skills required b outgoing engineers in international and intercultural situations.
	The Competence Level

[8]



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

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

Courses

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



Module M0563: Robotics

Courses							
Title				Тур		Hrs/wk	СР
Robotics: Modelling and C	Control (L0168)			Lecture		3	3
Robotics: Modelling and C	Control (L1305)			Recitation Section	n (small)	2	3
Module Responsible	Prof. Uwe We	Itin					
Admission Requirements	None						
	Fundamentals	of electrical er	ngineering				
Recommended	Broad knowle	dge of mechan	ics				
Previous Knowledge	Fundamentals	s of control theo	ry				
Educational Objectives	After taking pa	art successfully,	students have re	ached the follow	ving lea	rning resu	lts
Professional Competence							
Knowledge	Students are multiple probl	able to describ ems in robotics	e fundamental p	roperties of robo	ots and	solution a	pproaches
	Students are a	able to derive a	nd solve equatior	ns of motion for v	various	manipulate	ors.
Skills	Students can	generate trajec	tories in various c	coordinate syster	ms.		
	Students can	design linear ai	nd partially nonlir	near controllers f	or robo	tic manipu	lators.
Personal Competence							
Social Competence	Students are a	able to work go:	al-oriented in sma	all mixed groups			
	Students are a	able to recogniz	ze and improve kr	nowledge deficits	s indep	endently.	
Autonomy	With instructor a further cours	r assistance, stu se of study.	udents are able to	o evaluate their c	own kno	owledge le	vel and defi
Workload in Hours	Independent	Study Time 110	, Study Time in Le	ecture 70			
Credit points	6						
Course achievement	None						
Examination	Written exam						
Examination duration and scale	120 min						
Assignment for the Following Curricula	Aircraft Syster Computational Elective Comp International Compulsory International Compulsory International Production: El Mechanical E Mechatronics:	ence: Specialis ns Engineering I Science and Julsory Production M Management Management iective Compuls ngineering and Core qualificat elopment, Mat	ation intelligence : Specialisation A Engineering: Spe anagement: Spe and Engineering sory Management: Co tion: Compulsory erials and Proc	Engineering: El Aircraft Systems: ecialisation Syste ecialisation Pro ng: Specialisation : Specialisation ore qualification: duction: Special	ective (Elective ems En oduction on II. II. Pro : Compt isation	Compulsor Compuls agineering Mechatro oduct Deve ulsory Product	y ory and Roboti ogy: Electi nics: Electi elopment a Developme

Prod	uct Development,	Materials	and	Production:	Specialisation	Production:	Elective
Com	oulsory						
Prod	uct Development,	Materials	and	Production:	Specialisation	Materials:	Elective
Com	oulsory						
Theo	retical Mechanical	Engineerin	g: Sp	ecialisation P	roduct Develop	ment and Pr	oduction
Elect	ive Compulsory						
Theo	retical Mechanical	Engineering	: Tech	inical Comple	mentary Course	: Elective Co	mpulsory

Course L0168: Roboti	cs: Modelling and Control
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: Finite Elements Methods

Title			Τνρ	Hrs/wk	СР
Finite Element Methods (L	_0291)		Lecture	2	3
Finite Element Methods (L	_0804)		Recitation Section	n (large) 2	3
Module Responsible	Prof. Otto von Estorff				
Admission Requirements	None				
Recommended Previous Knowledge	Mechanics I (Statics, M Dynamics) Mathematics I, II, III (in pa	lechanics of Materia articular differential e	ls) and Mechani quations)	cs II (Hydrostatics	s, Kinematics
Educational Objectives	After taking part success	fully, students have r	eached the follow	ving learning resul	ts
Professional					
Competence					
Knowledge	The students possess an in-depth knowledge regarding the derivation of the finite element method and are able to give an overview of the theoretical and methodical basis of the method.				
Skills	The students are capa elements, assembling th equations.	ble to handle engin le corresponding sys	neering problems tem matrices, and	s by formulating d solving the resul	suitable finit ting system c
Personal Competence					
Social Competence	Students can work in sm	all groups on specifie	c problems to arri	ve at joint solution	S.
Autonomy	The students are able develop own finite elem scrutinized.	to independently s ent routines. Probler	solve challenging ns can be identif	g computational p ied and the result	oroblems and s are criticall
Workload in Hours	Independent Study Time	e 124, Study Time in I	_ecture 56		
Credit points	6				
Course achievement	Compulsory Bonus No 20 %	Form Midterm	De	scription	
Examination	Written exam				
Examination duration and scale	120 min				
	Civil Engineering: Core of Energy Systems: Core q Aircraft Systems Enginee Aircraft Systems Enginee	qualification: Compu ualification: Elective ering: Specialisation ering: Specialisation	lsory Compulsory Aircraft Systems: Air Transportatior	Elective Compulso	ory e Compulsor

	Computational Science and Engineering: Specialisation Scientific Computing: 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	Biomedical Engineering: Specialisation Implants and Endoprostheses: Compulsory						
	Biomedical Engineering: Specialisation Management and Business Administration: Elective						
	Compulsory						
	Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective						
	Compulsory						
	Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective						
	Compulsory						
	Product Development, Materials and Production: Core qualification: Compulsory						
	Technomathematics: Specialisation III. Engineering Science: Elective Compulsory						
	Technomathematics: Core qualification: Elective Compulsory						
	Theoretical Mechanical Engineering: Core qualification: Compulsory						

Course L0291: Finite 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	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
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: Control Systems Theory and Design

Courses				
Title		Тур	Hrs/wk	СР
Control Systems Theory a	and Design (L0656)	Lecture	2	4
Control Systems Theory a	and Design (L0657)	Recitation Sectior	ı (small) 2	2
Module Responsible	Prof. Herbert Werner			
Admission Requirements	None			
Recommended Previous Knowledge	Introduction to Control Systems			
Educational Objectives	After taking part successfully, students have	e reached the follow	ing learning resul	ts
Professional Competence				
Knowledge	 Students can explain how linear models; they can interpret the syster trajectories in state space They can explain the system prorelationship to state feedback and set They can explain the significance or They can explain observer-based tracking and disturbance rejection They can explain the z-transform ar They can explain state space more systems They can explain the experimental and how the identification problem They can explain how a state space more systems 	dynamic systems a em response to initia perties controllabili state estimation, resp f a minimal realisati state feedback and multi-input multi-ou nd its relationship wi dels and transfer fu l identification of AF can be solved by so ce model can be c	re represented a I states or externa ty and observabi bectively on how it can be us tput systems th the Laplace Tra inction models of RX models of dyna lving a normal equ onstructed from a	s state space I excitation as lity, and their ed to achieve ansform discrete-time amic systems, uation discrete-time
Skills	 Students can transform transfer fuversa They can assess controllability and They can design LQG controllers fo They can carry out a controller domain, and decide which is approximated to the control of the can identify transfer function r from experimental data They can carry out all these task Toolbox, System Identification Tool 	unction models into observability and co r multivariable plan design both in cor opriate for a given sa nodels and state sp ks using standard box, Simulink)	state space mod onstruct minimal ra- s ttinuous-time and ampling rate ace models of dyr software tools (N	dels and vice ealisations discrete-time namic systems latlab Control
Personal Competence		·~		
Social Competence	Students can work in small groups on spec	cific problems to arriv	ve at joint solution	S.
Autonomy	Students can obtain information from documentation, experiment guides) and us They can assess their knowledge in wee progress.	n provided sourd se it when solving gi kly on-line tests an	es (lecture not ven problems. d thereby control	tes, software their learning



Workload in Hours	Independent Study Time 124, Study Time in Lecture 56	
Credit points	6	
Course achievement	None	
Examination	Written exam	
Examination duration and scale	120 min	
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Core qualification: Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Computational Science and Engineering: Specialisation Kernfächer Ingenieurswissenschaften (2 Kurse): Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Biomedical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Compulsory	

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

Course L0657: Control Systems Theory and Design	
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

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Module M1106: V	ibration Theory (GES)			
Courses				
Courses		T		
Vibration Theory (GES) (I	1423)	Typ	Hrs/wk	CP 2
Vibration Theory (GES) (L	.1433)	Recitation Section (large)	1	3
Module Responsible	Prof. Norbert Hoffmann			
Admission	None			
Requirements				
Recommended				
Educational				
Objectives	After taking part successfully, students have re	eached the following lea	rning result	S
Professional Competence				
Compoteneo	The primary purpose of the study of Vibration	Theory is to develop th	e canacity t	o understan
	vibrations and the capacity to analyse, mea needed by the engineers involved in the supporting structures, vehicles, aircraft, etc.The	asure, predict and cont analysis and design e particular objectives o	rol vibration of machine f this course	ns, which is and thei are to:
Knowledge	1. Analyse mechanical structures taking i	nto account the effects of	of dynamic l	oads.
	 Appreciate the importance of vibration Formulate and solve the equations of 	in structures and mecha motion of mechanical sy	anical devic vstems.	es.
	Determine the natural frequencies and systems.	normal modes of	complex	mechanica
	At the end of this course the student should be	able to:		
	 Develop simple mathematical mode formulate and solve the equation of mode Carry out the linearization of equations 	ls for vibration analys ption to determine the dy s of motion.	is of comp mamic resp	lex systems onse.
Skills	 Determine natural frequencies and r continuous systems (rods, shafts, taut s Carry out modal analysis to predict systems to external excitations. Analyse, in terms of eigenvalues, systems. 	normal modes of multi strings, beams). the dynamic respons stability of time-ir	-degree-of- e of linear avariant line	freedom an mechanica ear dynami
Personal				
Competence				
Social Competence	Students can work in small groups and report	on the findings.		
Autonomy	Students are able to solve the problems indep	endently.		
Workload in Hours	Independent Study Time 138, Study Time in Lo	ecture 42		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	2 hours: 2. MDOF systems: Newton- Euler systems: eigenvalue problem, general solution forced vibrations. Continuous systems. Energy	r and Lagrange's equa on and stability. Linear I v methods or random vib	tions of m MDOF system prations.	otion. Linea ms: free and
Assignment for the	Mechanical Engineering and Management: Sp Mechatronics: Core qualification: Compulsory	pecialisation Mechatron	ics: Elective	Compulsor

Following Curricula Technomathematics: Core qualification: Elective Compulsory

Course L1423: Vibratio	on Theory (GES)	
Тур	Lecture	
Hrs/wk	2	
СР	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Lecturer	Prof. Norbert Hoffmann	
Language	EN	
Cycle	WISE SYSTEMS WITH FINITE NUMBER OF DEGREES OF ERFEDOM	
	(MULTI- DEGREE-OF-FREEDOM SYSTEMS)	
	 Revision of the theory of single-degree-of -freedom systems. Equations of motion of a single rigid body and of multi-body systems: 2.1. Newton- Euler equations 2.2. Lagrange's equations. 	
	3.Linearization of equations of motion.	
	4.Linear equations of motion in a state-space form. Transformation of coordinates.	
	5.Linear systems: eigenvalue problem (eigenvalues and eigenvectors).	
	6. General solution for time-invariant linear systems and stability of those systems.	
	7. Linear systems: eigenvalue problem, free vibrations, natural frequencies, normal	
	modes (mode shapes).	
Content	8. Forced vibrations of linear systems.	
	LINEAR CONTINUOUS SYSTEMS:	
	9. Longitudinal vibrations of a rod and torsional vibrations of a shaft:	
	9.1. Eigenvalue problem, free vibrations, natural frequencies, normal	
	modes (mode shapes).	
	9.2. Forced vibrations.	
	10. Transverse vibrations of a beam and of a taut string:	
	10.1. Eigenvalue problem, free vibrations, natural frequencies, normal	
	modes (mode shapes).	
	10.2. Forced vibrations.	
	1. S.S. Rao, Mechanical Vibrations, Addison-Wesley, 3rd edition, 1995.	
	2. C.F. Beards, Engineering Vibration Analysis with Application to Control Systems, Edward Arnold, 1995.	
Literature	3. M. Geradin, D.Rixen, Mechanical Vibrations. Theory and Application to Structural Dynamics, J. Wiley, 1994.	
	4. K. Klotter, Technische Schwingungslehre I, II, Springer Verlag, 1981.	

Course L1433: Vibration Theory (GES)	
Тур	Recitation Section (large)
Hrs/wk	1
СР	3
Workload in Hours	Independent Study Time 76, Study Time in Lecture 14
Lecturer	Prof. Norbert Hoffmann
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course



Module M1222: Design and Implementation of Software Systems

Courses				
Title		Тур	Hrs/wk	СР
Design and Implementation of Software Systems (L1657)		Lecture	2	3
Design and Implementatio	on of Software Systems (L1658)	Practical Course	2	3
Module Responsible	Prof. Bernd-Christian Renner			
Admission Requirements	None			
Recommended Previous Knowledge	 Imperativ programming languages (Simple data types (integer, double, and function calls 	C, Pascal, Fortran or similar) char, boolean), arrays, if-ther	n-else, for, wh	ile, procedure
Educational Objectives	After taking part successfully, students	s have reached the following	learning resu	lts
Professional				
Competence				
Knowledge	Students are able to describe mechatronic systems and define requirements.			
Skills	Students are able to design and implement mechatronic systems. They are able to argue the combination of Hard- and Software and the interfaces.			
Personal Competence				
Social Competence	Students are able to work goal-oriented in small mixed groups, learning and broadening teamwork abilities and define task within the team.			
Autonomy	Students are able to solve individually exercises related to this lecture with instructional direction. Students are able to plan, execute and summarize a mechatronic experiment.			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6	6		
Course achievement	None			
Examination	Written exam			
Examination duration and scale	90 min			
Assignment for the Following Curricula	Mechatronics: Core qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory			



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 M0565: N	lechatronic System	ns				
Courses						
Title Electro- and Contromecha	anics (L0174)		Tyr Lec Boo) ture	Hrs/wk 2	CP 2
Mechatronics Laboratory	(L0196)		Proj	ject-/problem-based rning	2	2
Module Responsible	Prof. Uwe Weltin					
Admission Requirements	None					
Recommended Previous Knowledge	Fundamentals of mechar	nics, electron	nechanics an	nd control theory		
Educational Objectives	After taking part successf	fully, students	s have reach	ed the following lea	Irning resu	lts
Professional Competence						
Knowledge	Students are able to de optimize mechatronic sys	escribe meth stems and ca	nods and ca In repeat met	Iculations to designation to the designation of the design term of the design of the d	ın, model, validate mo	simulate and odels.
Skills	Students are able to plar mechatronic systems and	n and execu d derive simu	te mechatror Ilations and o	nic experiments. Stu optimizations.	udents are	able to mode
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 instructiona direction.					
	Students are able to plan	udents are able to plan, execute and summarize a mechatronic experiment.				
Workload in Hours	Independent Study Time	110, Study 7	ime in Lectu	re 70		
Credit points	6					
Course achievement	Compulsory Bonus Yes None	Form Subject practical w	theoretical ork	Descriptio and	on	
Examination	Written exam					
Examination duration and scale	90 min					
Assignment for the Following Curricula	Aircraft Systems Enginee Aircraft Systems Engine Compulsory Mechatronics: Core quali	ering: Specia eering: Specia ification: Cor	lisation Aircra cialisation A npulsory	aft Systems: Elective vionic and Embe	e Compuls dded Sysi	ory tems: Elective



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- 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 [®] und Simulink [®]	
	Controller Design (Linear, Nonlinear, Observer)	
Content	Parameter identification	
	Control of a real system with a realtimeboard and Simulink $^{f B}$ RTW	
Literature	- Abhängig vom Versuchsaufbau	
	- Depends on the experiment	



Module M1211: Research Project Mechatronics Courses Title Hrs/wk СР Тур Module Responsible Prof. Uwe Weltin Admission None Requirements Recommended Subjects of the program of studies. **Previous Knowledge** Educational After taking part successfully, students have reached the following learning results Objectives 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. 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 Skills application has to be adjusted. General findings and further developments may essentially be outlined. Personal 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 Social Competence group. They can lead the discussion and give a feedback on the project to their colleagues. The students are capable of independently planning and documenting the work steps and procedures while considering the given deadlines. This includes the ability to accurately procure the newest scientific information. Furthermore, they can obtain feedback from experts Autonomy 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** It. FSPO and scale Assignment for the Mechatronics: Core qualification: Compulsory **Following Curricula**



1

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	Approxima [®]	tion and Sta	ability			
Courses						
Title Approximation and Stabilit Approximation and Stabilit	y (L0487) y (L0488)			Typ Lecture Recitation Section (small)	Hrs/wk 3 1	CP 4 2
Module Responsible	Prof. Marko L	ndner				
Admission Requirements	None					
Recommended Previous Knowledge	 Linear singul Analys 	[•] Algebra: syste ar values sis: sequences,	ems of linear eo series, differentia	uations, least squares ation, integration	problems,	eigenvalues,
Educational Objectives	After taking pa	art successfully,	, students have re	eached the following lea	rning resul	ts
Professional Competence						
Knowledge	Students are sketch name name discus	able to and interrelate and understanc and explain bas s spectral quan	basic concepts of d concrete approp sic stability theory tities, conditions	of functional analysis (Hi kimation methods, ems, numbers and methods o	lbert space of regularis	e, operators), ation
Skills	Students are apply apply apply apply compu apply	able to basic results fro approximation r stability theoren ute spectral qua regularisation n	om functional ana methods, ns, ntities, nethods.	lysis,		
Personal Competence						
Social Competence	Students are appropriately	able to solve (e.g. as a semin	e specific probl nar presentation)	ems in groups and t	o present	their results
Autonomy	 Stude own. 1 them. Stude a goal 	nts are capable They can specify nts have develo -oriented mann	e of checking the y open questions oped sufficient pe er on hard proble	eir understanding of con precisely and know wh rsistence to be able to w ems.	mplex cond ere to get h vork for long	cepts on their ielp in solving ger periods in
Workload in Hours	Independent	Study Time 124	, Study Time in L	ecture 56		



Credit points	6						
Course achievement	Compulsor Yes	y Bonus None	Form Presentation		Description		
Examination	Oral exam						
Examination duration and scale	20 min						
Assignment for the Following Curricula	Electrical En Electrical En Computation Compulsory Mathematica Numerics (T Mechatronic Technomath Theoretical Elective Con Theoretical I	gineering: Sp gineering: Sp al Science al Modelling UHH): Electiv s: Specialisat ematics: Spe Mechanical npulsory Mechanical E	ecialisation C becialisation M and Engineerin e Compulsory ion Intelligent cialisation I. M Engineering: Te	ontrol and Powe odeling and Sim ring: Specialisa g: Theory, Nun Systems and Ro athematics: Elec Specialisation chnical Comple	r Systems: Elective nulation: Elective ation Scientific nerics, Application botics: Elective Compulsory Numerics and mentary Course:	ve Compuls Compulsory Computing: ons: Specia Compulsory Computer Elective Co	ory / Elective lisation I. Science: mpulsory

Course L0487: Approx	imation 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 convolution and Toeplitz operators crash course on C*-algebras convergence of spectral quantities: spectrum, eigen values, singular values,
Literature	 regularisation methods (truncated SVD, Tichonov) 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	



Module M0714: Numerical Treatment of Ordinary Differential Equations Courses Title Hrs/wk СР Тур Numerical Treatment of Ordinary Differential Equations (L0576) Lecture 3 2 Numerical Treatment of Ordinary Differential Equations (L0582) Recitation Section (small) 2 3 Module Responsible Prof. Sabine Le Borne Admission None Requirements Mathematik I, II, III für Ingenieurstudierende (deutsch oder englisch) oder Analysis & Recommended Lineare Algebra I + II sowie Analysis III für Technomathematiker **Previous Knowledge** Basic MATLAB knowledge Educational After taking part successfully, students have reached the following learning results Objectives Professional Competence Students are able to list numerical methods for the solution of ordinary differential equations and explain their core ideas. repeat convergence statements for the treated numerical methods (including the Knowledge prerequisites tied to the underlying problem), explain aspects regarding the practical execution of a method. • select the appropriate numerical method for concrete problems, implement the .

numerical algorithms efficiently and interpret the numerical results 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 composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms.
	Students are capable
Autonomy	 to assess whether the supporting theoretical and practical excercises are better solved individually or in a team, to assess their individual progress and, if necessary, to ask questions and seek help.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6

Course achievement None

Skills



Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Mathematical Modelling in Engineering: Theory, Numerics, Applications: Specialisation I. Numerics (TUHH): Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0576: Numer	ical 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. Sabine Le Borne, Dr. Patricio Farrell
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. Sabine Le Borne, Dr. Patricio Farrell	
Language	DE/EN	
Cycle	SoSe	
Content	See interlocking course	
Literature	See interlocking course	



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 re	eached the following le	arning resul	ts
Professional Competence	Students are able to reflect existing terms	and concepts in Neu	alinoar Dyn	amios and to
Knowledge	develop and research new terms and concept Students are able to apply existing methods	and concepts in Nor ts. and procesures of No	onlinear Dyn	namics and to
Personal	develop novel methods and procedures.			
Competence				
Social Competence	Students can reach working results also in gro Students are able to approach given researc	oups. h tasks individually an	d to identify	and follow up
Autonomy	novel research tasks by themselves.			
Workload in Hours	Independent Study Time 124, Study Time in L	ecture 56		
	0 Nono			
Fxamination	Written exam			
Examination duration				
and scale	2 Hours			
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation A Computational Science and Engineering: Compulsory International Management and Engineeri Compulsory Mechanical Engineering and Management: S Mechatronics: Specialisation System Design: Mechatronics: Specialisation Intelligent Syste Biomedical Engineering: Specialisation Artific Compulsory Biomedical Engineering: Specialisation Impla Biomedical Engineering: Specialisation Med Compulsory Biomedical Engineering: Specialisation Med Compulsory Biomedical Engineering: Specialisation Man Compulsory Product Development, Materials and Producti Theoretical Mechanical Engineering: Technic	Aircraft Systems: Electiv Specialisation Scient ng: Specialisation II. pecialisation Mechatro Elective Compulsory ms and Robotics: Elect cial Organs and Regen ints and Endoprosthese dical Technology and agement and Busines on: Core qualification: al Complementary Cou alification: Elective Cou	ve Compulse tific Compute Mechatron nics: Elective ive Compulse erative Med es: Elective Control The s Administra Elective Con urse: Elective mpulsory	ory ting: Elective nics: Elective e Compulsory icine: Elective Compulsory eory: Elective ation: Elective ation: Elective



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.



Module M0840: Optimal and Robust Control

Title			Тур		Hrs/wk	СР
Optimal and Robust Conti	ol (L065	8)	Lecture		2	3
Optimal and Robust Conti	ol (L065	9)	Recitatio	n Section (small)	2	3
Module Responsible	Prof. H	erbert Werner				
Admission Requirements	None					
Recommended Previous Knowledge	• •	Classical control (fre State space methods Linear algebra, sing	quency response, root loci s ular value decomposition	(ยน		
Educational Objectives	After ta	king part successfully	v, students have reached th	ne following lea	rning resu	lts
Professional Competence						
Knowledge	• • • • • • • • • • • • • • • • • • • •	Students can explain LQ problems. They can explain the estimation. They can explain ho performance constra They can explain ho an H2 design proble They can explain ho to robust controller d They can explain ho guarantee stability a They understand ho represented as linear	he duality between optim w the H2 and H-infinity no ints. w an LQG design problem m. w model uncertainty can be esign w - based on the small nd performance for an unc w analysis and synthesis r matrix inequalities.	atrix Riccati eq nal state feed orms are used t n can be formu be represented gain theorem - ertain plant. conditions on	uation for back and to represen ilated as s in a way t a robust feedback	the solution optimal sta nt stability a pecial case hat lends its controller c loops can
Skills	• • •	Students are capable models. They are capable of generalized plant, and They are capable of loops into constraint sensitivity design. They are capable of and of designing a m They are capable of inequalities (LMI), and They can carry out a toolbox).	e of designing and tuning f representing a H2 or H-i nd of using standard softwa translating time and freq s on closed-loop sensitivity f constructing an LFT unce nixed-objective robust cont f formulating analysis and of using standard LMI-so II of the above using standard	LQG controlle infinity design p are tools for solv uency domain y functions, and ertainty model roller. d synthesis con plvers for solvin ard software too	rs for mult problem in ving it. specificatio l of carryin for an unc nditions as g them. pls (Matlab	ivariable pla the form o ons for cont g out a mixe certain syste s linear mat robust cont
Personal Competence						
Social Competence	Studer	nts can work in small g	groups on specific problem	is to arrive at joi	int solution	IS.
Autonomy	Studer softwa	nts are able to find re re documentation) an	equired information in sou d use it to solve given prob	rces provided blems.	(lecture no	otes, literatu

Workload in Hours Independent Study Time 124, Study Time in Lecture 56

Workload in Hours	Independent Study Time 124, Study Time in Lecture 56	
Credit points	6	
Course achievement	None	
Examination	Oral exam	
Examination duration and scale	30 min	
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: 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 M1145: Automation and Simulation

Titlo		Typ	Hrewk	CP
Automation and Simulation	n (l 1525)	i yp Lecture	nis/wk 3	СР 3
Automation and Simulation	n (L1527)	Recitation Section (large)	2	3
Module Responsible	NN			
Admission Requirements	None			
Recommended Previous Knowledge	BSc Mechanical Engineering or simi	lar		
Educational Objectives	After taking part successfully, students	have reached the following lea	rning resu	lts
Professional				
Competence				
	Students can describe the structure a components, the data transfer via bus	n the function of process comp systems an programmable logic	uters, the o c computer	correspondin s .
Knowledge	They can describe the basich princ parameters.	siple of a numeric simulation	and the o	correspondin
	Thy can explain the usual method machines.	to simulate the dynamic be	haviour o	t three-phas
	Students can describe and design sim	ple controllers using establishe	d methode	es.
	They are able to assess the basic evaluate, if it is adequate for a given p	characterisitcs of a given aut lant.	tomation s	system and t
Skills	They can modell and simulate techn and can use Matlab/Simulink for the si	ical systems with respect to th mulation.	eir dynami	cal behaviou
	They are able to applay established m three-phase machines.	ethods for the caclulation of the	e dynamica	al behaviour o
Personal				
Competence				
Social Competence	i leamwork in small teams.	and of motional surfaces in	الملح في الم	of outcome?
Autonomy	systems, to do these analysisis in an a	dequate manner und to evalua	te the resul	lts critically.
Workload in Hours	Independent Study Time 110, Study T	ime in Lecture 70		
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and scale	Vorzugsweise in Dreier-Gruppen, etw	a 1 Stunde		
	Energy Systems: Core qualification: E Aircraft Systems Engineering: Special Aircraft Systems Engineering: Special	lective Compulsory isation Cabin Systems: Elective isation Aircraft Systems: Elective	Compulso e Compulse	ry ory

	Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory
	International Management and Engineering: Specialisation II. Energy and Environmental
	Engineering: Elective Compulsory
	International Management and Engineering: Specialisation II. Aviation Systems: Elective
Assignment for the	Compulsory
Following Curricula	International Management and Engineering: Specialisation II. Product Development and
	Production: Elective Compulsory
	Mechatronics: Specialisation System Design: Elective Compulsory
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory
	Product Development, Materials and Production: Specialisation Product Development:
	Elective Compulsory
	Product Development, Materials and Production: Specialisation Production: Elective
	Compulsory
	Product Development, Materials and Production: Specialisation Materials: Elective
	Compulsory

Course L1525: Automation and Simulation		
Тур	Lecture	
Hrs/wk	3	
СР	3	
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42	
Lecturer	NN	
Language	DE	
Cycle	SoSe	
	Structure of automation systsems	
	Aufbau von Automationseinrichtungen	
	Structure and function of process computers and corresponding componentes	
	Data transfer via bus systems	
Content	Programmable Logic Computers	
Contoni	Methods to describe logic sequences	
	Prionciples of the modelling and the simulation of continous technical systems	
	Practical work with an established simulation program (Matlab/Simulink)	
	Simulation of the dynamic behaviour of a three-phase maschine, simulation of a mixed continous/discrete system on base of tansistion flow diagrams.	
	U. Tietze, Ch. Schenk: Halbleiter-Schaltungstechnik; Springer Verlag	
Literature	R. Lauber, P. Göhner: Prozessautomatisierung 2, Springer Verlag	
	Färber: Prozessrechentechnik (Grundlagen, Hardware, Echtzeitverhalten), Springer Verlag	
	Einführung/Tutorial Matlab/Simulink - verschiedene Autoren	



Course L1527: Automation and Simulation	
Тур	Recitation Section (large)
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	NN
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course



Module M1156: Systems Engineering

Courses				
Title		Тур	Hrs/wk	СР
Systems Engineering (L1	547)	Lecture	3	4
Systems Engineering (L1	548)	Recitation Section (large)	1	2
Module Responsible	Prof. Ralf God			
Admission Requirements	None			
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: • Aircraft Cabin Systems			
Educational Objectives	After taking part successfully, students h	ave reached the following lea	rning resul	lts
Professional				
Competence				
Knowledge	 Students are able to: understand systems engineering process models, methods and tools for the development of complex Systems describe innovation processes and the need for technology Management explain the aircraft development process and the process of type certification for aircraft explain the system development process, including requirements for systems reliability identify environmental conditions and test procedures for airborne Equipment value the methodology of requirements-based engineering (RBE) and model-based requirements engineering (MBRE) 			
Skills	Students are able to: • plan the process for the development of complex Systems • organize the development phases and development Tasks • assign required business activities and technical Tasks • apply systems engineering methods and tools			
Personal				
Competence				
Social Competence	Students are able to: • understand their responsibilities within their role in the overall process	n a development team and ir	ntegrate the	emselves with
Autonomy	Students are able to: • interact and communicate in a development team which has distributed tasks			
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 Minutes			
	Aircraft Systems Engineering: Core qual	lification: Compulsory		

	International Management and Engineering: Specialisation II. Aviation Systems: Elective
	Compulsory
	International Management and Engineering: Specialisation II. Product Development and
	Production: Elective Compulsory
	Mechatronics: Specialisation System Design: Elective Compulsory
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory
Assignment for the	Product Development, Materials and Production: Specialisation Product Development:
Following Curricula	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 Aircraft Systems Engineering: Elective
	Compulsory

Course L1547: Systems Engineering		
Тур	Lecture	
Hrs/wk	3	
CP	4	
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42	
Lecturer	Prof. Ralf God	
Language	DE	
Cycle	SoSe	
Content	The objective of the lecture with the corresponding exercise is to accomplish the prerequisites for the development and integration of complex systems using the example of commercial aircraft and cabin systems. Competences in the systems engineering process, tools and methods is to be achieved. Regulations, guidelines and certification issues will be known. Key aspects of the course are processes for innovation and technology management, system design, system integration and certification as well as tools and methods for systems engineering: • Innovation processes • IP-protection • Technology management • Systems engineering • Aircraft program • Certification issues • Systems development • Safety objectives and fault tolerance • Environmental and operating conditions • Tools for systems engineering • Requirements-based engineering (MBRE) • 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 Regulati	ions)		
Courses			
Title	Тур Н	rs/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 learn	ing result	S
Professional Competence Knowledge	see selected module according to FSPO		
Skills	see selected module according to FSPO		
Personal Competence Social Competence	see selected module according to FSPO		
Autonomy	see selected module according to FSPO		
Workload in Hours	Depends on choice of courses		
Credit points	6		
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective	Compuls	ory

TUHH Hamburg University of Tachnolog

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

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Title	Тур	Hrs/wk	СР
Applied Automation (L1592)	Project-/problem-based Learning	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 Engineering (MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Process Measurement Engineering (L1077)	Lecture	2	3
Process Measurement Engineering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medical Technology (L0664)	Lecture	2	3
Six Sigma (L1130)	Lecture	2	3
Applied Dynamics (L1630)	Lecture	2	3
Reliability in Engineering Dynamics (L0176)	Lecture	2	2
Reliability in Engineering Dynamics (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 reached the following learning results
Professional Competence	
Knowledge	 Students are able to express their extended knowledge and discuss the connection of different special fields or application areas of mechatronics Students are qualified to connect different special fields with each other
Skills	 Students can apply specialized solution strategies and new scientific methods in selected areas Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches
Personal Competence	
Social Competence	None
Autonomy	 Students are able to develop their knowledge and skills by autonomous election of courses.
Workload in Hours	Depends on choice of courses
Credit points	12
Assignment for the	Mechatronics: Specialisation System Design: Elective Compulsory



Following Curricula Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

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	SoSe	
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 John Wüey & Sons, Inc., 1992	



Course L1512: Develo	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 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	90 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: Micros	systems 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, RIE, Bosch process, cryo process, XeF2 etching) Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Organi microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping) Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: thermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, IR sensor: thermopile and bolometer) Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistive, piezoresistive, 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, plance dectroking principle of biosensor, Clark electrode, enzyme electode, DNA chip) Micro Actuators, Microfluidics and TAS (drives: thermal, electrostance, microvalves: passive and active, micropumps, valveless micropump, electrokin

	fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L1551: Model-Based Systems Engineering (MBSE) with SysML/UML	
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 L1077: Proces	ss 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	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	 Process measurement engineering in the context of process control engineering Challenges of process measurement engineering Instrumentation of processes Classification of pickups Systems theory in process measurement engineering Generic linear description of pickups Mathematical description of two-port systems Fourier and Laplace transformation Correlational measurement Wide band signals Auto- and cross-correlation function and their applications Fault-free operation of correlational methods Transmission of analog and digital measurement signals Modulation process (amplitude and frequency modulation) Multiplexing Analog to digital converter
Literature	 Färber: "Prozeßrechentechnik", Springer-Verlag 1994 Kiencke, Kronmüller: "Meßtechnik", Springer Verlag Berlin Heidelberg, 1995 A. Ambardar: "Analog and Digital Signal Processing" (1), PWS Publishing Company, 1995, NTC 339 A. Papoulis: "Signal Analysis" (1), McGraw-Hill, 1987, NTC 312 (LB) M. Schwartz: "Information Transmission, Modulation and Noise" (3,4), McGraw-Hill, 1980, 2402095 S. Haykin: "Communication Systems" (1,3), Wiley&Sons, 1983, 2419072 H. Sheingold: "Analog-Digital Conversion Handbook" (5), Prentice-Hall, 1986, 2440072 J. Fraden: "AIP Handbook of Modern Sensors" (5,6), American Institute of Physics, 1993, MTB 346

Course L1083: Process Measurement Engineering	
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	
Lecturer	Johannes Kreuzer, Christian Neuhaus
Language	DE
Cycle	SoSe
Content	 Taking an engineering point of view, the lecture is structured as follows. Introduction to the topic with selected examples Physiology - introduction and overview Regeneration of functions of the cardiovascular system Regeneration of the respiratory functions Closed loop control in anesthesia regeneration of kidney and liver functions regeneration of motorize function/ rehabilitation engineering navigation systems and robotic in medicine The lecture will use knowledge from modeling, simulation and controller design and MATLAB and SIMULINK will be used.
Literature	Silbernagel/Depopoulos: Taschenatlas der Physiologie, Thieme Verlag Stuttgart Werner: Kooperative und autonome Systeme der Medizintechnik, Oldenburg Verlag M.C.K.Khoo:"Physiological Control System", IEEE Press, 2000

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.

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Course L0176: Reliabi	lity 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

TUHH Hamburg University of Tachnolog

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

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Title	Тур	Hrs/wk	СР
Applied Automation (L1592)	Project-/problem-based Learning	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 Engineering (MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Process Measurement Engineering (L1077)	Lecture	2	3
Process Measurement Engineering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medical Technology (L0664)	Lecture	2	3
Six Sigma (L1130)	Lecture	2	3
Applied Dynamics (L1630)	Lecture	2	3
Reliability in Engineering Dynamics (L0176)	Lecture	2	2
Reliability in Engineering Dynamics (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 reached the following learning results
Professional Competence	
Knowledge	 Students are able to express their extended knowledge and discuss the connection of different special fields or application areas of mechatronics Students are qualified to connect different special fields with each other
Skills	 Students can apply specialized solution strategies and new scientific methods in selected areas Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches
Personal Competence	
Social Competence	None
Autonomy	 Students are able to develop their knowledge and skills by autonomous election of courses.
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory



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	SoSe
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 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
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	90 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

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Course L0724: Micros	systems Technology
Тур	Lecture
Hrs/wk	< <u>2</u>
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	1 30 min
Lecturer	Prof. Hoc Khiem Trieu
Language	a EN
Cycle	WiSe
Content	 Introduction (historical view, scientific and economic relevance, scaling laws) Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting) Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) Etching and Bulk Micromachining (definitions, wet chemical etching, isotropic etch with HNA, electrochemical etching, anisotropic etching with KOH/TMAH: theory, corner undercutting, measures for compensation and etch-stop techniques; plasma processes, dry etching: back sputtering, plasma etching, RIE, Bosch process, cryo process, XeF2 etching) Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SUB, 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 and Radiation Sensor: thermopile and blometer) 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: spinning current Hall sensor, Clark electrode, enzyme electode, DNA chip) Micro Actuators, Microfluidics and TAS (drives: thermal, electrokinetic microvalves: passive and active, micropumps, valveless micropump, electrokinetic microvalves: passive and active, micropanalytics) MEMS in medical Engineering (wireless energy and data transm

	fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L1551: Model-Based Systems Engineering (MBSE) with SysML/UML		
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 L1077: Process 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	Prof. Roland Harig	
Language	DE/EN	
Cycle	SoSe	
Content	 Process measurement engineering in the context of process control engineering Challenges of process measurement engineering Instrumentation of processes Classification of pickups Systems theory in process measurement engineering Generic linear description of pickups Mathematical description of two-port systems Fourier and Laplace transformation Correlational measurement Wide band signals Auto- and cross-correlation function and their applications Fault-free operation of correlational methods Transmission of analog and digital measurement signals Modulation process (amplitude and frequency modulation) Multiplexing Analog to digital converter 	
Literature	 Färber: "Prozeßrechentechnik", Springer-Verlag 1994 Kiencke, Kronmüller: "Meßtechnik", Springer Verlag Berlin Heidelberg, 1995 A. Ambardar: "Analog and Digital Signal Processing" (1), PWS Publishing Company, 1995, NTC 339 A. Papoulis: "Signal Analysis" (1), McGraw-Hill, 1987, NTC 312 (LB) M. Schwartz: "Information Transmission, Modulation and Noise" (3,4), McGraw-Hill, 1980, 2402095 S. Haykin: "Communication Systems" (1,3), Wiley&Sons, 1983, 2419072 H. Sheingold: "Analog-Digital Conversion Handbook" (5), Prentice-Hall, 1986, 2440072 J. Fraden: "AIP Handbook of Modern Sensors" (5,6), American Institute of Physics, 1993, MTB 346 	

Course L1083: Process Measurement Engineering	
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		
Lecturer	Johannes Kreuzer, Christian Neuhaus	
Language	DE	
Cycle	SoSe	
Content	 Taking an engineering point of view, the lecture is structured as follows. Introduction to the topic with selected examples Physiology - introduction and overview Regeneration of functions of the cardiovascular system Regeneration of the respiratory functions Closed loop control in anesthesia regeneration of kidney and liver functions regeneration of motorize function/ rehabilitation engineering navigation systems and robotic in medicine The lecture will use knowledge from modeling, simulation and controller design and MATLAB and SIMULINK will be used.	
Literature	Silbernagel/Depopoulos: Taschenatlas der Physiologie, Thieme Verlag Stuttgart Werner: Kooperative und autonome Systeme der Medizintechnik, Oldenburg Verlag M.C.K.Khoo:"Physiological Control System", IEEE Press, 2000	

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

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Module M1269: L	ab Cyber-Physical Systems			
Courses				
Title		Τνρ	Hrs/wk	СР
Lab Cyber-Physical Syste	ems (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 re	eached the following lea	rning result	S
Professional				
Competence	Cuber Bhusiaal Sustama (CBS) are tightly int	encoded with their ourre	unding only	ironmont via
	sensors, A/D and D/A converters, and actors. specialized sensors, processors and actors a of different specification approaches for CPS approaches.	egrated with their surro . Due to their particular are common. Accordingly S - in contrast to classic	application y, there is a cal software	areas, highly large variety engineering
Knowledge	Based on practical experiments using robot ki modelling of CPS are taught. The lab introdu properties) and their specification techniques data flow models, petri nets, imperative app tasks, the lab's experiments will base on simp state-of-the-art industrial specification tools model cyber-physical models that interact with	its and computers, the baces into the area (basic (models of computation roaches). Since CPS fro ble control applications. (MATLAB/Simulink, Lab In the environment via se	asics of spe c notions, ch n, hierarchic equently pe The experin VIEW, NXC ensors and a	cification and laracteristical cal automata, rform control nents will use i) in order to lotors.
Skills	After successful attendance of the lab, stu understand the interdependencies between a from the fact that a CPS interacts with the e processors, D/A converters and actors. The approaches, to evaluate their advantages ar use for a concrete task. They will be able to They obtain first experiences in hardware-rel specification tools and in the area of simple co	dents are able to dev a CPS and its surroundir environment via sensors e lab enables students nd limitations, and to de o apply these technique lated software developm ontrol applications.	elop simple ng processe s, A/D conv s to compa ecide which es to practio nent, in indu	CPS. They s which stem erters, digital re modelling technique to cal problems. ustry-relevant
Personal				
Competence Social Competence	Students are able to solve similar problems accordingly.	alone or in a group ar	nd to prese	nt the results
Autonomy	Students are able to acquire new knowledg knowledge with other classes.	ge from specific literatu	re and to a	ssociate this
Workload in Hours	Independent Study Time 124, Study Time in L	ecture 56		
Credit points	6			
Course achievement	None			
Examination	Written elaboration			
Examination duration and scale	Execution and documentation of all lab exper	iments		
	General Engineering Science (German pro Science: Elective Compulsory	ogram, 7 semester): S	Specialisatio	n Computer



	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory		
	General Engineering Science (English program, 7 semester): Specialisation Computer		
	Science: Elective Compulsory		
Assignment for the	Computational Science and Engineering: Specialisation Computer Science: Elective		
Following Curricula	Compulsory		
	Computational Science and Engineering: Specialisation Mathematics & Engineering Science:		
	Elective Compulsory		
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory		
	Mechatronics: Specialisation System Design: Elective Compulsory		
	Mechatronics: Technical Complementary Course: Elective Compulsory		

Course L1740: Lab Cy	ber-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 M1302: A	Applie	ed Hum	anoid Ro	obotics	i			
Courses								
Title						Тур	Hrs/wk	СР
Applied Humanoid Robotic	Applied Humanoid Robotics (L1794)			Project-/problem-based Learning	6	6		
Module Responsible	Patrick	< Göttsch						
Admission Requirements	None							
Recommended Previous Knowledge		Object or Introduct Control s Mechani	riented prog ion to contro systems theo cs	ramming; ol systems ory and de	algorithi s esign	ns and data structure:	3	
Educational Objectives	After ta	aking part	successfully	y, students	s have re	ached the following le	arning resu	lts
Professional Competence	•							
Knowledge	•	Students Students inverse k Students	can explain can explain cinematics learn to app	n humano n the bas ply basic (id robots ic conce control co	pts, relationships and oncepts for different ta	l methods o sks in huma	f forward- and noid robotics.
Skills	•	Students use these They are necessar They are standard	can implem e models for capable of ry with C++ o capable o methods ar	nent mode r robot mo using mo code on tl of selectin re availab	els for hu otion or o odels in N he real ro g metho le, and a	manoid robotic syster ther tasks. Aatlab for simulation a bot system. ds for solving abstra pply it successfully.	ns in Matlab and testing th ct problems	and C++, and nese models if , for which no
Personal Competence								
Social Competence	•	Students They car on their c	can develo n provide ap own results	p joint sol propriate	utions in feedbac	mixed teams and pre k to others, and cons	sent these. tructively ha	ndle feedback
Autonomy	•	Students to put in i They car	are able to into the cont independe	o obtain re text of the ently define	equired ir lecture. e tasks a	nformation from provid	led literature ate means to	e sources, and o solve them.
Workload in Hours	Indepe	endent Stu	udy Time 96,	, Study Tir	me in Le	cture 84		
Credit points	6							
Course achievement	t None							
Examination	Written	n elaborati	ion					
Examination duration and scale	5-10 p	ages						
Assignment for the Following Curricula	Compu Compu Electiv Mecha Theore	uter Scien utational S ve Compul atronics: S etical Mec	ce: Speciali Science and Isory pecialisatior chanical Eng	isation Inte d Enginee n Intellige gineering	elligence ring: Spe nt Syster : Specia	Engineering: Elective ecialisation Systems I ns and Robotics: Elec lisation Bio- and Mee	Compulsor Engineering tive Compul dical Techno	y and Robotics: sory blogy: Elective



Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1794: Applied Humanoid Robotics				
Тур	Project-/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	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 M1306: Control Lab C

Courses					
Title		Тур		Hrs/wk	СР
Control Lab IX (L1836)		Practic	al Course	1	1
Control Lab VII (L1834)		Practic	al Course	1	1
Control Lab VIII (L1835)		Practic	al Course	1	1
Module Responsible	Prof. Herbert Werner				
Admission Requirements	None				
Recommended Previous Knowledge	 State space method LQG control H2 and H-infinity of uncertain plant model LPV control 	ods optimal control odels and robust control			
Educational Objectives	After taking part successfu	Illy, students have reached	the following lea	rning result	S
Professional Competence					
Knowledge	 Students can expl and experimental 	ain the difference betweer validation	n validation of a	control lop	in simulation
Skills	 Students are capaldentification Tool synthesis They are capable design and implem They are capable the mixed-sensitiv They are capable implementing a ro They are capable the design and the design and the 	able of applying basic sys box) to identify a dynamic of using standard softwar nentation of LQG controllers of using standard software ity design and the impleme le of representing mode bust controller of using standard software implementation of LPV ga	stem identificatio c model that car e tools (Matlab s tools (Matlab Rol ntation of H-infini el uncertainty, a tools (Matlab Rol in-scheduled cor	n tools (Ma be used Control Too bust Contro ty optimal c and of de bust Contro trollers	atlab System for controller blbox) for the I Toolbox) for ontrollers signing and I Toolbox) for
Personal Competence					
Social Competence	 Students can work 	in teams to conduct experi	ments and docur	nent the res	ults
Autonomy	 Students can inde loops 	pendently carry out simulat	ion studies to de	sign and va	lidate control
Workload in Hours	Independent Study Time 4	18, Study Time in Lecture 4	2		
Credit points	3				
Course achievement	None				
Examination	Written elaboration				
Examination duration and scale	1				
Assignment for the Following Curricula	Mechatronics: Specialisat Mechatronics: Specialisat Theoretical Mechanical E	ion Intelligent Systems and ion System Design: Elective ngineering: Core qualificati	Robotics: Elective Compulsory on: Elective Com	ve Compuls	ory



Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

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 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			
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 Vibra	tion (L1743)	Project-/problem-based Learning	4	6
Module Responsible	Prof. Norbert Hoffmann			
Admission Requirements	None			
Recommended Previous Knowledge	Vibration Theory			
Educational Objectives	After taking part successfully, students have	reached the following lea	arning result	íS
Professional Competence				
Knowledge	Students are able to reflect existing terms and research new terms and concepts.	concepts of Advanced Vib	rations and t	o develop and
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 groups.			
Autonomy	Students are able to approach given research research tasks by themselves.	tasks individually and to i	dentify and f	ollow up novel
Workload in Hours	Independent Study Time 124, Study Time in	Lecture 56		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	2 Hours			
Assignment for the Following Curricula	Computational Science and Engineering Compulsory Mechatronics: Specialisation System Design Mechatronics: Specialisation Intelligent Syst Mechatronics: Technical Complementary Co Theoretical Mechanical Engineering: Techn Theoretical Mechanical Engineering: Spec Elective Compulsory	: Specialisation Scienti n: Elective Compulsory tems and Robotics: Electiourse: Elective Compulso ical Complementary Cou cialisation Product Devel	fic Comput ve Compuls ry rse: Elective opment and	ing: Elective ory Compulsory d Production:

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	luma	noid Ro	botics					
Courses								
Title					Тур		Hrs/wk	СР
Humanoid Robotics (L066	63)				Semina	ır	2	2
Module Responsible	Patrick	< Göttsch						
Admission Requirements	None							
Recommended Previous Knowledge	•	Introductio Control th	on to contro eory and de	l systems esign				
Educational Objectives	After ta	aking part s	uccessfully	, students	have reached	the following I	earning resu	lts
Professional Competence								
Knowledge	•	Students o Students I	can explain earn to app	humanoic bly basic co	d robots. ontrol concepts	s for different ta	asks in huma	noid robotics.
Skills	•	Students specified Students Students	acquire kno literature generalize o practice to p	owledge a developed prepare an	bout selected I results and pl id give a prese	aspects of hur resent them to ntation	manoid robo the participa	tics, based or nts
Personal Competence								
Social Competence	•	Students them They are their own	are capable able to pro results	e of devel ovide appl	loping solutior ropriate feedb	is in interdisci ack and hand	plinary team Ile constructi	s and presen ve criticism o
Autonomy	•	Students specific ta Students f presentati	evaluate a sks and sel familiarize t ons of othe	dvantages lect the be hemselves r students,	and drawbac st solution s with a scienti , such that a sc	cks of differen fic field, are ab ientific discuss	t forms of p le of introduc sion develop	resentation fo ce it and follow s
Workload in Hours	Indepe	endent Stud	dy Time 32,	Study Tim	ne in Lecture 2	3		
Credit points	2							
Course achievement	None							
Examination	Preser	ntation						
Examination duration and scale	30 min	ı						
Assignment for the Following Curricula	Electri Mecha Biome Compu Biome Biome Compu	cal Engine atronics: Sp atronics: Sp edical Engir ulsory edical Engir edical Engi ulsory	ering: Spec ecialisation ecialisation neering: Sp neering: Sp neering: Sp	ialisation (n Intelligen n System D ecialisation ecialisation pecialisation	Control and Po t Systems and Design: Elective n Artificial Org n Implants and on Medical Te	wer Systems: Robotics: Elec Compulsory ans and Rege Endoprosthes echnology and	Elective Con ctive Compul nerative Mec ses: Elective d Control Th	npulsory sory licine: Elective Compulsory leory: Elective



Biomedical Engineering: Specialisation Management and Business Administration: Elective
Compulsory
Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory
Theoretical Mechanical Engineering: Core qualification: Elective Compulsory

Course L0663: Humar	noid 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 RegelungstechnikControl systems theory and design
Literature	- B. Siciliano, O. Khatib. "Handbook of Robotics. Part A: Robotics Foundations", Springer (2008).



	mear		minear Sy				
Courses							
Title					Тур	Hrs/wk	СР
Linear and Nonlinear Syst	tem Ider	ntification (LO	660)		Lecture	2	3
Module Responsible	Prof. ⊢	lerbert Wer	ner				
Admission Requirements	None						
Recommended Previous Knowledge	• • •	Classical o State space Discrete-ti Linear algo Basic know	control (freque e methods me systems ebra, singular wledge about s	ncy response value decom stochastic pro	, root locus) position cesses		
Educational Objectives	After ta	aking part si	uccessfully, stu	udents have r	eached the fol	lowing learning res	ults
Professional Competence							
Knowledge	 Students can explain the general framework of the prediction error method and its application to a variety of linear and nonlinear model structures They can explain how multilayer perceptron networks are used to model nonlinear dynamics They can explain how an approximate predictive control scheme can be based on neural network models They can explain the idea of subspace identification and its relation to Kalman realisation theory 						
Skills	 Students are capable of applying the predicition error method to the experimental identification of linear and nonlinear models for dynamic systems They are capable of implementing a nonlinear predictive control scheme based on a neural network model They are capable of applying subspace algorithms to the experimental identification o linear models for dynamic systems They can do the above using standard software tools (including the Matlab System Identification Toolbox) 						
Personal							
Social Competence	Studer	nts can worl	k in mixed grou	ups on specifi	c problems to	arrive at joint soluti	ons.
Autonomy	Studer softwa	nts are able re documer	e to find requination) and us	red informationse it to solve g	on in sources iven problems	provided (lecture r 3.	notes, literatur
Workload in Hours	Indepe	endent Stud	y Time 62, Stu	udy Time in Le	ecture 28		
Credit points	3	3					
Course achievement	None						
Examination	Oral e	xam					
Examination duration and scale	30 mir	1					
	Electri Mecha Mecha	cal Enginee atronics: Spe atronics: Spe	ering: Specialis ecialisation Int ecialisation Sy	sation Contro celligent Syste vstem Design:	l and Power S ms and Robot Elective Com	ystems: Elective Co tics: Elective Compt pulsory	mpulsory ulsory

Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective
Compulsory
Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory
Biomedical Engineering: Specialisation Medical Technology and Control Theory: Compulsory
Biomedical Engineering: Specialisation Management and Business Administration: Elective
Compulsory
Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory
Theoretical Mechanical Engineering: Core qualification: Elective Compulsory

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

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Module M0939: Control Lab A

Courses				
Titlo		Tun	Hrewk	CP
Control Lab I (L1093)		Practical Course	1 11 5/WK	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 co uncertain plant models and LPV control 	ntrol robust control		
Educational Objectives	After taking part successfully, stude	nts have reached the following le	arning resu	Its
Professional Competence				
Knowledge	 Students can explain the d and experimental validation 	ifference between validation of a	a control lop	o in simulation
Skills	 Students are capable of a Identification Toolbox) to it synthesis They are capable of using design and implementation They are capable of using s the mixed-sensitivity design They are capable of re implementing a robust contining the design and the implemented sensitive of the design and the implemented sensitive setting the design and the implemented setting a robust contining the design and the implemented setting setting setting and the implemented setting setting setting and the implemented setting settin	applying basic system identificat dentify a dynamic model that ca standard software tools (Matlab of LQG controllers standard software tools (Matlab R and the implementation of H-infi presenting model uncertainty, roller standard software tools (Matlab R entation of LPV gain-scheduled co	ion tools (N an be used o Control To obust Contro nity optimal and of d obust Contro ontrollers	Matlab System for controller polbox) for the ol Toolbox) for controllers esigning and ol Toolbox) for
Personal Competence				
Social Competence	 Students can work in teams 	to conduct experiments and doc	ument the re	sults
Autonomy	 Students can independently loops 	y carry out simulation studies to d	esign and v	alidate control
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			
	Electrical Engineering: Specialisati	on Control and Power Systems: E	Elective Con	npulsory



TUHH

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: Contro	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: Contro	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 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: Software for Embedded Systems

Courses						
Title		Typ	Hrs/wk	CP		
Software for Embdedded	Systems (L1069)	Lecture	2	3		
Software for Embdedded	Systems (L1070)	Recitation Section (smal) 3	3		
Module Responsible	Prof. Volker Turau					
Admission Requirements	None					
Recommended Previous Knowledge	 Good knowledge and experien Basis knowledge in software er Basic understanding of assemb 	 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 reached the following le	arning resu	lts		
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 Ti	me 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 Con Computational Science and Enginee Technology: Elective Compulsory Information and Communication Syste Focus Software and Signal Processing Information and Communication Sys Software: Elective Compulsory Mechatronics: Technical Complementa Mechatronics: Specialisation Intelligen Mechatronics: Specialisation System E	nputer and Software Engineer ering: Specialisation Informat ms: Specialisation Secure and Elective Compulsory tems: Specialisation Commu ary Course: Elective Compulso t Systems and Robotics: Elect Design: Elective Compulsory	ing: Elective ion and C I Dependat nication Sy pry ive Compul	e Compulsory ommunication ole IT Systems vstems, Focus sory		



Course L1069: Software for Embdedded Systems		
Тур	Lecture	
Hrs/wk	2	
СР	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Lecturer	Prof. Volker Turau	
Language	DE/EN	
Cycle	SoSe	
Content	 General-Purpose Processors Programming the Atmel AVR Interrupts C for Embedded Systems Standard Single Purpose Processors: Peripherals Finite-State Machines Memory Operating Systems for Embedded Systems Real-Time Embedded Systems Boot loader and Power Management 	
Literature	 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. Volker Turau
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course



Module M1248: Compilers for Embedded Systems

Courses				
Title		Тур	Hrs/wk	СР
Compilers for Embedded	Systems (L1692)	Lecture	3	4
Compilers for Embedded Systems (L1693) Project-/problem-based Learning		1	2	
Module Responsible	Prof. Heiko Falk			
Admission Requirements	None			
Pacammandad	Module "Embedded Systems"			
Previous Knowledge	C/C++ Programming skills			
Educational Objectives	After taking part successfully, student	s have reached the following lea	arning resu	lts
Professional				
Knowledge	 The relevance of embedded systems increases from year to year. Within such systems, the amount of software to be executed on embedded processors 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 register allocation is performed, and how memory hierarchies can be exploited effectively. Since compilers for embedded systems often have to optimize for multiple objectives (e.g., average- or worst-case execution time, energy dissipation, code size), the students learn to evaluate the influence of optimizations on these different criteria.			
Skills	After successful completion of the program code into machine code. optimization should be applied most assembly code) within a compiler. While attending the labs, the stude including optimizations.	They will be enabled to asso st effectively at which abstraction ents will learn to implement a	e to transi ess which on level (e fully functi	ate high-leve kind of cod e.g., source c onal compile
Personal				
Competence Social Competence	Students are able to solve similar p accordingly.	roblems alone or in a group a	nd to prese	ent the result
,	Students are able to acquire new k	knowledge from specific literatu	ire and to	associate this

	\sim		
Hamhur	e Elnivar	eitu of	Technology

Autonomy knowledge with other classes.
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Autonomy	knowledge with other classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1692: Compilers 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 M0630: Robotics and Navigation in Medicine Courses Title Hrs/wk СР Тур Robotics and Navigation in Medicine (L0335) Lecture 2 3 2 Robotics and Navigation in Medicine (L0338) **Project Seminar** 2 Robotics and Navigation in Medicine (L0336) Recitation Section (small) 1 1 Module Responsible Prof. Alexander Schlaefer Admission None Requirements principles of math (algebra, analysis/calculus) Recommended principles of programming, e.g., in Java or C++ Previous Knowledge solid R or Matlab skills Educational After taking part successfully, students have reached the following learning results Objectives Professional Competence The students can explain kinematics and tracking systems in clinical contexts and illustrate systems and their components in detail. Systems can be evaluated with respect to collision Knowledge detection and safety and regulations. Students can assess typical systems regarding design and limitations. The students are able to design and evaluate navigation systems and robotic systems for medical applications. Skills Personal Competence The students discuss the results of other groups, provide helpful feedback and can Social Competence incoorporate feedback into their work. The students can reflect their knowledge and document the results of their work. They can Autonomy present the results in an appropriate manner. Workload in Hours Independent Study Time 110, Study Time in Lecture 70 Credit points 6 **Compulsory Bonus** Form Description **Course achievement** Yes 10 % Written elaboration Yes 10 % Presentation **Examination** Written exam **Examination duration** 90 minutes and scale Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: **Elective Compulsory** International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective

Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory

Compulsory

Assignment for the Following Curricula	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: Specialisation Bio- and Medical Technology: Elective
	Compulsory

Course L0335: Robotics 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
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course



Course L0336: Robotics and Navigation in Medicine		
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	



Module M0803: E	mbedded Systems				
Courses					
Title Embedded Systems (L080 Embedded Systems (L080	D5) D6)		Typ Lecture Recitation Section (sma	Hrs/wk 3 all) 1	CP 4 2
Module Responsible	Prof. Heiko Falk				
Admission Requirements	None				
Recommended Previous Knowledge	Computer Engineering				
Educational Objectives	After taking part successfully	y, students have rea	ached the following l	earning resul	ts
Professional Competence					
Knowledge	Embedded systems can be defined as information processing systems embedded into enclosing products. This course teaches the foundations of such systems. In particular, it deals with an introduction into these systems (notions, common characteristics) and their specification languages (models of computation, hierarchical automata, specification of distributed systems, task graphs, specification of real-time applications, translations between different models). Another part covers the hardware of embedded systems: Sonsors, A/D and D/A converters, real-time capable communication hardware, embedded processors, memories, energy				
Skills	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. 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 iudge in which areas of embedded system design specific risks exist				
Personal					
Competence Social Competence	Students are able to solve accordingly.	similar problems a	alone or in a group	and to prese	nt the results
Autonomy	Students are able to acqui knowledge with other classe	ire new knowledge es.	e from specific litera	ture and to a	associate this
Workload in Hours	Independent Study Time 12	4, Study Time in Le	ecture 56		
Credit points	6				
Course achievement	Compulsory BonusFYes10 %p	Form Subject theoret practical work	Descrip ical and	tion	
Examination	Written exam				
Examination duration and scale	90 minutes, contents of cour	rse and labs			
	General Engineering Scie Science: Elective Compulso Computer Science: Speciali	nce (German pro rry sation Computer a	gram, 7 semester): nd Software Enginee	Specialisatio	on Computer Compulsory

	Electrical Engineering: Core qualification: Elective Compulsory				
	Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective				
Assignment for the	Compulsory				
Following Curricula	General Engineering Science (English program, 7 semester): Specialisation Computer				
5	Science: Elective Compulsory				
	Computational Science and Engineering: Core qualification: 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: Embed	ded 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 M0550: D	igital Image Analysis			
Courses				
Title		Тур	Hrs/wk	СР
Digital Image Analysis (L0	126)	Lecture	4	6
Module Responsible	Prof. Rolf-Rainer Grigat			
Admission Requirements	None			
Recommended Previous Knowledge	System theory of one-dimensional interpolation and decimation, Fourie (Eigenvalue decomposition, SVD), influence of sample size, correlation basics of Matlab, basics in optics	signals (convolution and r transform, linear time-inv basic stochastics and and covariance, normal c	l correlation, sar variant systems), statistics (expec distribution and its	npling theory, linear algebra tation values, s parameters),
Educational Objectives	After taking part successfully, student	s have reached the follow	ing learning resu	Its
Professional				
Knowledge Skills	 Students can Describe imaging processes Depict the physics of sensorid Explain linear and non-linear Establish interdisciplinary concontext Interpret effects of the most in mathematical methods and physics Students are able to Use highly sophisticated meth Identify problems and develop Students can solve simple arithmeti image processing and image analysi Students are able to assess different making areas. 	filtering of signals nnections in the subject a mportant classes of imagi nysical models. nods and procedures of the p and implement creative s cal problems relating to t s systems. ent solution approaches al analysis of processes in	area and arrange ng sensors and o e subject area solutions. he specification in multidimensio Matlab.	e them in their displays using and design of onal decision-
Personal Competence Social Competence Autonomy	k.A. Students can solve image analysis ta	isks independently using t	he relevant litera	ture.
Workload in Hours	Independent Study Time 124, Study	Time in Lecture 56		
Credit points	6			
Course achievement	None			



Examination Written exam

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



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Module M0552: 3	D Computer Vision			
Courses				
Title 3D Computer Vision (L012 3D Computer Vision (L013	29) 30)	Typ Lecture Recitation Section (small)	Hrs/wk 2) 2	CP 3 3
Module Responsible	Prof. Rolf-Rainer Grigat			
Admission Requirements	None			
Recommended Previous Knowledge	 Knowlege of the modules Digital In Compression are used in the practic Linear Algebra (including PCA, SVI basics of stochastics and basics of detail during the lecture. 	nage Analysis and Patter al task D), nonlinear optimization Matlab are required and	rn Recognit I (Levenber I cannot be	ion and Data g-Marquardt), explained in
Educational Objectives	After taking part successfully, students have	reached the following lea	arning resul	ts
Professional Competence				
Knowledge	Students can explain and describe the field	of projective geometry.		
Skills	 Implementing an exemplary 3D or vo Using highly sophisticated methods Identifying problems and Developing and implementing creati With assistance from the teacher students areas (modules) Digital Image Analysis Pattern Recognition and Data Comp and 3D Computer Vision in practical assignments. 	olumetric analysis task and procedures of the sul ive solution suggestions. are able to link the cont pression	bject area	three subject
Personal Competence				
Social Competence	Students can collaborate in a small team or reconstruct a three-dimensional scene or to	n the practical realization a evaluate volume data set	and testing ts.	of a system to
Autonomy	Students are able to solve simple tasks in lectures and the exercise sets. Students are able to solve detailed probl programming task.	dependently with referen	ce to the co the aid of	ontents of the the tutorial's
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 material	ls in StudIP		
1				

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

Course L0129: 3D Con	nputer 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 M0623: Intelligent Systems in Medicine

Courses					
Title			Түр	Hrs/wk	СР
Intelligent Systems in Med	licine (L0331)		Lecture	2	3
Intelligent Systems in Medicine (L0334)			Project Seminar	2	2
Intelligent Systems in Mec	licine (L0333)		Recitation Section (small)	1	1
Module Responsible	Prof. Alexander Schlaefe	r			
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 successf	ully, students have re	ached the following lea	rning resul	ts
Professional Competence					
Knowledge	The students are able to analyze and solve clinical treatment planning and decision support problems using methods for search, optimization, and planning. They are able to explain methods for classification and their respective advantages and disadvantages in clinical contexts. The students can compare different methods for representing medical knowledge. They can evaluate methods in the context of clinical data and explain challenges due to the clinical nature of the data and its acquisition and due to privacy and safety requirements.				
Skills	The students can give reasons for selecting and adapting methods for classification, regression, and prediction. They can assess the methods based on actual patient data and evaluate the implemented methods.				
Personal Competence					
Social Competence	The students discuss the results of other groups, provide helpful feedback and can incoorporate feedback into their work.				
Autonomy	The students can reflect their knowledge and document the results of their work. They can present the results in an appropriate manner.				
Workload in Hours	Independent Study Time	110, Study Time in L	ecture 70		
Credit points	6				
Course achievement	Compulsory BonusYes10 %Yes10 %	Form Written elaboration Presentation	Descriptio	on	
Examination	Written exam				
Examination duration and scale	90 minutes				
Assignment for the	Computer Science: Speci Electrical Engineering: Sp Computational Science a Elective Compulsory Mechatronics: Specialisa Biomedical Engineering: Compulsory	ialisation Intelligence pecialisation Medical and Engineering: Spe tion Intelligent Syster Specialisation Artific	Engineering: Elective (Technology: Elective C ecialisation Systems Er ns and Robotics: Electiv ial Organs and Regene	Compulsor compulsory igineering ve Compuls rative Med	y and Robotics: sory icine: Elective

Following Curricula	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				

Course L0331: Intelligent 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 M0633: Industrial Process Automation

Courses					
Title			Тур	Hrs/wk	СР
Industrial Process Automa	ation (L0344)	l	Lecture	2	3
Industrial Process Automa	ation (L0345)		Recitation Section (small)	2	3
Module Responsible	Prof. Alexander Schlaefer				
Admission Requirements	None				
Recommended Previous Knowledge	mathematics and optimization principles of automata principles of algorithms and da programming skills	methods ata structures			
Educational Objectives	After taking part successfully, s	students have rea	ached the following lea	rning resul	ts
Professional					
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 deve involves taking into account o implementation using PLCs.	lop and model p optimal scheduli	processes and evaluate	e them acc prithmic co	ordingly. This mplexity, and
Personal					
Competence					
Social Competence	The students work in teams to	solve problems.			
Autonomy	The students can reflect their k	nowledge and d	ocument the results of t	heir work.	
Workload in Hours	Independent Study Time 124,	Study Time in Le	cture 56		
Credit points	6				
Course achievement	Compulsory BonusForYes10 %Exc	r m cercises	Descriptio	n	
Examination	Written exam				
Examination duration and scale	90 minutes				
	Bioprocess Engineering: Sp Compulsory Chemical and Bioprocess E Elective Compulsory Chemical and Bioprocess Eng Compulsory	ecialisation A - Engineering: Sp jineering: Specia	- General Bioprocess ecialisation Chemical Ilisation General Proce	Engineer Process ss Enginee	ring: Elective Engineering: ering: Elective



Assignment for the	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory
Following Curricula	International Production Management: Specialisation Production Technology: Elective
	Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory
	Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory
	Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science:
	Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory
	Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0344: Industr	ial 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	

Courses				
Title Digital Signal Processing a Digital Signal Processing a	and Digital Filters (L0446) and Digital Filters (L0447)	Typ Lecture Recitation Sectior	Hrs/wk 3 n (large) 1	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 theory as well as random processes. Fundamentals of spectral transforms (Fourier series, Fourier transform, Laplace transform) 			
Educational Objectives	After taking part successfully, students h	nave reached the follow	ving learning resu	lts
Professional Competence				
Knowledge	The students know and understand basic algorithms of digital signal processing. They are familiar with the spectral transforms of discrete-time signals and are able to describe and analyse signals and systems in time and image domain. They know basic structures of digital filters and can identify and assess important properties including stability. They are aware of the effects caused by quantization of filter coefficients and signals. They are familiar with the basics of adaptive filters. They can perform traditional and parametric methods of spectrum estimation, also taking a limited observation window into account.			
Skills	The students are able to apply methods of digital signal processing to new problems. They can choose and parameterize suitable filter striuctures. In particular, the can design adaptive filters according to the minimum mean squared error (MMSE) criterion and develop an efficient implementation, e.g. based on the LMS or RLS algorithm. Furthermore, the students are able to apply methods of spectrum estimation and to take the effects of a limited observation window into account.			
Personal				
Competence				
Social Competence Autonomy	The students can jointly solve specific problems. 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,			
Workload in Hours	Independent Study Time 124, Study Tin	ne in Lecture 56		
Credit points	6 None			
Examination	Written exam			
Examination duration and scale	90 min			
	Computer Science: Specialisation Intell Electrical Engineering: Specialisation Compulsory Electrical Engineering: Specialisation C Computational Science and Engineerin Elective Compulsory Computational Science and	igence Engineering: El Information and Con control and Power Syste ng: Specialisation Syste Engineering:	ective Compulson nmunication Sys ems: Elective Cor ems Engineering Specialisation	ry tems: Elective npulsory and Robotics Kernfäche

	Ingenieurswissenschaften (2 Kurse): Elective Compulsory
Assignment for the	Information and Communication Systems: Specialisation Communication Systems, Focus
Following Curricula	Signal Processing: Elective Compulsory
	Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory
	Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective
	Compulsory
	Microelectronics and Microsystems: Specialisation Communication and Signal Processing:
	Elective Compulsory
	Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science:
	Elective Compulsory
	Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory



Course L0446: Digital	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
Cycle	WiSe
	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
Content	 Characterization of digital filters using pole-zero plots, important properties of digital filters
	Quantization effects
	Design of linear-phase filters
	 Fundamentals of stochastic signal processing and adaptive filters
	• MMSE criterion
	• Wiener Filter
	 LMS- and RLS-algorithm
	Traditional and parametric methods of spectrum estimation
	KD. Kammeyer, K. Kroschel: Digitale Signalverarbeitung. Vieweg Teubner.
	V. Oppenheim, R. W. Schafer, J. R. Buck: Zeitdiskrete Signalverarbeitung. Pearson StudiumA. V.
	W. Hess: Digitale Filter. Teubner.
Literature	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	1	
СР	2	
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14	
Lecturer	Prof. Gerhard Bauch	
Language	EN	
Cycle	WiSe	
Content	See interlocking course	
Literature	See interlocking course	



Module M0832: Advanced Topics in Control

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Courses				
Title		Тур	Hrs/wk	СР
Advanced Topics in Contr	rol (L0661)	Lecture	2	3
Advanced Topics in Contr	rol (L0662)	Recitation Section (sm	all) 2	3
Module Responsible	Prof. Herbert Werner			
Admission Requirements	None			
Recommended Previous Knowledge	H-infinity optimal control, mixed-s	ensitivity design, linear matrix ine	qualities	
Educational Objectives	After taking part successfully, stuc	After taking part successfully, students have reached the following learning results		
Professional Competence				
Knowledge	 Students can explain the scheduling approach They can explain the repsystems They can explain how staformulated as LMI condition They can explain how synthesis problems for LP They are familiar with poly the basic synthesis technic Students can explain he communication topology of They can explain the convolution topology of They can explain the convolution of the systems that are discretized. Students can explain the systems that are discretized. They can explain (in our distributed systems and the systems are systems and the systems and the systems are systems and the systems and the systems are systems are systems and the systems are systems are systems a	he advantages and shortcomin presentation of nonlinear system ability and performance condition ons gridding techniques can be us V systems ytopic and LFT representations o ques associated with each of thes ow graph theoretic concepts a of multiagent systems vergence properties of first order of sis and synthesis conditions for / agent models state space representation of sp ed according to an actuator/senso utine) the extension of the bou he associated synthesis conditions	igs of the s in the form as for LPV sy ed to solve f LPV system are used to consensus pro- for formation patially invari r array nded real less for distribute	classical gain of quasi-LPV ystems can be analysis and s and some of ctures represent the cotocols control loops ant distributed emma to such ed controllers
Skilla	 Students are capable of or mixed-sensitivity design polytopic, LFT or general I They are able to use stan tasks 	constructing LPV models of nonli of gain-scheduled controllers; LPV models idard software tools (Matlab robu	near plants a they can o st control too	Ind carry out a do this using Ibox) for these
Skills	 Students are able to designing either LTI or LPV dynamic 	gn distributed formation controlle s, using Matlab tools provided	rs for groups	of agents with
	 Students are able to design using the Matlab MD-tools 	gn distributed controllers for spatia	Illy interconn	ected systems,



Personal Competence Social Competence Autonomy	Students can work in small groups and arrive at joint results. Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Management and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Advical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory



Course L0661: Advand	ced 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	 EN WiSe Linear Parameter-Varying (LPV) Gain Scheduling Linearizing gain scheduling, hidden coupling Jacobian linearization vs. quasi-LPV models Stability and induced L2 norm of LPV systems Synthesis of LPV controllers based on the two-sided projection lemma Simplifications: controller synthesis for polytopic and LFT models Experimental identification of LPV models Controller synthesis based on input/output models Applications: LPV torque vectoring for electric vehicles, LPV control of a robotic manipulator Control of Multi-Agent Systems Communication graphs Spectral properties of the graph Laplacian First and second order consensus protocols Formation control, stability and performance LPV models for agents subject to nonholonomic constraints Application: formation control for a team of quadrotor helicopters Control of Spatially Interconnected Systems Multidimensional signals, I2 and L2 signal norm Multidimensional systems in Roesser state space form Extension of real-bounded lemma to spatially interconnected systems LMI-based synthesis of distributed controllers 	
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 Statistics				
Courses					
Title Applied Statistics (L1584)			yp ecture	Hrs/wk 2	CP 3
Applied Statistics (L1586)		Pi	roject-/problem-based	2	2
Applied Statistics (L1585)		R	ecitation Section (small)	1	1
Module Responsible	Prof. Michael Morlock				
Admission Requirements	None				
Recommended Previous Knowledge	Basic knowledge of statistical	l methods			
Educational Objectives	After taking part successfully,	students have read	ched the following lea	rning resul	ts
Professional Competence					
Knowledge	Students can explain the statistical methods and the conditions of their use.				
Skills	Students are able to use the statistics program to solve statistics problems and to interpret and depict the results				
Personal					
Social Competence	Team Work, joined presentati	ion of results			
Autonomy	To understand and interpret the question and solve				
Workload in Hours	Independent Study Time 110	, Study Time in Lec	ture 70		
Credit points	6				
Course achievement	Compulsory BonusForYesNoneWesting	orm ritten elaboration	Descriptio	n	
Examination	Written exam				
Examination duration and scale	90 minutes, 28 questions				
Assignment for the Following Curricula	Mechanical Engineering and Mechatronics: Specialisation Mechatronics: Specialisation Biomedical Engineering: Corr Product Development, Materi Theoretical Mechanical Engir Theoretical Mechanical Engir Compulsory	Management: Spe System Design: Ele Intelligent Systems e qualification: Con als and Production neering: Technical ineering: Specialis	cialisation Manageme ective Compulsory and Robotics: Electiv npulsory : Core qualification: El Complementary Cours ation Bio- and Medic	ent: Elective e Compuls lective Con se: Elective cal Techno	e Compulsory sory npulsory e Compulsory logy: Elective



Course L1584: Applied	I 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 t 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	
Examination duration

30 min



Module M1204: N	Iodelling and Optimization	n in Dynamics				
Courses						
Title Flexible Multibody System Optimization of dynamical	ns (L1632) I 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 Sy 	stems				
Educational Objectives	After taking part successfully, stude	ents have reached the followi	ng learning resul	ts		
Professional Competence						
Knowledge	Students demonstrate basic kno analysis of complex rigid and flexi systems after successful completio	wledge and understanding ble multibody systems and m n of the module.	of modeling, si nethods for optimi	mulation and izing dynamic		
	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 optimize dynamics problems					
Personal Competence						
	Students are able to					
Social Competence	+ solve problems in heterogeneou	s groups and to document the	e corresponding r	esults.		
	Students are able to					
	+ assess their knowledge by means of exercises.					
Autonomy	+ acquaint themselves with the ne	cessary knowledge to solve r	esearch oriented	tasks.		
Workload in Hours	Independent Study Time 124, Stud	ly Time in Lecture 56				
Credit points	6					
Course achievement	Inone Oral exam					
	Orarexam					

and scale Energy Systems: Core qualification: Elective Compulsory
Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory



Assignment for the Following Curricula Nechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1632: Flexible	e 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
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	zation of dynamical 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. Leo Dostal
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.

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Module M1229: C	control La	b B				
Courses						
Title Control Lab V (L1667) Control Lab VI (L1668)				Typ Practical Course Practical Course	Hrs/wk 1 1	CP 1 1
Module Responsible	Prof. Herber	t Werner				
Admission Requirements	None					
Recommended Previous Knowledge	 State LQG H2 a unce LPV 	e space methods control nd H-infinity opti rtain plant mode control	mal control Is and robust cor	ntrol		
Educational Objectives	After taking	part successfully	r, students have r	eached the following	learning resu	Its
Professional Competence						
Knowledge	• Stud and	ents can explair experimental val	n the difference b idation	between validation o	f a control lop	o in simulatior
Skills	 Stud Identisynth They desig They the m They imple They the designed 	ents are capable ification Toolbo nesis r are capable of are capable of are capable of nixed-sensitivity r are capable ementing a robus r are capable of esign and the in	le of applying b x) to identify a of tusing standard ntation of LQG co using standard so design and the ir of representing st controller using standard so nplementation of	asic system identific dynamic model that software tools (Matl ntrollers oftware tools (Matlab nplementation of H-ir model uncertaint oftware tools (Matlab LPV gain-scheduled	cation tools (N can be used ab Control To Robust Contr nfinity optimal y, and of d Robust Contr controllers	Matlab System for controlle oolbox) for the ol Toolbox) fo controllers esigning and ol Toolbox) fo
Personal Competence						
Social Competence	 Stud 	ents can work in	teams to conduc	t experiments and do	ocument the re	esults
Autonomy	• Stud	ents can indepe s	ndently carry out	simulation studies to	design and v	alidate contro
Workload in Hours	Independen	t Study Time 32,	Study Time in Le	ecture 28		
Credit points	2					
Course achievement	None					
Examination	Written elab	oration				
Examination duration and scale	1					
Assignment for the Following Curricula	Electrical Er Mechatronic Mechatronic	igineering: Spec s: Specialisatior s: Specialisatior	ialisation Contro Intelligent Syste System Design:	and Power Systems ms and Robotics: Ele Elective Compulsory	: Elective Con ective Compul /	npulsory sory

Course L1667: Control Lab V			
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: Contro	ourse 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			



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Module M1305: S	emin	ar Adv	anced T	Topic	s in Cor	ntrol			
Courses									
Title Advanced Topics in Cont	rol (L180	03)				Typ Seminar		Hrs/wk 2	CP 2
Module Responsible	Prof. H	lerbert We	erner						
Admission Requirements	None								
Recommended Previous Knowledge	•	Introduct Control t optimal a	tion to cont heory and and robust	trol syste I design t control	ems				
Educational Objectives	After ta	aking part	successfu	ılly, stud	lents have	reached the fo	llowing lea	arning resu	lts
Professional Competence									
Knowledge	•	Students Students	s can expla s learn to a	ain mode apply ba	ern control sic control	concepts for d	ifferent tas	ks	
Skills	•	Students specified Students Students	acquire l literature generaliz practice to	knowled ze devel zo prepa	dge about oped resu re and give	selected asp Its and present e a presentatio	ects of m them to th n	odern cont e participa	rol, based o nts
Personal Competence									
Social Competence	•	Students They are their owr	are capat able to p results	ble of de provide	eveloping : appropria	solutions and p te feedback a	oresent the nd handle	m constructi	ve criticism c
Autonomy	•	Students specific t Students presenta	evaluate tasks and s familiarize tions of oth	advant select th e thems her stud	tages and he best soli selves with lents, such	drawbacks of ution a scientific fiel that a scientifi	different f d, are able c discussio	forms of pr of introduc on develop:	resentation fo ce it and follow s
Workload in Hours	Indepe	endent Stu	udy Time 3	32, Stud	y Time in L	ecture 28.			
Credit points	2								
Course achievement	None								
Examination	Prese	ntation							
Examination duration and scale	90 mir	ו							
Assignment for the Following Curricula	Electri Mecha Mecha	cal Engine atronics: S atronics: S	eering: Sp pecialisati pecialisati	ecialisa ion Syst ion Intel	tion Contro em Desigr ligent Syst	ol and Power S n: Elective Com ems and Robo	Systems: E npulsory itics: Electi	lective Con ve Compul	npulsory sory

Course L1803: Advan	ced 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 Dynamics and Roboti	cs					
Courses							
Title Formulas and Vehicles - (L1981)	Typ Mathematics and Mechanics in Autonomous Driving 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 reached the following lea	rning resul	ts				
Professional Competence							
Knowledge	After successful completion of the module students demonstrate understanding in selected application areas of multibody dynamics ar	deeper kn nd robotics	owledge and				
	Students are able						
	+ to think holistically						
Skills	+ to independently, securly and critically analyze and optimize dynamics of rigid and flexible multibody systems	basic pro	blems of the				
	+ to describe dynamics problems mathematically						
	+ to implement dynamical problems on hardware						
Personal							
Competence	Students are able to						
Social Competence	+ solve problems in heterogeneous groups and to document the co present them	orrespondir	ng results and				
	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 Lecture 28						
Credit points	6						
Course achievement	None						
Examination	Presentation						
Examination duration and scale	ТВА						
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Election Mechatronics: Specialisation System Design: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Cour Theoretical Mechanical Engineering: Core qualification: Elective Com	ve Compuls se: Elective pulsory	sory e Compulsory				

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/EN		
Cycle	WiSe		
Content			
	Seifried, R.: Dynamics of underactuated multibody systems, Springer, 2014		
Literature	Popp, K.; Schiehlen, W.: Ground vehicle dynamics, Springer, 2010		



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		Тур	Hrs/wk	СР		
Nonlinear Dynamics (L07		Integrated Lecture	4	6		
Module Responsible	Prof. Norbert Hoffmann					
Admission Requirements	None					
Recommended Previous Knowledge	CalculusLinear AlgebraEngineering Mechanics					
Educational Objectives	After taking part successfully, students have	reached the following le	earning resu	Its		
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 method develop novel methods and procedures.	Students are able to apply existing methods and procesures of Nonlinear Dynamics and to develop novel methods and procedures.				
Personal Competence						
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	Independent Study Time 124, Study Time in Lecture 56				
Credit points	6					
Course achievement	None	None				
Examination	Written exam	Written exam				
Examination duration and scale	2 Hours					
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory					

Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective
Compulsory
Biomedical Engineering: Specialisation Management and Business Administration: Elective
Compulsory
Product Development, Materials and Production: Core qualification: Elective Compulsory
Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory
Theoretical Mechanical Engineering: Core qualification: Elective Compulsory

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.



Module M0803: E	mbedded Systems			
Courses				
Title		Тур	Hrs/wk	СР
Embedded Systems (L08	05)	Lecture	3	4
Embedded Systems (LU8	06)	Recitation Section	(small) 1	2
Module Responsible	Prof. Heiko Falk			
Requirements	None			
Recommended Previous Knowledge	Computer Engineering			
Educational Objectives	After taking part successfully, students ha	ave reached the follow	ing learning resu	Ilts
Professional Competence				
Knowledge	Embedded systems can be defined a enclosing products. This course teaches with an introduction into these syste specification languages (models of co distributed systems, task graphs, specific different models). Another part covers the hardware of em real-time capable communication han dissipation, reconfigurable logic and act real-time operating systems, middle implementation of embedded systems us partitioning, high-level transformation compilers for embedded processors) is c After having attended the course, studen The students shall realize which relevar	as information process the foundations of suc- ems (notions, comm omputation, hierarchic cation of real-time app abedded systems: Sor dware, embedded p uators. The course als eware and real-time sing hardware/software s of specifications, overed. ts shall be able to real at parts of technologica	sing systems e h systems. In par on characteristi cal automata, s plications, transla nsors, A/D and D rocessors, mem so features an in the scheduling. e co-design (hard energy-efficient ize simple ember al competences f	mbedded into ticular, it deals cs) and their pecification o ations between D/A converters nories, energy troduction into Finally, the dware/software t realizations
Personal	judge in which areas of embedded systems	nniques for system-lev m design specific risks	el design. They s exist.	shall be able to
Competence				
Social Competence	Students are able to solve similar probl accordingly.	lems alone or in a gr	oup and to pres	ent the results
Autonomy	Students are able to acquire new know know know know know know know kno	vledge from specific I	iterature and to	associate this
Workload in Hours	Independent Study Time 124, Study Time	e in Lecture 56		
Credit points	6			
• •• •	Compulsory Bonus Form	Des	cription	
Course achievement	Yes 10 % Subject th practical work	eoretical and		
Examination	Written exam			
Examination duration and scale	90 minutes, contents of course and labs			
	General Engineering Science (German Science: Elective Compulsory Computer Science: Specialisation Comp	n program, 7 semes uter and Software Eng	ineering: Elective	tion Computer

	Electrical Engineering: Core qualification: Elective Compulsory
	Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective
Assignment for the	Compulsory
Following Curricula	General Engineering Science (English program, 7 semester): Specialisation Computer
0	Science: Elective Compulsory
	Computational Science and Engineering: Core qualification: 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: 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: 1 Acoustics)	Fechnical Acoustics I (Acoustic Waves, Noise Protection, Psychology	
Courses		
Title Technical Acoustics I (Ac (L0516) Technical Acoustics I (Ac	Typ Hrs/wk CP oustic Waves, Noise Protection, Psycho Acoustics) Lecture 2 3 oustic Waves, Noise Protection, Psycho Acoustics) Desire if the cousting (here) 0 0	
(L0518)	Recitation Section (large) 2 3	
Module Responsible	Prof. Otto von Estorff	
Admission Requirements	None	
Recommended Previous Knowledge	Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics Dynamics) Mathematics I, II, III (in particular differential equations)	
Educational Objectives	After taking part successfully, students have reached the following learning results	
Professional Competence		
Knowledge	The students possess an in-depth knowledge in acoustics regarding acoustic waves, nois protection, and psycho acoustics and are able to give an overview of the correspondin theoretical and methodical basis.	
Skills	The students are capable to handle engineering problems in acoustics by theory-base application of the demanding methodologies and measurement procedures treated within th 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 area treated within the module. Possible conflicting issues and limitations can be identified and th results are critically scrutinized.	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56	
Credit points	6	
Course achievement	None	
Examination	Written exam	
Examination duration and scale	90 min	
Assignment for the Following Curricula	Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elec Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Curricula Technomathematics: Core qualification: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compuls Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compuls Theoretical Mechanical Engineering: Specialisation Product Development and Product Elective Compulsory	

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

Title			Тур	Hrs/wk	СР
Boundary Element Method	ds (L0523)		Lecture	2	3
Boundary Element Method	ds (L0524)		Recitation Section	(large) 2	3
Module Responsible	Prof. Otto von Estorff				
Admission Requirements	None				
Recommended Previous Knowledge	Mechanics I (Statics, Me Dynamics) Mathematics I, II, III (in pa	echanics of Materia articular differential e	uls) and Mechanic quations)	es II (Hydrostatic	s, Kinematic
Educational Objectives	After taking part successf	fully, students have r	reached the follow	ing learning resu	lts
Professional					
Competence					
Knowledge	element method and are the method.	an in-depiri knowle able to give an ov	erview of the theo	retical and metho	odical basis
Skills	The students are capabl elements, assembling the equations.	le to handle engine e corresponding sys	ering problems by stem matrices, and	formulating suita solving the resul	able bounda Iting system
Personal Competence					
Social Competence	Students can work in sma	all groups on specifi	c problems to arriv	e at joint solution	S.
Autonomy	The students are able develop own boundary critically scrutinized.	to independently s element routines. I	solve challenging Problems can be	computational p identified and th	problems ar ne results a
Workload in Hours	Independent Study Time	124, Study Time in I	Lecture 56		
Credit points	6				
Course achievement	Compulsory Bonus No 20 %	Form Midterm	Des	cription	
Examination	Written exam				
Examination duration and scale	90 min				
	Civil Engineering: Specia Civil Engineering: Specia Civil Engineering: Specia Energy Systems: Core qu	alisation Structural E alisation Geotechnic alisation Coastal En ualification: Elective	ngineering: Electiv al Engineering: Elective gineering: Elective Compulsory	ve Compulsory ective Compulsor Compulsory	у

	Computational Science and Engineering: Specialisation Scientific Computing: Elective
	Compulsory
Assignment for the	Mechanical Engineering and Management: Specialisation Product Development and
Following Curricula	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
	Technomathematics: Core qualification: Elective Compulsory
	Theoretical Mechanical Engineering: Core qualification: 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: Mechanical Design Methodology

Courses					
Title			Тур	Hrs/wk	СР
Mechanical Design Metho	dology (L1523)		Lecture	3	4
Mechanical Design Metho	dology (L1524)		Recitation Section (smal	l) 1	2
Module Responsible	Prof. Josef Schlattmann				
Admission Requirements	None				
Recommended Previous Knowledge					
Educational Objectives	After taking part success	fully, students have	e reached the following le	arning resu	Its
Brofossional					
Competence					
Knowledge	Science-based working o design techniques	on product design	considering targeted appl	lication of s	pecific product
Skills	Creative handling of pro product design problen theoretical aspects.	ocesses used for ns / Application	scientific preparation and of various product desi	d formulatio gn techniq	on of complex ues following
Personal Competence					-
Social Competence					
Autonomv					
Workload in Hours	Independent Study Time	124 Study Time i	n Lecture 56		
Credit nointe					
	0				
Course achievement	None				
Examination	Oral exam				
Examination duration and scale	30 min				
	International Manageme	ent and Engineer	ing: Specialisation II. Pr	oduct Dev	elopment and
Assignment for the Following Curricula	Production: Elective Com Mechatronics: Specialisa Biomedical Engineering: Compulsory Biomedical Engineering Compulsory Biomedical Engineering Compulsory Product Development, Elective Compulsory Product Development, Compulsory Product Development, Compulsory Product Development, Compulsory Theoretical Mechanical Elective Compulsory Theoretical Mechanical E	npulsory ation System Desig Specialisation Ar Specialisation Im Specialisation M Specialisation M Materials and F Materials and Materials and Engineering: Spe	gn: Elective Compulsory tificial Organs and Regen plants and Endoprosthese Medical Technology and lanagement and Busines Production: Specialisation Production: Specialisation Production: Specialisation ecialisation Product Deve nical Complementary Cou	erative Mec es: Elective Control Th s Administr n Product on Product tion Mater lopment ar	licine: Elective Compulsory leory: Elective ation: Elective Development: tion: Elective ials: Elective nd Production: e Compulsory



Course L1523: Mechanical Design Methodology				
Тур	Lecture			
Hrs/wk	3			
СР	4			
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42			
Lecturer	Prof. Josef Schlattmann			
Language	DE			
Cycle	SoSe			
Content	 Systematic reflection and analysis of the mechanical design process Process structuring in sections (task, functions, acting principles, design-elements and total construction) as well as levels (working-, controlling-, and deciding-levels) Creativity (basics, methods, practical application in mechatronics) Diverse methods applied as tools (function structure, GALFMOS, AEIOU method, GAMPFT, simulation tools, TRIZ) Evaluation and selection (technical-economical evaluation, preference matrix) Value analysis, cost-benefit analysis Low-noise design of technical products Project monitoring and leading (leading projects / employees, organisation in product development, creating ideas / responsibility and communication) Aesthetic product design (industrial design, colouring, specific examples / exercises) 			
Literature	 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 			



Course L1524: Mechanical Design Methodology			
Тур	Recitation Section (small)		
Hrs/wk	1		
СР	2		
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14		
Lecturer	Prof. Josef Schlattmann		
Language	DE		
Cycle	SoSe		
Content	 Systematic reflection and analysis of the mechanical design process Process structuring in sections (task, functions, acting principles, design-elements and total construction) as well as levels (working-, controlling-, and deciding-levels) Creativity (basics, methods, practical application in mechatronics) Diverse methods applied as tools (function structure, GALFMOS, AEIOU method, GAMPFT, simulation tools, TRIZ) Evaluation and selection (technical-economical evaluation, preference matrix) Value analysis, cost-benefit analysis Low-noise design of technical products Project monitoring and leading (leading projects / employees, organisation in product development, creating ideas / responsibility and communication) Aesthetic product design (industrial design, colouring, specific examples / exercises) 		
Literature	 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 		



Module M1145: Automation and Simulation

Courses				
Title		Тур	Hrs/wk	СР
Automation and Simulation	n (L1525)	Lecture	3	3
Automation and Simulation	ו (L1527)	Recitation Section (large)	2	3
Module Responsible	NN			
Admission Requirements	None			
Recommended Previous Knowledge	BSc Mechanical Engineering or similar			
Educational Objectives	After taking part successfully, students h	ave reached the following lea	arning resu	lts
Professional				
Competence				
	Students can describe the structure an components, the data transfer via bus sy	the function of process comp stems an programmable logi	outers, the o c computer	correspondin s .
Knowladza	They can describe the basich princip parameters.	le of a numeric simulation	and the	correspondin
Khowledge	Thy can explain the usual method to simulate the dynamic behaviour of three-phase machines.			
	Students can describe and design simpl	e controllers using establishe	ed methode	es.
	They are able to assess the basic characterisitcs of a given automation system and to evaluate, if it is adequate for a given plant.			
Skills	They can modell and simulate technical systems with respect to their dynamical behaviour and can use Matlab/Simulink for the simulation.			
	They are able to applay established met three-phase machines.	hods for the caclulation of th	e dynamica	al behaviour d
Personal				
Competence				
Social Competence	Teamwork in small teams.			
Autonomy	Students are able to identify the need systems, to do these analysisis in an add	d of methocic analysises in equate manner und to evalua	the field te the resu	of automation Its critically.
Workload in Hours	Independent Study Time 110 Study Tim	e in Lecture 70		
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and scale	Vorzugsweise in Dreier-Gruppen, etwa 1	Stunde		
	Energy Systems: Core qualification: Elec Aircraft Systems Engineering: Specialisa Aircraft Systems Engineering: Specialisa	tive Compulsory tion Cabin Systems: Elective tion Aircraft Systems: Electiv	Compulso e Compuls	ry ory

	Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory				
	International Management and Engineering: Specialisation II. Energy and Environmental				
	Engineering: Elective Compulsory				
	International Management and Engineering: Specialisation II. Aviation Systems: Elective				
Assignment for the	Compulsory				
Following Curricula	International Management and Engineering: Specialisation II. Product Development and				
	Production: Elective Compulsory				
	Mechatronics: Specialisation System Design: Elective Compulsory				
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory				
	Product Development, Materials and Production: Specialisation Product Development:				
	Elective Compulsory				
	Product Development, Materials and Production: Specialisation Production: Elective				
	Compulsory				
	Product Development, Materials and Production: Specialisation Materials: Elective				
	Compulsory				

Course L1525: Automa	ation and Simulation
Тур	Lecture
Hrs/wk	3
СР	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	NN
Language	DE
Cycle	SoSe
	Structure of automation systsems
	Aufbau von Automationseinrichtungen
	Structure and function of process computers and corresponding componentes
	Data transfer via bus systems
Contont	Programmable Logic Computers
Coment	Methods to describe logic sequences
	Prionciples of the modelling and the simulation of continous technical systems
	Practical work with an established simulation program (Matlab/Simulink)
	Simulation of the dynamic behaviour of a three-phase maschine, simulation of a mixed continous/discrete system on base of tansistion flow diagrams.
	U. Tietze, Ch. Schenk: Halbleiter-Schaltungstechnik; Springer Verlag
	R. Lauber, P. Göhner: Prozessautomatisierung 2, Springer Verlag
Literature	Färber: Prozessrechentechnik (Grundlagen, Hardware, Echtzeitverhalten), Springer Verlag
	Einführung/Tutorial Matlab/Simulink - verschiedene Autoren



Course L1527: Automation and Simulation		
Тур	Recitation Section (large)	
Hrs/wk	2	
СР	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Lecturer	NN	
Language	DE	
Cycle	SoSe	
Content	See interlocking course	
Literature	See interlocking course	



Module M1156: Systems Engineering

Courses				
Title		Тур	Hrs/wk	СР
Systems Engineering (L1	547)	Lecture	3	4
Systems Engineering (L1	548)	Recitation Section (large)	1	2
Module Responsible	Prof. Ralf God			
Admission Requirements	None			
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: • Aircraft Cabin Systems			
Educational Objectives	After taking part successfully, students	have reached the following lea	rning resu	lts
Professional				
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 • organize the development phases an • assign required business activities ar • apply systems engineering methods a	of complex Systems d development Tasks nd technical Tasks and tools		
Personal				
Competence Social Competence	Students are able to: • understand their responsibilities with their role in the overall process	nin a development team and ir	ntegrate the	emselves with
Autonomy	Students are able to: • interact and communicate in a develo	opment team which has distribu	ted tasks	
Workload in Hours	Independent Study Time 124, Study Ti	me in Lecture 56		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	120 Minutes			
	Aircraft Systems Engineering: Core qu	alification: Compulsory		

	International Management and Engineering: Specialisation II. Aviation Systems: Elective
	Compulsory
	International Management and Engineering: Specialisation II. Product Development and
	Production: Elective Compulsory
	Mechatronics: Specialisation System Design: Elective Compulsory
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory
Assignment for the	Product Development, Materials and Production: Specialisation Product Development:
Following Curricula	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 Aircraft Systems Engineering: Elective
	Compulsory

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



Course L1548: Systems Engineering		
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 Regulati	ions)		
Courses			
Title	Тур Н	rs/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 learn	ing result	S
Professional Competence Knowledge	see selected module according to FSPO		
Skills	see selected module according to FSPO		
Personal Competence Social Competence	see selected module according to FSPO		
Autonomy	see selected module according to FSPO		
Workload in Hours	Depends on choice of courses		
Credit points	6		
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective	Compuls	ory

TUHH Hamburg University of Tachnolog

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

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Title	Тур	Hrs/wk	СР
Applied Automation (L1592)	Project-/problem-based Learning	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 Engineering (MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Process Measurement Engineering (L1077)	Lecture	2	3
Process Measurement Engineering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medical Technology (L0664)	Lecture	2	3
Six Sigma (L1130)	Lecture	2	3
Applied Dynamics (L1630)	Lecture	2	3
Reliability in Engineering Dynamics (L0176)	Lecture	2	2
Reliability in Engineering Dynamics (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 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	
Social Competence	None
Autonomy	 Students are able to develop their knowledge and skills by autonomous election of courses.
Workload in Hours	Depends on choice of courses
Credit points	12
Assignment for the	Mechatronics: Specialisation System Design: Elective Compulsory



Following Curricula Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

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	SoSe	
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 John Wüey & Sons, Inc., 1992	



Course L1512: Develo	pment 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
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 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: Micros	ystems Technology
Тур	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration	20 min
and scale	
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, Are 2 etching) Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping) Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: thermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, ralicometry, IR sensor: thermopile and bolometer) Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivi, pressure sensor: piezoresistive, capacitive; angular rate sensor: operating principle and fabrication process; accelerometer; piezoresistive, piezoelectric and capacitive; angular rate sensor: operating principle and fabrication process) Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer) Micro Actuators, Microfluidos and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, microvalves: passive a

	fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L1551: Model-Based Systems Engineering (MBSE) with SysML/UML		
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 L1077: Proces	ss Measurement Engineering
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 Minuten
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	 Process measurement engineering in the context of process control engineering Challenges of process measurement engineering Instrumentation of processes Classification of pickups Systems theory in process measurement engineering Generic linear description of pickups Mathematical description of two-port systems Fourier and Laplace transformation Correlational measurement Wide band signals Auto- and cross-correlation function and their applications Fault-free operation of correlational methods Transmission of analog and digital measurement signals Modulation process (amplitude and frequency modulation) Multiplexing Analog to digital converter
Literature	 Färber: "Prozeßrechentechnik", Springer-Verlag 1994 Kiencke, Kronmüller: "Meßtechnik", Springer Verlag Berlin Heidelberg, 1995 A. Ambardar: "Analog and Digital Signal Processing" (1), PWS Publishing Company, 1995, NTC 339 A. Papoulis: "Signal Analysis" (1), McGraw-Hill, 1987, NTC 312 (LB) M. Schwartz: "Information Transmission, Modulation and Noise" (3,4), McGraw-Hill, 1980, 2402095 S. Haykin: "Communication Systems" (1,3), Wiley&Sons, 1983, 2419072 H. Sheingold: "Analog-Digital Conversion Handbook" (5), Prentice-Hall, 1986, 2440072 J. Fraden: "AIP Handbook of Modern Sensors" (5,6), American Institute of Physics, 1993, MTB 346

Course L1083: Process Measurement Engineering	
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		
Lecturer	Johannes Kreuzer, Christian Neuhaus	
Language	DE	
Cycle	SoSe	
Content	 Taking an engineering point of view, the lecture is structured as follows. Introduction to the topic with selected examples Physiology - introduction and overview Regeneration of functions of the cardiovascular system Regeneration of the respiratory functions Closed loop control in anesthesia regeneration of kidney and liver functions regeneration of motorize function/ rehabilitation engineering navigation systems and robotic in medicine The lecture will use knowledge from modeling, simulation and controller design and MATLAB and SIMULINK will be used.	
Literature	Silbernagel/Depopoulos: Taschenatlas der Physiologie, Thieme Verlag Stuttgart Werner: Kooperative und autonome Systeme der Medizintechnik, Oldenburg Verlag M.C.K.Khoo:"Physiological Control System", IEEE Press, 2000	

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: Reliabi	lity 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	90 min
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

TUHH Hamburg University of Tachnolog

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

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Title	Тур	Hrs/wk	СР
Applied Automation (L1592)	Project-/problem-based Learning	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 Engineering (MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Process Measurement Engineering (L1077)	Lecture	2	3
Process Measurement Engineering (L1083)	Recitation Section (large)	1	1
Feedback Control in Medical Technology (L0664)	Lecture	2	3
Six Sigma (L1130)	Lecture	2	3
Applied Dynamics (L1630)	Lecture	2	3
Reliability in Engineering Dynamics (L0176)	Lecture	2	2
Reliability in Engineering Dynamics (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 reached the following learning results
Professional Competence	
Knowledge	 Students are able to express their extended knowledge and discuss the connection of different special fields or application areas of mechatronics Students are qualified to connect different special fields with each other
Skills	 Students can apply specialized solution strategies and new scientific methods in selected areas Students are able to transfer learned skills to new and unknown problems and can develop own solution approaches
Personal Competence	
Social Competence	None
Autonomy	 Students are able to develop their knowledge and skills by autonomous election of courses.
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory



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	SoSe
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 John Wüey & Sons, Inc., 1992



Course L1512: Develo	pment 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	90 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: Micros
Тур
Hrs/wk
CP
Workload in Hours
Examination Form
Examination duration and scale
Lecturer
Language
Cycle
Content

	fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L1551: Model-Based Systems Engineering (MBSE) with SysML/UML		
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 L1077: Proces	ss 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	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	 Process measurement engineering in the context of process control engineering Challenges of process measurement engineering Instrumentation of processes Classification of pickups Systems theory in process measurement engineering Generic linear description of pickups Mathematical description of two-port systems Fourier and Laplace transformation Correlational measurement Wide band signals Auto- and cross-correlation function and their applications Fault-free operation of correlational methods Transmission of analog and digital measurement signals Modulation process (amplitude and frequency modulation) Multiplexing Analog to digital converter
Literature	 Färber: "Prozeßrechentechnik", Springer-Verlag 1994 Kiencke, Kronmüller: "Meßtechnik", Springer Verlag Berlin Heidelberg, 1995 A. Ambardar: "Analog and Digital Signal Processing" (1), PWS Publishing Company, 1995, NTC 339 A. Papoulis: "Signal Analysis" (1), McGraw-Hill, 1987, NTC 312 (LB) M. Schwartz: "Information Transmission, Modulation and Noise" (3,4), McGraw-Hill, 1980, 2402095 S. Haykin: "Communication Systems" (1,3), Wiley&Sons, 1983, 2419072 H. Sheingold: "Analog-Digital Conversion Handbook" (5), Prentice-Hall, 1986, 2440072 J. Fraden: "AIP Handbook of Modern Sensors" (5,6), American Institute of Physics, 1993, MTB 346

Course L1083: Process Measurement Engineering	
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		
Lecturer	Johannes Kreuzer, Christian Neuhaus	
Language	DE	
Cycle	SoSe	
Content	 Taking an engineering point of view, the lecture is structured as follows. Introduction to the topic with selected examples Physiology - introduction and overview Regeneration of functions of the cardiovascular system Regeneration of the respiratory functions Closed loop control in anesthesia regeneration of kidney and liver functions regeneration of motorize function/ rehabilitation engineering navigation systems and robotic in medicine The lecture will use knowledge from modeling, simulation and controller design and MATLAB and SIMULINK will be used.	
Literature	Silbernagel/Depopoulos: Taschenatlas der Physiologie, Thieme Verlag Stuttgart Werner: Kooperative und autonome Systeme der Medizintechnik, Oldenburg Verlag M.C.K.Khoo:"Physiological Control System", IEEE Press, 2000	

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

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Module M1269: L	ab Cyber-Physical Systems			
Courses				
Title		Τνρ	Hrs/wk	СР
Lab Cyber-Physical Syste	ems (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 re	eached the following lea	rning result	S
Professional				
Competence	Cuber Dhusiaal Custama (CDC) are tightly int			ive a meant with
	sensors, A/D and D/A converters, and actors. specialized sensors, processors and actors a of different specification approaches for CPS approaches.	egrated with their surro . Due to their particular .re common. Accordingly S - in contrast to classic	application y, there is a al software	areas, highly large variety engineering
Knowledge	Based on practical experiments using robot ki modelling of CPS are taught. The lab introdu properties) and their specification techniques data flow models, petri nets, imperative app tasks, the lab's experiments will base on simp state-of-the-art industrial specification tools model cyber-physical models that interact with	its and computers, the baces into the area (basic (models of computation roaches). Since CPS fro ele control applications. (MATLAB/Simulink, Lab In the environment via se	asics of spec notions, ch n, hierarchic equently pe The experim VIEW, NXC nsors and a	cification and laracteristical cal automata, rform control nents will use in order to lotors.
Skills	After successful attendance of the lab, stu understand the interdependencies between a from the fact that a CPS interacts with the e processors, D/A converters and actors. The approaches, to evaluate their advantages ar use for a concrete task. They will be able to They obtain first experiences in hardware-rel specification tools and in the area of simple co	dents are able to dev a CPS and its surroundir environment via sensors a lab enables students ad limitations, and to de b apply these technique lated software developm ontrol applications.	elop simple ng processe s, A/D conve s to compa ecide which es to practio nent, in indu	CPS. They s which stem erters, digital re modelling technique to cal problems. ustry-relevant
Personal				
Competence Social Competence	Students are able to solve similar problems accordingly.	alone or in a group ar	nd to presei	nt the results
Autonomy	Students are able to acquire new knowledg knowledge with other classes.	ge from specific literatu	re and to a	ssociate this
Workload in Hours	Independent Study Time 124, Study Time in L	ecture 56		
Credit points	6			
Course achievement	None			
Examination	Written elaboration			
Examination duration and scale	Execution and documentation of all lab experi	iments		
	General Engineering Science (German pro	ogram, 7 semester): S	Specialisatic	n Computer



	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory
	General Engineering Science (English program, 7 semester): Specialisation Computer
	Science: Elective Compulsory
Assignment for the	Computational Science and Engineering: Specialisation Computer Science: Elective
Following Curricula	Compulsory
	Computational Science and Engineering: Specialisation Mathematics & Engineering Science:
	Elective Compulsory
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory
	Mechatronics: Specialisation System Design: Elective Compulsory
	Mechatronics: Technical Complementary Course: Elective Compulsory

Course L1740: Lab Cy	ber-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: Control Lab C

Courses						
Title				Тур	Hrs/wk	СР
Control Lab IX (L1836)				Practical Course	1	1
Control Lab VII (L1834)				Practical Course	1	1
Control Lab VIII (L1835)				Practical Course	1	1
Module Responsible	Prof. H	lerbert Werner				
Admission Requirements	None					
Recommended Previous Knowledge	•	State space methods LQG control H2 and H-infinity optimal c uncertain plant models and LPV control	control d robust cont	rol		
Educational Objectives	After ta	aking part successfully, stud	ents have rea	ached the following	learning resul	ts
Professional						
Competence						
Knowledge	•	Students can explain the and experimental validatio	difference be n	etween validation o	of a control lop	in simulation
Skills	• • •	Students are capable of Identification Toolbox) to synthesis They are capable of using design and implementation They are capable of using the mixed-sensitivity desig They are capable of m implementing a robust con They are capable of using the design and the implement	applying bas identify a dy g standard so n of LQG con standard sof n and the imp epresenting troller standard sof nentation of L	sic system identific ynamic model that oftware tools (Mat trollers tware tools (Matlab olementation of H-i model uncertaint tware tools (Matlab PV gain-scheduled	cation tools (M can be used lab Control To Robust Contro nfinity optimal of y, and of do Robust Contro controllers	fatlab System for controller olbox) for the ol Toolbox) for controllers esigning and ol Toolbox) for
Personal Competence						
Social Competence	•	Students can work in team	s to conduct	experiments and de	ocument the re	sults
Autonomy	•	Students can independent loops	tly carry out s	imulation studies to	o design and v	alidate control
Workload in Hours	Indepe	endent Study Time 48, Study	y Time in Lec	ture 42		
Credit points	3					
Course achievement	None					
Examination	Writte	n elaboration				
Examination duration and scale	1					
Assignment for the Following Curricula	Mecha Mecha Theor	atronics: Specialisation Intel atronics: Specialisation Syst etical Mechanical Engineeri	ligent System em Design: E ing: Core qua	ns and Robotics: El Elective Compulsor Ilification: Elective (ective Compuls y Compulsory	sory



Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

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 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		
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 Vibra	tion (L1743)	Project-/problem-based Learning	4	6
Module Responsible	Prof. Norbert Hoffmann			
Admission Requirements	None			
Recommended Previous Knowledge	Vibration Theory			
Educational Objectives	After taking part successfully, students have	reached the following lea	arning result	íS
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 groups.			
Autonomy	Students are able to approach given research tasks individually and to identify and follow up n research tasks by themselves.			
Workload in Hours	Independent Study Time 124, Study Time in	Lecture 56		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	2 Hours			
Assignment for the Following Curricula	Computational Science and Engineering Compulsory Mechatronics: Specialisation System Desigr Mechatronics: Specialisation Intelligent Syst Mechatronics: Technical Complementary Co Theoretical Mechanical Engineering: Technic Theoretical Mechanical Engineering: Speci Elective Compulsory	: Specialisation Scienti : Elective Compulsory ems and Robotics: Elective purse: Elective Compulso cal Complementary Cou ialisation Product Devel	fic Comput ve Compuls ry rse: Elective opment and	ing: Elective ory Compulsory d Production:

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	luma	noid Ro	botics						
Courses									
Title					Тур			Hrs/wk	СР
Humanoid Robotics (L066	63)				Semir	nar		2	2
Module Responsible	Patrick	< Göttsch							
Admission Requirements	None								
Recommended Previous Knowledge	•	Introductio Control th	on to contro eory and d	ol systems esign					
Educational Objectives	After ta	aking part s	uccessfully	∕, students	have reache	d the follow	ing lea	arning resu	ts
Professional Competence									
Knowledge	•	Students of Students I	can explain earn to app	n humanoio ply basic c	d robots. ontrol concep	ts for differ	ent tas	ks in huma	noid robotics.
Skills	•	Students specified Students Students	acquire kno literature generalize practice to p	owledge a developec prepare ar	about selected d results and pres	d aspects o present the centation	of huma m to th	anoid robo e participa	tics, based o nts
Personal Competence									
Social Competence	•	Students them They are their own	are capabl able to pr results	le of deve ovide app	loping solutic ropriate feed	ons in inter back and	rdiscipl handle	inary team constructi	s and preser ve criticism c
Autonomy	•	Students specific ta Students f presentati	evaluate a sks and se familiarize t ons of othe	idvantages lect the be themselve er students	s and drawba est solution s with a scien , such that a s	acks of diff tific field, a scientific di	ferent f re able scussic	forms of pr of introduc on develops	esentation fo e it and follow
Workload in Hours	Indepe	endent Stud	dy Time 32,	, Study Tim	ne in Lecture	28			
Credit points	2								
Course achievement	None								
Examination	Preser	ntation							
Examination duration and scale	30 min	ı							
Assignment for the Following Curricula	Electri Mecha Biome Compu Biome Biome Compu	cal Engine atronics: Sp atronics: Sp dical Engir ulsory dical Engir dical Engi ulsory	ering: Spec ecialisatior ecialisatior neering: Sp neering: Sp neering: S	cialisation n Intelliger n System E pecialisatio pecialisatio pecialisati	Control and F nt Systems an Design: Election n Artificial Or n Implants an on Medical	Power Syste d Robotics ve Compul gans and F d Endopro Fechnology	ems: El : Electi sory Regene sthese y and	lective Com ve Comput erative Med s: Elective Control Th	ipulsory sory icine: Electiv Compulsory eory: Electiv



Biomedical Engineering: Specialisation Management and Business Administration: Elective
Compulsory
Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory
Theoretical Mechanical Engineering: Core qualification: Elective Compulsory

Course L0663: Humanoid 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).			



Courses					
Title		Тур	Hrs/wk	СР	
Linear and Nonlinear Syst	em Identification (L0660)	Lecture	2	3	
Module Responsible	Prof. Herbert Werner				
Admission Requirements	None				
Recommended Previous Knowledge	 Classical control (frequency response, root locus) State space methods Discrete-time systems Linear algebra, singular value decomposition Basic knowledge about stochastic processes 				
Educational Objectives	After taking part successfully, stude	ents have reached the follow	ving learning resu	lts	
Professional Competence					
Knowledge	 Students can explain the application to a variety of lin They can explain how mudynamics They can explain how an neural network models They can explain the ide realisation theory 	general framework of the p near and nonlinear model si Itilayer perceptron network approximate predictive con a of subspace identification	prediction error m tructures is are used to mo ntrol scheme can on and its relatio	nethod and it odel nonlinea be based o on to Kalma	
Skills	 Students are capable of a identification of linear and r They are capable of implemental network model They are capable of applying linear models for dynamic set. They can do the above us Identification Toolbox) 	applying the predicition err nonlinear models for dynam menting a nonlinear predic ng subspace algorithms to t systems sing standard software tool	for method to the ic systems tive control schem he experimental id s (including the N	experimentane based on dentification of Matlab System	
Personal Competence					
Social Competence	Students can work in mixed groups	s on specific problems to arr	ive at joint solution	ns.	
Autonomy	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.				
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28				
Credit points	3				
Course achievement	None				
Examination	Oral exam				
Examination duration and scale	30 min				
	Electrical Engineering: Specialisat Mechatronics: Specialisation Intelli Mechatronics: Specialisation Syste	on Control and Power Syste gent Systems and Robotics m Design: Elective Compul	ems: Elective Con :: Elective Compul sory	npulsory sory	

Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective
Compulsory
Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory
Biomedical Engineering: Specialisation Medical Technology and Control Theory: Compulsory
Biomedical Engineering: Specialisation Management and Business Administration: Elective
Compulsory
Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory
Theoretical Mechanical Engineering: Core qualification: Elective Compulsory

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

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Module M0939: Control Lab A

Courses					
Title			Typ	Hrs/wk	CP
Control Lab I (L1093)			Practical Course	1	1
Control Lab II (L1291)			Practical Course	1	1
Control Lab III (L1665)			Practical Course	1	1
Control Lab IV (L1666)			Practical Course	1	1
Module Responsible	Prof. Her	bert Werner			
Admission Requirements	None				
Recommended Previous Knowledge	• S • L • H • u • L	State space methods QG control I2 and H-infinity optimal control ncertain plant models and robus _PV control	t control		
Educational Objectives	After taki	ng part successfully, students ha	ve reached the following le	earning resu	lts
Professional					
Competence	•				
Knowledge	• S	tudents can explain the differen nd experimental validation	ce between validation of	a control lop	in simulation
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 mixed-sensitivity design and the implementation of H-infinity optimal controllers They are capable of representing model uncertainty, and of designing and implementing a robust controller They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers 				
Personal					
Competence					
Social Competence	• S	students can work in teams to cor	nduct experiments and doc	ument the re	sults
Autonomy	• S	tudents can independently carry	out simulation studies to o	design and v	alidate control
Workload in Hours	Independ	dent Study Time 64, Study Time i	n Lecture 56		
Credit points	4				
Course achievement	None				
Examination	Written e	laboration			
Examination duration	1				
and scale	·				
	Electrica	I Engineering: Specialisation Co	ntrol and Power Systems:	Elective Con	npulsory



TUHH

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 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: Software for Embedded Systems

Courses				
Title		Тур	Hrs/wk	СР
Software for Embdedded	Systems (L1069)	Lecture	2	3
Software for Embdedded	Systems (L1070)	Recitation Section (small)	3	3
Module Responsible	Prof. Volker Turau			
Admission Requirements	None			
Recommended Previous Knowledge	 Good knowledge and experience in programming language C Basis knowledge in software engineering Basic understanding of assembly language 			
Educational Objectives	After taking part successfully, students	After taking part successfully, students have reached the following learning results		
Professional Competence				
Knowledge	Students know the basic principles and procedures of software engineering for embedded systems. They are able to describe the usage and pros of event based programming using interrupts. They know the components and functions of a concrete microcontroller. The participants explain requirements of real time systems. They know at least three scheduling algorithms for real time operating systems including their pros and cons.			
Skills	Students build interrupt-based programs for a concrete microcontroller. They build and use a preemptive scheduler. They use peripheral components (timer, ADC, EEPROM) to realize complex tasks for embedded systems. To interface with external components they utilize serial protocols.			
Personal				
Competence				
Social Competence				
Autonomy				
Workload in Hours	Independent Study Time 110, Study Ti	me 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 Computer and Software Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems Focus Software and Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory			



Course L1069: Softwa	re for Embdedded Systems
Тур	Lecture
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Volker Turau
Language	DE/EN
Cycle	SoSe
Content	 General-Purpose Processors Programming the Atmel AVR Interrupts C for Embedded Systems Standard Single Purpose Processors: Peripherals Finite-State Machines Memory Operating Systems for Embedded Systems Real-Time Embedded Systems Boot loader and Power Management
Literature	 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. Volker Turau	
Language	DE/EN	
Cycle	SoSe	
Content	See interlocking course	
Literature	See interlocking course	



Module M1248: Compilers for Embedded Systems

Courses Title Typ Hrs/wk CP Compilers for Embedded Systems (L1692) Lecture 3 4 Compilers for Embedded Systems (L1693) Project-/problem-based Learning 1 2 Module Responsible Recommended Previous Knowledge None Image: C/C+++ Programming skills Image: C/C+++ Programming skills Educational Objectives Module "Embedded Systems" C/C++ Programming skills Image: C/C+++ Programming skills Professional Competence C/C++ Programming skills Image: C/C+++ Programming skills Image: C/C+++ Programming skills Professional Competence The relevance of embedded systems increases from year to year. Within such syste amount of software to be executed on embedded processors grows continuously d lower costs and higher flexibility. Because of the particular application areas of en systems, highly optimized and application-specific processors are deployed. Suc specialized processors impose high demands on compilers which have to generate 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 abstractio and • to assess optimizations and their underlying problems in all compiler phases. Knowledge The high demands on compilers for embedded systems make effective code optin mandatory. The students learn	
Inte Iyp Hrs/wk CP Compilers for Embedded Systems (L1692) Lecture 3 4 Compilers for Embedded Systems (L1693) Project-/problem-based Learning 1 2 Module Responsible Prof. Heiko Falk Image: Compilers for Embedded Systems 1 2 Module Responsible Prof. Heiko Falk Module "Embedded Systems" Image: Compilers for Embedded Systems 1 2 Recommended Module "Embedded Systems" Module Tembedded Systems" Image: Compilers for Embedded Systems 1 2 Provious Knowledge C/C++ Programming skills Image: Compilers for Embedded Systems increases from year to year. Within such systems amount of software to be executed on embedded processors grows continuously do lower costs and higher flexibility. Because of the particular application areas of emsectal processors inpose high demands on compilers which have to generate 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 abstractio and to assess optimizations and their underlying problems in all compiler phases. Module the translation from source code to assembly code is performed,	
Compilers for Embedded Systems (L1693) Project-/problem-based Learning 1 2 Module Responsible Requirements Prof. Heiko Falk 1 2 Module Responsible Previous Knowledge Prof. Heiko Falk 1 2 Module Responsible Previous Knowledge Module "Embedded Systems" 1 2 Recommended Previous Knowledge Module "Embedded Systems" 1 2 Professional Competence Module Tembedded Systems 1 2 Professional Competence After taking part successfully, students have reached the following learning results Professional Competence The relevance of embedded systems increases from year to year. Within such system amount of software to be executed on embedded processors grows continuously d lower costs and higher flexibility. Because of the particular application areas of en systems, highly optimized and application-specific processors are deployed. Suc specialized processors impose high demands on compilers which have to generate 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 abstractio and • to assess optimizations and their underlying problems in all compiler phases. The high demands on compilers for embedded systems make effective code optim mandatory. The students learn in particular, <td< th=""><th></th></td<>	
Module Responsible Prof. Heiko Falk Admission Requirements None Module "Embedded Systems" Module "Embedded Systems" Recommended Previous Knowledge C/C++ Programming skills Educational Objectives After taking part successfully, students have reached the following learning results Professional Competence The relevance of embedded systems increases from year to year. Within such syste amount of software to be executed on embedded processors grows continuously d lower costs and higher flexibility. Because of the particular application areas of en systems, highly optimized and application-specific processors are deployed. Suc specialized processors impose high demands on compilers which have to generate 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 abstractio and • to assess optimizations and their underlying problems in all compiler phases. Knowledge The high demands on compilers for embedded systems make effective code optim 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	
Admission Requirements None Recommended Previous Knowledge Module "Embedded Systems" C/C++ Programming skills Educational Objectives After taking part successfully, students have reached the following learning results Professional Competence The relevance of embedded systems increases from year to year. Within such syste amount of software to be executed on embedded processors grows continuously d lower costs and higher flexibility. Because of the particular application areas of en systems, highly optimized and application-specific processors are deployed. Suc specialized processors impose high demands on compilers which have to generate 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 abstractio and • to assess optimizations and their underlying problems in all compiler phases. Knowledge The high demands on compilers for embedded systems make effective code optim 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	
Recommended Previous Knowledge Module "Embedded Systems" Educational Objectives After taking part successfully, students have reached the following learning results Professional Competence The relevance of embedded systems increases from year to year. Within such syste amount of software to be executed on embedded processors grows continuously d lower costs and higher flexibility. Because of the particular application areas of en systems, highly optimized and application-specific processors are deployed. Suc specialized processors impose high demands on compilers which have to generate 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 abstractio and to assess optimizations and their underlying problems in all compiler phases. The high demands on compilers for embedded systems make effective code optim 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	
Recommended Previous Knowledge C/C++ Programming skills Educational Objectives After taking part successfully, students have reached the following learning results Professional Competence The relevance of embedded systems increases from year to year. Within such syste amount of software to be executed on embedded processors grows continuously d lower costs and higher flexibility. Because of the particular application areas of en systems, highly optimized and application-specific processors are deployed. Suc specialized processors impose high demands on compilers which have to generate 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 abstractio and • to assess optimizations and their underlying problems in all compiler phases. Knowledge The high demands on compilers for embedded systems make effective code optim 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	
Educational Objectives After taking part successfully, students have reached the following learning results Professional Competence The relevance of embedded systems increases from year to year. Within such syste amount of software to be executed on embedded processors grows continuously d lower costs and higher flexibility. Because of the particular application areas of en systems, highly optimized and application-specific processors are deployed. Suc specialized processors impose high demands on compilers which have to generate 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 abstractio and • to assess optimizations and their underlying problems in all compiler phases. Knowledge The high demands on compilers for embedded systems make effective code optim 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	
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 how memory hierarchies can be exploited effectively. Since compilers for embedded systems often have to optimize for multiple objectiv average- or worst-case execution time, energy dissipation, code size), the students evaluate the influence of optimizations on these different criteria. 	ue to i ibedde n high code o n level nization
<i>Skills</i> program code into machine code. They will be enabled to assess which kind optimization should be applied most effectively at which abstraction level (e.g., so <i>Skills</i> assembly code) within a compiler. While attending the labs, the students will learn to implement a fully functional including optimizations.	of cod ource o
Personal Competence	
Students are able to solve similar problems alone or in a group and to present the accordingly.	e resul
Students are able to acquire new knowledge from specific literature and to assoc	iate th

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Hamhur	e Elnivar	eitu of	Technology

Autonomy knowledge with other classes.
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Autonomy	knowledge with other classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1692: Compilers 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 M0840: Optimal and Robust Control

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Title	rol (1.0658)	Тур	Hrs/wk	CP		
Optimal and Robust Contr Optimal and Robust Contr	'0I (LU658) rol (LU659)	Lecture Becitation Section (s	2 small) 2	3		
				0		
Module Responsible	Prof. Herbert Werner					
Admission Requirements	None					
Recommended Previous Knowledge	 Classical control (freq State space methods Linear algebra, singu 	 Classical control (frequency response, root locus) State space methods Linear algebra, singular value decomposition 				
Educational Objectives	After taking part successfully,	, students have reached the followin	g learning resu	ilts		
Professional Competence						
Knowledge	 Students can explain the significance of the matrix Riccati equation for the solution of LQ problems. They can explain the duality between optimal state feedback and optimal state estimation. They can explain how the H2 and H-infinity norms are used to represent stability and performance constraints. They can explain how an LQG design problem can be formulated as special case of an H2 design problem. They can explain how model uncertainty can be represented in a way that lends itself to robust controller design They can explain how - based on the small gain theorem - a robust controller can guarantee stability and performance for an uncertain plant. They understand how analysis and synthesis conditions on feedback loops can be represented as linear matrix inequalities. 					
Skills	 Students are capable of designing and tuning LQG controllers for multivariable planodels. They are capable of representing a H2 or H-infinity design problem in the form of 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 matinequalities (LMI), and of using standard LMI-solvers for solving them. They can carry out all of the above using standard software tools (Matlab robust controllox). 			tivariable plan in the form of ons for contro og out a mixed certain system s linear matri o robust contro		
Personal Competence						
Social Competence	Students can work in small g	roups on specific problems to arrive	at joint solutior	ıs.		
Autonomy	Students are able to find red software documentation) and	quired information in sources provi I use it to solve given problems.	ded (lecture no	otes, literature		

Workload in Hours Independent Study Time 124, Study Time in Lecture 56

Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and scale	30 min			
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory			



Course L0658: Optima	l 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 M1400: Design of Dependable Systems

Courses					
Title			Тур	Hrs/wk	СР
Designing Dependable Systems (L2000)			Lecture	2	3
Designing Dependable Sy	vstems (L2001)		Recitation Section (sm	all) 2	3
Module Responsible	Prof. Görschwin Fey				
Admission Requirements	None				
Recommended Previous Knowledge	Basic knowledge about da	ata structures and	algorithms		
Educational Objectives	After taking part successfu	Illy, students have	reached the following I	earning resul	ts
Professional Competence					
	In the following "dep Maintainability, Safety and	pendable" summ d Security.	arizes the concepts	Reliability,	Availability,
	Knowledge about approa	ches for designing	dependable systems,	ə.g.,	
Knowledge	 Structural solutions like modular redundancy Algorithmic solutions like handling byzantine faults or checkpointing 				
	Knowledge about method	s for the analysis o	of dependable systems		
Skills	Ability to implement deper Ability to analyzs the depe	ndable systems us endability of syster	ing the above approacl ns using the above met	hes. hods for analy	vsis.
Personal Competence					
	Students				
Social Competence	 discuss relevant to present their soluti 	ppics in class and ons orally.			
Autonomy	Using accompanying ma	aterial students i lecture and additi	ndependently learn ir onal solution strategies	n-depth relati	ons between
Workload in Hours	Independent Study Time 1	124, Study Time in	Lecture 56		
Credit points	6				
	Compulsory Bonus	Form	Descrip	tion	
Course achievement	No None	Excercises	Praktisc Anwend	he Übungsa lung der geler	ufgaben zur nten Ansätze
Examination	Oral exam				
Examination duration and scale	30 min				
Assignment for the Following Curricula	Computational Science Elective Compulsory Information and Communi Elective Compulsory Mechatronics: Specialisat Microelectronics and Micro	and Engineering ication Systems: S ion System Design osystems: Special	: Specialisation Kernf pecialisation Secure ar n: Elective Compulsory isation Embedded Syst	ächer Compu nd Dependabl ems: Elective	uter Science: le IT Systems: Compulsory



Course L2000: Design	ing 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	

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		



Module M0603: Nonlinear Structural Analysis

Courses				
Title		Тур	Hrs/wk	СР
Nonlinear Structural Analy	/SiS (L0277)	Lecture Recitation Section (small	3 IN 1	4 2
			1) 1	2
Module Responsible	Prof. Alexander Duster			
Requirements	None			
Recommended Previous Knowledge	Knowledge of partial differential equati	ions is recommended.		
Educational Objectives	After taking part successfully, students	have reached the following le	arning resu	lts
Professional				
Competence				
Knowledge	Students are able to + give an overview of the different nonlinear phenomena in structural mechanics. + explain the mechanical background of nonlinear phenomena in structural mechanics. + to specify problems of nonlinear structural analysis, to identify them in a given situation and to explain their mathematical and mechanical background.			s. hanics. ι situation and
Skills	Students are able to + model nonlinear structural problems. + select for a given nonlinear structural + apply finite element procedures for n + critically verify and judge results of non- + to transfer their knowledge of nonline	I problem a suitable computati onlinear structural analysis. onlinear finite elements. ear solution procedures to new	onal procec v problems.	lure.
Personal Competence				
Social Competence	Students are able to + solve problems in heterogeneous gro + share new knowledge with group me	oups and to document the corr embers.	responding	results.
Autonomy	Students are able to + acquire independently knowledge to	solve complex problems.		
Workload in Hours	Independent Study Time 124, Study Time	me 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 Struct International Management and Engin Compulsory Materials Science: Specialisation Mode Mechatronics: Specialisation System D Product Development, Materials and P Naval Architecture and Ocean Enginee Ship and Offshore Technology: Core q Theoretical Mechanical Engineering: 1	tural Engineering: Elective Co neering: Specialisation II. Ci eling: Elective Compulsory Vesign: Elective Compulsory Production: Core qualification: ering: Core qualification: Elect pualification: Elective Compuls Core qualification: Elective Con Fechnical Complementary Cou	mpulsory vil Enginee Elective Con ive Compul: ory mpulsory urse: Electiv	ring: Elective mpulsory sory e Compulsory
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Course L0277: Nonlinear 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: N	licrosystem Engine	eering			
Courses					
Title			Түр	Hrs/wk	СР
Microsystem Engineering	(L0680)		Lecture	2	4
Microsystem Engineering	(L0682)		Project-/problem-based Learning	2	2
Module Responsible	Prof. Manfred Kasper				
Admission Requirements	None				
Recommended Previous Knowledge	Basic courses in physics,	mathematics and el	ectric engineering		
Educational Objectives	After taking part successf	ully, students have re	eached the following lea	Irning resul	ts
Professional					
Competence					
Knowledge	The students know about their applications in sense	t the most important ors and actuators.	technologies and mate	rials of MEI	VS as well as
Skills	Students are able to anal to evaluate the potential of	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 solv accordingly.	ve specific problems	alone or in a group a	nd to prese	ent the results
Autonomy	Students are able to acquire particular knowledge using specialized literature and to integrate and associate this knowledge with other fields.				
Workload in Hours	Independent Study Time	124, Study Time in L	ecture 56		
Credit points	6				
Course achievement	Compulsory Bonus	Form Presentation	Descriptio	on	
Examination	Written exam				
Examination duration and scale	2h				
Assignment for the Following Curricula	Electrical Engineering: Co Computational Science a Elective Compulsory International Managemer Compulsory International Managemer Compulsory Mechanical Engineering Mechatronics: Specialisa Biomedical Engineering: Compulsory Biomedical Engineering: Biomedical Engineering: Biomedical Engineering:	ore qualification: Con and Engineering: Sp nt and Engineering: ent and Engineering: and Management: S tion System Design: Specialisation Artific Specialisation Impla : Specialisation Man	mpulsory ecialisation Systems Er Specialisation II. Electric ng: Specialisation II. pecialisation Mechatror Elective Compulsory cial Organs and Regene ints and Endoprosthese dical Technology and b	ngineering a cal Enginee Mechatror nics: Elective erative Med s: Elective (Control The a Administra	and Robotics ering: Elective hics: Elective e Compulsory icine: Elective Compulsory eory: Elective ation: Elective



Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0680: Microsystem Engineering	
Тур	Lecture
Hrs/wk	2
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)



Course L0682: Microsystem 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	
Content	Examples of MEMS components Layout consideration Electric, thermal and mechanical behaviour Design aspects	
Literature	Wird in der Veranstaltung bekannt gegeben	



Module M0806: T	echnical Acoustics II (Room Aco	ustics, Computat	ional Me	thods)
Courses				
Title Technical Acoustics II (Re Technical Acoustics II (Re	oom Acoustics, Computational Methods) (L0519) oom 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			
Recommended Previous Knowledge	Technical Acoustics I (Acoustic Waves, Noise Mechanics I (Statics, Mechanics of Materia Dynamics) Mathematics I, II, III (in particular differential er	Protection, Psycho Acou Is) and Mechanics II (H quations)	ustics) Hydrostatics,	Kinematics
Educational Objectives	After taking part successfully, students have r	eached the following lea	rning result	6
Professional				
Knowledge	The students possess an in-depth knowled computational methods and are able to give a methodical basis.	lge in acoustics regard an overview of the corre	ing room a sponding the	coustics and eoretical and
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	c problems to arrive at jo	int solutions	
Autonomy	The students are able to independently solv treated within the module. Possible conflicting results are critically scrutinized.	ve challenging acoustica g issues and limitations	al problems can be iden	in the areas tified and the
Workload in Hours	Independent Study Time 124, Study Time in L	₋ecture 56		
Credit points	6			
Course achievement	None			
Examination Examination duration and scale	Oral exam 20-30 Minuten			
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Mechatronics: Specialisation System Design: Product Development, Materials and Product Theoretical Mechanical Engineering: Technic Theoretical Mechanical Engineering: Specia Elective Compulsory	Cabin Systems: Elective Elective Compulsory ion: Core qualification: E cal Complementary Cour alisation Product Develo	Compulsory lective Com se: Elective opment and	/ pulsory Compulsory I Production



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: 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: Advanced Topics in Control

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Courses				
Title		Тур	Hrs/wk	СР
Advanced Topics in Contr	rol (L0661)	Lecture	2	3
Advanced Topics in Contr	rol (L0662)	Recitation Section (sr	nall) 2	3
Module Responsible	Prof. Herbert Werner			
Admission Requirements	None			
Recommended Previous Knowledge	H-infinity optimal control, mixed-se	ensitivity design, linear matrix inc	equalities	
Educational Objectives	After taking part successfully, stude	ents have reached the following	learning resu	lts
Professional Competence				
Knowledge	 Students can explain the scheduling approach They can explain the representation of the systems They can explain how state formulated as LMI condition They can explain how get synthesis problems for LPV They are familiar with poly the basic synthesis techniq Students can explain how communication topology of the system explain the conversion of the systems that are discretized. They can explain (in out distributed systems and the systems are systems and the systems and the systems are s	e advantages and shortcomi resentation of nonlinear system bility and performance conditions iridding techniques can be u / systems topic and LFT representations of jues associated with each of the w graph theoretic concepts a f multiagent systems ergence properties of first order is and synthesis conditions agent models state space representation of s d according to an actuator/sense line) the extension of the boo e associated synthesis condition	ngs of the one in the form ons for LPV system sed to solve of LPV system se model struct are used to consensus profor formation spatially invarion or array unded real less for distribute	classical gain of quasi-LPV /stems can be analysis and s and some of ctures represent the otocols control loops ant distributed emma to such ed controllers
Skills	 Students are capable of comixed-sensitivity design polytopic, LFT or general L They are able to use stand tasks 	onstructing LPV models of nonl of gain-scheduled controllers PV models dard software tools (Matlab robu	inear plants a ; they can o ust control too	nd carry out a do this using lbox) for these
	 Students are able to desig either LTI or LPV dynamics 	n distributed formation controlle , using Matlab tools provided	ers for groups	of agents with
	 Students are able to design using the Matlab MD-toolbox 	n distributed controllers for spati	ally interconne	ected systems,



Personal Competence Social Competence Autonomy	Students can work in small groups and arrive at joint results. Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Management and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Aircraft Corgans and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory



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 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 systems in Roesser state space form Extension of real-bounded lemma to spatially interconnected systems LMI-based synthesis of distributed controllers Spatial LPV control of spatially varying systems Applications: control of temperature profiles, vibration damping for an actuated beam 	
Literature	 Werner, H., Lecture Notes "Advanced Topics in Control" Selection of relevant research papers made available as pdf documents via StudIP 	

Course L0662: Advanced Topics in Control	
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 M0919: Laboratory: Analog and Digital Circuit Design

Courses				
Title		Тур	Hrs/wk	СР
Laboratory: Analog Circui Laboratory: Digital Circuit	it Design (L0692) Design (L0694)	Practical Course Practical Course	2 2	3 3
Module Responsible	Prof. Matthias Kuhl			-
Admission Requirements	None			
Recommended Previous Knowledge	Basic knowledge of semicondu	ctor devices and circuit design		
Educational Objectives	After taking part successfully, st	udents have reached the following	learning resu	lts
Professional Competence				
Knowledge	 Students can explain the design. Students can determine Students know the basic Students are able to explain the Students can explain the Students are able to se simulations. 	e structure and philosophy of the se all necessary input parameters for cs physics of the analog behavior. In the functions of the logic gates algorithms of checking routines. elect the appropriate transistor me	oftware frame circuit simulat of their digita odels for fast	work for circuit tion. I design. and accurate
Skills	 Students can activate a proper circuit functionali Students are able to run Students can define the Students can optimize th Students can develop an Students can define the 	and execute all necessary checking ty. the input desks for definition of the specifications of the electronic circu ne electronic circuits for low-noise a nalog circuits for mobile medical ap building blocks of digital systems.	g routines for ir electronic ci uits to be desi and low-power oplications.	verification of ircuits. gned. r.
Personal Competence				
Social Competence	 Students are trained to v Students are able to sha Students can help each software. Students are aware of ahead, but they involve a students can present the experts. 	work through complex circuits in tea are their knowledge for efficient des a other to understand all the detail their limitations regarding circuit experts when required. eir design approaches for easy che	ims. ign work. s and options design, so th ecking by mor	of the design ney do not go e experienced
Autonomy	 Students are able to reactions for improvement Students can break dow work in a realistic way. Students can handle the 	ealistically judge the status of thei is when necessary. In their design work in sub-tasks a e complex data structures of their o	r knowledge nd can sched design task ar	and to define ule the design nd document it



in consice but understandable way.

• Students are able to judge the amount of work for a major design project.

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 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Microelectronics and Microsystems: Core qualification: Elective Compulsory

Course L0692: Laboratory: Analog Circuit Design			
Тур	Practical Course		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Lecturer	Prof. Matthias Kuhl		
Language	DE		
Cycle	WiSe		
Content	 Input desk for circuits Algorithms for simulation MOS transistor model Simulation of analog circuits Placement and routing Generation of layouts Design checking routines Postlayout simulations 		
Literature	Handouts to be distributed		



Course L0694: Labora	tory: Digital Circuit Design
Тур	Practical Course
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Matthias Kuhl
Language	DE
Cycle	SoSe
Content	 Definition of specifications Architecture studies Digital simulation flow Philosophy of standard cells Placement and routing of standard cells Layout generation Design checking routines
Literature	Handouts will be distributed



Module M1024: Methods of Integrated Product Development Courses Title Hrs/wk СР Тур Integrated Product Development II (L1254) Lecture З 3 Project-/problem-based 2 Integrated Product Development II (L1255) 3 Learning Module Responsible Prof. Dieter Krause Admission None Requirements Recommended Basic knowledge of Integrated product development and applying CAE systems **Previous Knowledge** Educational After taking part successfully, students have reached the following learning results Objectives Professional Competence After passing the module students are able to: explain technical terms of design methodology, Knowledge · describe essential elements of construction management, describe current problems and the current state of research of integrated product development. 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, Skills 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: • prepare and lead team meetings and moderation processes, Social Competence work in teams on complex tasks, • represent problems and solutions and advance ideas. After passing the module students are able to: Autonomy give a structured feedback and accept a critical feedback, implement the accepted feedback autonomous. Workload in Hours Independent Study Time 110, Study Time in Lecture 70 Credit points 6 Course achievement None **Examination** Oral exam **Examination duration** 30 Minuten and scale 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

Assignment for the	Product	Development,	Materials	and	Production:	Specialisation	Product Deve	elopment:
Assignment for the	Compuls	ory						
Following Curricula	Product	Development,	Materials	and	Production	: Specialisatior	Production:	Elective
	Compuls	ory						
	Product	Development,	Materials	and	Production	n: Specialisatio	on Materials:	Elective
	Compuls	ory						
	Theoretic	cal Mechanical I	Engineering	g: Tec	hnical Comp	lementary Cours	se: Elective Co	mpulsory
	Theoretic	al Mechanical	Engineerir	ng: Sp	ecialisation	Product Develo	pment and Pi	roduction:
	Elective	Compulsory						



Course L1254: Integra	ted Product Development II
Тур	Lecture
Hrs/wk	3
СР	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.
	Topics of the course include in particular:
Content	 Methods of product development, Presentation techniques, Industrial Design, Design for variety Modularization methods, Design catalogs, Adapted QFD matrix, Systematic material selection, Assembly oriented design, Construction management CE mark, declaration of conformity including risk assessment,
	 Patents, patent rights, patent monitoring Project management (cost, time, quality) and escalation principles, Development management for mechatronics, Technical Supply Chain Management.
	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 Statistics				
Courses					
Title Applied Statistics (L1584)			Typ Lecture	Hrs/wk 2	СР 3
Applied Statistics (L1586)		l	Project-/problem-based	2	2
Applied Statistics (L1585)			Recitation Section (small)	1	1
Module Responsible	Prof. Michael Morlock				
Admission Requirements	None				
Recommended Previous Knowledge	Basic knowledge of statistical	methods			
Educational Objectives	After taking part successfully,	students have rea	ached the following lea	rning resul	ts
Professional Competence					
Knowledge	Students can explain the statistical methods and the conditions of their use.				
Skills	Students are able to use the statistics program to solve statistics problems and to interpret and depict the results				
Personal					
Social Competence	Team Work, joined presentation of results				
Autonomy	To understand and interpret the question and solve				
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70				
Credit points	6				
Course achievement	Compulsory BonusForYesNoneWr	rm ritten elaboration	Descriptio	n	
Examination	Written exam				
Examination duration and scale	90 minutes, 28 questions				
Assignment for the Following Curricula	Mechanical Engineering and Mechatronics: Specialisation S Mechatronics: Specialisation I Biomedical Engineering: Core Product Development, Materia Theoretical Mechanical Engin Theoretical Mechanical Engin Compulsory	Management: Sp System Design: E Intelligent System e qualification: Co als and Productio neering: Technica neering: Speciali	ecialisation Manageme Elective Compulsory Is and Robotics: Electiv Impulsory n: Core qualification: El I Complementary Cours sation Bio- and Medic	ent: Elective e Compuls lective Cor se: Elective cal Techno	 Compulsory sory npulsory Compulsory logy: Elective



Typ Lecture Hrs/wk 2 CP 3 Workload in Hours Independent Study Time 62, Study Time in Lecture 28 Lecturer Prof. Michael Morlock Language DE/EN	
Hrs/wk 2 CP 3 Workload in Hours Independent Study Time 62, Study Time in Lecture 28 Lecturer Prof. Michael Morlock Language DE/EN	
CP 3 Workload in Hours Independent Study Time 62, Study Time in Lecture 28 Lecturer Prof. Michael Morlock Language DE/EN	
Workload in Hours Independent Study Time 62, Study Time in Lecture 28 Lecturer Prof. Michael Morlock Language DE/EN	
Lecturer Prof. Michael Morlock Language DE/EN	
Language DE/EN	
Cycle WiSe	
The goal is to introduce students to the basic statistical methods and their applied 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	ation to
Applied Regression Analysis and Multivariable Methods, 3rd Edition, David G. Kle Emory University, Lawrence L. Kupper University of North Carolina at Chapel Hill, Muller University of North Carolina at Chapel Hill, Azhar Nizam Emory University, P by Duxbury Press, CB © 1998, ISBN/ISSN: 0-534-20910-6	einbaum Keith E. ublished

Course L1586: Applied	d 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	d 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

Examination duration

30 min



Module M1204: M	Iodelling and Optimization	in Dynamics				
Courses						
Title Flexible Multibody System Optimization of dynamical	ns (L1632) I systems (L1633)	Typ Lecture Lecture	Hrs/wk CP 2 3 2 3			
Module Responsible	Prof. Robert Seifried					
Admission Requirements	None					
Recommended Previous Knowledge	 Mathematics I, II, III Mechanics I, II, III, IV Simulation of dynamical Sys 	tems				
Educational Objectives	After taking part successfully, studer	nts have reached the follow	ing learning results			
Professional						
Knowledge	Students demonstrate basic knowledge and understanding of modeling, simulation and analysis of complex rigid and flexible multibody systems and methods for optimizing dynamic systems after successful completion of the module.					
	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 optimize dynamics problems					
Personal						
Competence	Students are able to					
Social Competence	+ solve problems in heterogeneous	groups and to document th	e corresponding results.			
oolai oompeteriee						
	Students are able to					
	+ assess their knowledge by means of exercises.					
Autonomy	+ acquaint themselves with the necessary knowledge to solve research oriented tasks.					
Workload in Hours	Independent Study Time 124, Study	Time in Lecture 56				
Credit points	6					
Course achievement	None					
Examination	Oral exam					



Assignment for the Following Curricula Following Curricula Nechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1632: Flexible	e 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
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	zation of dynamical 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. Leo Dostal
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 M1268: L	inear and Nonlinear Waves			
Courses				
Title		Тур	Hrs/wk	СР
Linear and Nonlinear Wav	res (L1737)	Project-/problem-based Learning	4	6
Module Responsible	Prof. Norbert Hoffmann			
Admission Requirements	None			
Recommended Previous Knowledge	Good Knowledge in Mathematics, Mechanic	s and Dynamics.		
Educational Objectives	After taking part successfully, students have	reached the following lea	arning result	S
Professional Competence				
Knowledge	Students are able to reflect existing terms an research new terms and concepts.	d concepts in Wave Mech	nanics and to	o develop and
Skills	Students are able to apply existing methods and methods and procedures.	procesures of Wave Mech	nanics and to	develop novel
Personal Competence				
Social Competence	Students can reach working results also in group	S.		
Autonomy	Students are able to approach given research research tasks by themselves.	tasks individually and to i	dentify and f	ollow up novel
Workload in Hours	Independent Study Time 124, Study Time in	Lecture 56		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	2 Hours			
Assignment for the Following Curricula	Computational Science and Engineering Compulsory Mechatronics: Specialisation System Design Naval Architecture and Ocean Engineering: Theoretical Mechanical Engineering: S Compulsory Theoretical Mechanical Engineering: Technic	: Specialisation Scienti : Elective Compulsory Core qualification: Electi Specialisation Maritime ical Complementary Cou	ific Comput ve Compulse Technolo rse: Elective	ing: Elective ory gy: Elective Compulsory

Course L1737: Linear and Nonlinear Waves		
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	
Language	DE/EN	
Cycle	WiSe	
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	Contro	ol Lab B					
Courses							
Title Control Lab V (L1667) Control Lab VI (L1668)					Typ Practical Course Practical Course	Hrs/wk 1 1	CP 1 1
Module Responsible	Prof. H	lerbert Werner					
Admission Requirements	None						
Recommended Previous Knowledge	• • •	State space m LQG control H2 and H-infir uncertain plan LPV control	ethods hity optimal o ht models an	control Id robust con	itrol		
Educational Objectives	After ta	aking part succe	essfully, stuc	dents have re	eached the followin	g learning resu	llts
Professional Competence							
Knowledge	•	Students can and experime	explain the ntal validatio	difference b on	etween validation	of a control lop	o in simulation
Skills	•	Students are Identification synthesis They are capa design and im They are capa the mixed-sen They are cap implementing They are capa the design and	capable of Toolbox) to able of usin plementatio ble of using sitivity desig upable of a robust con ble of using d the implen	applying ba identify a c on of LQG co g standard so gn and the in representing ntroller g standard so nentation of l	asic system identif dynamic model that software tools (Ma ntrollers oftware tools (Matla nplementation of H- model uncertair oftware tools (Matla LPV gain-schedule	ication tools (I at can be used atlab Control To b Robust Contr infinity optimal hty, and of c b Robust Contr d controllers	Matlab System I for controller colbox) for the rol Toolbox) for controllers lesigning and rol Toolbox) for
Personal Competence							
Social Competence	•	Students can	work in tean	ns to conduc	t experiments and c	document the re	esults
Autonomy	•	Students can i loops	independen	tly carry out	simulation studies	to design and v	validate control
Workload in Hours	Indepe	endent Study Ti	me 32, Stud	ly Time in Le	cture 28		
Credit points	2						
Course achievement	None						
Examination	Writter	n elaboration					
Examination duration and scale	1						
Assignment for the Following Curricula	Electri Mecha Mecha	cal Engineering atronics: Specia atronics: Specia	g: Specialisa lisation Inte lisation Sys	ation Control Iligent Syste tem Design:	and Power System ms and Robotics: E Elective Compulso	ns: Elective Cor lective Compu ry	npulsory Isory

Course L1667: Control Lab V		
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: Contro	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	Seminar Advanced Topics in	Control		
Courses				
Title Advanced Topics in Conti	rol (L1803)	Typ Seminar	Hrs/wk 2	CP 2
Module Responsible	Prof. Herbert Werner			
Admission Requirements	None			
Recommended Previous Knowledge	 Introduction to control systems Control theory and design optimal and robust control 			
Educational Objectives	After taking part successfully, students	have reached the follow	ing learning resul	ts
Professional Competence				
Knowledge	 Students can explain modern of Students learn to apply basic c 	ontrol. ontrol concepts for differe	ent tasks	
Skills	 Students acquire knowledge specified literature Students generalize developed Students practice to prepare ar 	about selected aspects results and present the rd give a presentation	of modern conti m to the participar	rol, based on
Personal Competence				
Social Competence	 Students are capable of develo They are able to provide app their own results 	ping solutions and prese ropriate feedback and I	ent them nandle constructiv	ve criticism of
Autonomy	 Students evaluate advantages specific tasks and select the be Students familiarize themselve presentations of other students 	s and drawbacks of diff st solution s with a scientific field, an , such that a scientific dis	erent forms of pr re able of introduc scussion develops	esentation for e it and follow
Workload in Hours	Independent Study Time 32, Study Tim	ne in Lecture 28		
Credit points	2			
Course achievement	None			
Examination	Presentation			
and scale	90 min			
Assignment for the Following Curricula	Electrical Engineering: Specialisation Mechatronics: Specialisation System E Mechatronics: Specialisation Intelliger	Control and Power Syste Design: Elective Compute It Systems and Robotics:	ems: Elective Com sory : Elective Compuls	pulsory

Course L1803: Advance	Course L1803: Advanced 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 M1340: Introduction to Waveguides, Antennas, and Electromagnetic Compatibility Courses Title Hrs/wk CP Тур Introduction to Waveguides, Antennas, and Electromagnetic Compatibility 3 4 (L1669) Introduction to Waveguides, Antennas, and Electromagnetic Compatibility Recitation Section (small) 2 2 (L1877) Module Responsible Prof. Christian Schuster Admission None Requirements Recommended Basic principles of physics and electrical engineering **Previous Knowledge** Educational After taking part successfully, students have reached the following learning results Objectives Professional Competence Students can explain the basic principles, relationships, and methods for the design of waveguides and antennas as well as of Electromagnetic Compatibility. Specific topics are: - Fundamental properties and phenomena of electrical circuits - Steady-state sinusoidal analysis of electrical circuits - Fundamental properties and phenomena of electromagnetic fields and waves - Steady-state sinusoidal description of electromagnetic fields and waves Useful microwave network parameters - Transmission lines and basic results from transmission line theory - Plane wave propagation, superposition, reflection and refraction *Knowledge* - 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 Skills properties. They can apply results and strategies from the field of Electromagnetic Compatibility to the development of electrical components and systems. Personal Competence Students are able to work together on subject related tasks in small groups. They are able to Social Competence present their results effectively in English (e.g. during small group exercises). 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 Autonomy between their knowledge obtained in this lecture with the content of other lectures (e.g. theory of electromagnetic fields, fundamentals of electrical engineering / physics). They can discuss technical problems and physical effects in English. Workload in Hours Independent Study Time 110, Study Time in Lecture 70



Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	45 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory

Course L1669: Introdu	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	DE/EN
Cycle	WiSe
Content	This course is intended as an introduction to the topics of wave propagation, guiding, sending, and receiving as well as Electromagnetic Compatibility (EMC) for graduate engineering students that do not have a formal background in electrical engineering. It will be useful for engineers that face the technical challenge of transmitting high frequency / high bandwidth data in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of wave propagation and Electromagnetic Compatibility will be introduced and discussed. Topics: - Fundamental properties and phenomena of electrical circuits - Steady-state sinusoidal analysis of 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 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
	 Zinke, Brunswig, "Hochfrequenztechnik 1", Springer (1999) J. Detlefsen, U. Siart, "Grundlagen der Hochfrequenztechnik", Oldenbourg (2012) D. M. Pozar, "Microwave Engineering", Wiley (2011)
Literature	- 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	WiSe	
Content	See interlocking course	
Literature	See interlocking course	



Module M0913: CMOS Nanoelectronics with Practice

Courses							
Title				Тур		Hrs/wk	СР
CMOS Nanoelectronics (I	L0764)			Lecture		2	3
CMOS Nanoelectronics (I	L1063)			Practical Course	a (amall)	2	2
	L1039)			Recitation Section	i (Sinali)	I	I
Module Responsible	NN						
Requirements	None						
Recommended Previous Knowledge	Funda	Fundamentals of MOS devices and electronic circuits					
Educational Objectives	After ta	After taking part successfully, students have reached the following learning results					
Professional Competence							
Knowledge	 Students can explain the functionality of very small MOS transistors and explain the problems occurring due to scaling-down the minimum feature size. Students are able to explain the basic steps of processing of very small MOS devices. Students can exemplify the functionality of volatile and non-volatile memories und give their specifications. Students can describe the limitations of advanced MOS technologies. Students can explain measurement methods for MOS quality control. 						
Skills	 Students can quantify the current-voltage-behavior of very small MOS transistors and list possible applications. Students can describe larger electronic systems by their functional blocks. Students can name the existing options for the specific applications and select the most appropriate ones. 						
Personal Competence Social Competence	 	Students can professional ba Students are a	team up with ackgrounds ble to work by	one or several parti their own or in small g	ners wl roups fo	ho may or solving	have different problems and
Autonomy	 Students are able to assess their knowledge in a realistic manner. The students are able to draw scenarios for estimation of the impact of advanced mobile electronics on the future lifestyle of the society. 						
Workload in Hours	Indepe	endent Study Tim	ne 110, Study T	ime in Lecture 70			
Credit points	6	,					
	Comn	ulsory Bonus	Form	De	scriptio	n	
Course achievement			Subject	theoretical and			



	Yes	None	practical work
Examination	Written exam		
Examination duration and scale	90 min		
Assignment for the Following Curricula	Computationa Technology: E International N Compulsory Mechanical E Mechatronics: Microelectroni	I Science Elective Co Manageme ngineering Specialisa ics and Mic	and Engineering: Specialisation Information and Communication mpulsory ant and Engineering: Specialisation II. Electrical Engineering: Elective and Management: Specialisation Mechatronics: Elective Compulsory ation System Design: Elective Compulsory crosystems: Core qualification: Elective Compulsory

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

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

Course L1059: CMOS Nanoelectronics				
Түр	Recitation Section (small)			
Hrs/wk	1			
СР	1			
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14			
Lecturer	Prof. Wolfgang Krautschneider			
Language	EN			
Cycle	WiSe			
Content	See interlocking course			
Literature	See interlocking course			



Module M1398: Selected Topics in Multibody Dynamics and Robotics							
Courses							
Title Formulas and Vehicles - (L1981)	Typ Mathematics and Mechanics in Autonomous Driving 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 reached the following learning results						
Professional Competence							
Knowledge	After successful completion of the module students demonstrate deeper knowledge and understanding in selected application areas of multibody dynamics and robotics						
	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 hardware						
Personal							
Competence	Students are able to						
Social Competence	Social Competence + solve problems in heterogeneous groups and to document the correspondin present them						
	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 Lecture 28						
Credit points	6						
Course achievement	None						
Examination	Presentation						
Examination duration and scale	ТВА						
Assignment for the Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Mechatronics: Specialisation System Design: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Cour Theoretical Mechanical Engineering: Core qualification: Elective Com	ve Compuls se: Elective pulsory	sory e Compulsory				
Course L1981: Formulas and Vehicles - Mathematics and Mechanics in Autonomous Driving							
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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/EN						
Cycle	WiSe						
Content							
Literature	Seifried, R.: Dynamics of underactuated multibody systems, Springer, 2014						
	Popp, K.; Schiehlen, W.: Ground vehicle dynamics, Springer, 2010						

Thesis

Module M-002: Master Thesis				
Courses				
Title	Тур	Hrs/wk	СР	
Module Responsible	Professoren der TUHH			
Admission Requirements	 According to General Regulations §21 (1): At least 60 credit points have to be achieved in study prog board decides on exceptions. 	ramme. The	examinations	
Recommended Previous Knowledge				
Educational Objectives	After taking part successfully, students have reached the following l	earning resul	ts	
Professional Competence				
Knowledge	 The students can use specialized knowledge (facts, theor subject competently on specialized issues. The students can explain in depth the relevant approaches or more areas of their subject, describing current developme position on them. The students can place a research task in their subject area and critically assess the state of research. 	ies, and met s and termino ents and takir in its context	thods) of their blogies in one ng up a critical t and describe	
Skills	 The students are able: To select, apply and, if necessary, develop further methods the specialized problem in question. To apply knowledge they have acquired and methods they litheir studies to complex and/or incompletely defined problimay. To develop new scientific findings in their subject area and assessment. 	that are suita nave learnt ir ems in a sol d subject the	ble for solving I the course of ution-oriented m to a critical	
Personal Competence	Students can			
Social Competence	 Both in writing and orally outline a scientific issue for an e understandably and in a structured way. Deal with issues competently in an expert discussion and that is appropriate to the addressees while upholding th viewpoints convincingly. 	xpert audien answer then eir own asse	ce accurately, n in a manner essments and	
	Students are able:			
Autonomy	 To structure a project of their own in work packages and to w To work their way in depth into a largely unknown su information required for them to do so. 	vork them off ubject and t	accordingly. o access the	

	• 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	Thesis
Examination duration and scale	According to General Regulations
Assignment for the Following Curricula	Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy and Environmental Engineering: Thesis: Compulsory Energy and Environmental Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Global Innovation Management: Thesis: Compulsory Computational Science and Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Production Management: Thesis: Compulsory Joint European Master in Environmental Studies - Cities and Sustainability: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Materials Science: 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 Theoretical Mechanical Engineering: Thesis: Compulsory Process Engineering: Thesis: Compulsory Mater and Environmental Engineering: Thesis: Compulsory Process Engineering: Thesis: Compulsory Water and Environmental Engineering: Thesis: Compulsory