

# **Module Manual**

Master of Science (M.Sc.)

# Mechatronics Dual study program

Cohort: Winter Term 2022 Updated: 24th April 2023

# **Table of Contents**

Table of Conte		2
Program descr	***************************************	4
Core Qualifica		6
	Business & Management	6
Module M0563:		7
	Finite Elements Methods	9
In	Control Systems Theory and Design Design and Implementation of Software Systems	11 13
	Vibration Theory	13
	Linking theory and practice (dual study program, Master's degree)	15
	Practical module 1 (dual study program, Master's degree)	17
	Practical module 2 (dual study program, Master's degree)	19
the second second second second second	Communication Networks	21
	Research Project Mechatronics	23
	Practical module 3 (dual study program, Master's degree)	24
	Energy Efficiency in Embedded Systems	26
	Intelligent Systems and Robotics	29
	Approximation and Stability	29
	Nonlinear Dynamics Numerical Methods for Ordinary Differential Equations	31 32
	Optimal and Robust Control	34
	Systems Engineering	36
	Technical Complementary Course for IMPMEC (according to Subject Specific Regulations)	38
	Selected Topics of Mechatronics (Alternative A: 12 LP)	39
	Selected Topics of Mechatronics (Alternative B: 6 LP)	47
	Applied Humanoid Robotics	55
	Lab Cyber-Physical Systems	56
Module M1306:		57
	Advanced Topics in Vibration	59
	Humanoid Robotics Linear and Nonlinear System Identifikation	60 61
Module M0838. Module M0939:		62
	Software for Embedded Systems	64
	Compilers for Embedded Systems	66
	Robotics and Navigation in Medicine	68
	Applied Dynamics: Numerical and experimental methods	70
Module M0803:	Embedded Systems	72
	Machine Learning and Data Mining	74
	Applied Statistics	76
	Selected Topics in Multibody Dynamics and Robotics	78
	Advanced Topics in Control	79
	Construction Robotics Image Processing	81 83
	Digital Signal Processing and Digital Filters	85
	Advanced Machine Learning	87
	Engineering Haptic Systems	89
	Mathematical Image Processing	91
	Intelligent Autonomous Agents and Cognitive Robotics	93
	Intelligent Systems in Medicine	95
	Modelling and Optimization in Dynamics	97
	Matrix Algorithms	99
	Optics for Engineers	101
Module M0633: Module M1229:	Industrial Process Automation	103 105
	Seminar Advanced Topics in Control	105
	Sustainable operation of technical assets	107
	System Design	109
	Nonlinear Dynamics	109
Module M0803:	Embedded Systems	111
Module M0805:	Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics )	113
	Boundary Element Methods	115
	Technical Complementary Course for IMPMEC (according to Subject Specific Regulations)	117
	Systems Engineering	118
	Selected Topics of Mechatronics (Alternative A: 12 LP)	120
	Selected Topics of Mechatronics (Alternative B: 6 LP) Lab Cyber-Physical Systems	128 136
Module M1269: Module M1306:	Control Lab C	136
	Advanced Topics in Vibration	139
	Humanoid Robotics	140
	Linear and Nonlinear System Identifikation	141
Module M0939:		142

Module M0924: Software for Embedded Systems	144
Module M1248: Compilers for Embedded Systems	146
Module M0840: Optimal and Robust Control	148
Module M1400: Design of Dependable Systems	150
Module M1143: Applied Design Methodology in Mechatronics	152
Module M1340: Introduction to Waveguides, Antennas, and Electromagnetic Compatibility	154
Module M0627: Machine Learning and Data Mining	156
Module M1616: Flight Control Law Design and Application	158
Module M1203: Applied Dynamics: Numerical and experimental methods	160
Module M1173: Applied Statistics	162
Module M1398: Selected Topics in Multibody Dynamics and Robotics	164
Module M0832: Advanced Topics in Control	165
Module M1598: Image Processing	167
Module M1048: Integrated Circuit Design	169
Module M1596: Engineering Haptic Systems	171
Module M1552: Advanced Machine Learning	173
Module M1268: Linear and Nonlinear Waves	175
Module M0881: Mathematical Image Processing	176
Module M0720: Matrix Algorithms	178
Module M1024: Methods of Product Development	180
Module M0746: Microsystem Engineering	182
Module M1204: Modelling and Optimization in Dynamics	184
Module M1614: Optics for Engineers	186
Module M0603: Nonlinear Structural Analysis	188
Module M1229: Control Lab B	190
Module M1305: Seminar Advanced Topics in Control	191
Module M0806: Technical Acoustics II (Room Acoustics, Computational Methods)	192
Module M1919: Sustainable operation of technical assets	194
Thesis	196
Module M1801: Master thesis (dual study program)	196

## Program description

## Content

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

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

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

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

#### **Career prospects**

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

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

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

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

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

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

# Learning target

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

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

#### System Design

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

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

## Intelligent Systems and Robotics

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

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

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

## **Program structure**

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

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

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

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

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

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

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

- System designIntelligent systems and robotics.

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

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

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

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

# **Core Qualification**

Module M0523: Busin	ess & Management
Madula Despensible	Draf. Matthias Mayor
Module Responsible	• •
Admission Requirements	
<b>Recommended Previous</b>	
Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge Skills	<ul> <li>Students are able to find their way around selected special areas of management within the scope of business managemen</li> <li>Students are able to explain basic theories, categories, and models in selected special areas of business management.</li> <li>Students are able to interrelate technical and management knowledge.</li> </ul>
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.
	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: Robot	tics						
Courses							
					<b>T</b>	Have to alla	67
T <b>itle</b> Robotics: Modelling and Control (LC	160)				Typ Integrated Lecture	Hrs/wk 4	<b>СР</b> 4
obotics: Modelling and Control (LC					Project-/problem-based Learning	2	2
Module Responsible	Dr. Martin Gomse				riojeet (problem bused Learning	2	L
Admission Requirements	None						
Recommended Previous	Fundamentals of ele	ctrical engir	neering				
Knowledge		5	5				
	Broad knowledge of	mechanics					
	Fundamentals of con	trol theory					
	i andamentais of con	a or ancory					
Educational Objectives	After taking part suc	cessfully, st	udents have re	eached the followir	ng learning results		
Professional Competence							
Knowledge	Students are able to	describe fu	ndamental pro	perties of robots a	nd solution approaches for mult	iple problems	in robotics.
Skills	Students are able to	derive and	solve equatior	is of motion for var	ious manipulators.		
	Students can genera	to trajector	ios in various d	oordinato systems			
	Students can genera	ite trajectori		oordinate systems			
	Students can design	linear and p	partially nonlin	ear controllers for	robotic manipulators.		
Personal Competence							
-							
Autonomy	e Students are able to work goal-oriented in small mixed groups. Students are able to recognize and improve knowledge deficits independently.						
Autonomy	Students are able to	recognize a	ind improve ki	iowieuge deficits ii	idependentiy.		
	With instructor assist	tance, stude	ents are able to	o evaluate their ow	n knowledge level and define a	further course	e of study.
Workload in Hours	Independent Study T	ime 96. Stu	Idv Time in Leo	ture 84			
Credit points	6						
Course achievement	Compulsory Bonus	Form		Description			
course achievement	Yes None		theoretical	•	n PBL-Einheiten sowie Erreic	hen des Ge	samtziels und
		practical	work	jeweiligen Se	ssion-Ziele		
Examination	Written exam						
Examination duration and	120 min						
scale							
Assignment for the	Aircraft Systems Eng	ineering: Co	ore Qualificatio	n: Elective Compu	Isory		
Following Curricula		-			duct Development and Production	on: Elective C	ompulsory
<u> </u>	-				chatronics: Elective Compulsory		
	Mechanical Engineer						
	Mechatronics: Core (			e quanneacióni co	mpaisory		
				n: Specialization P	roduct Development: Elective Co	ompulsory	
						Jinpuisory	
					roduction: Elective Compulsory		
					aterials: Elective Compulsory		
					Computer Science: Elective Con		
	Theoretical Mechanic	cal Enginoor	ring. Specialica	tion Product Dovo	opment and Production: Electiv	o ( 'omnulcorv	

Course L0168: Robotics: Modelling and Control				
Тур	Integrated Lecture			
Hrs/wk				
CP	4			
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56			
Lecturer	Dr. Martin Gomse			
Language	EN			
Cycle	WiSe			
Content	Fundamental kinematics of rigid body systems			
	Newton-Euler equations for manipulators			
	Trajectory generation			
	Linear and nonlinear control of robots			
Literature	Craig, John J.: Introduction to Robotics Mechanics and Control, Third Edition, Prentice Hall. ISBN 0201-54361-3			
	Spong, Mark W.; Hutchinson, Seth; Vidyasagar, M. : Robot Modeling and Control. WILEY. ISBN 0-471-64990-2			

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

Courses				
Title		Тур	Hrs/wk	СР
Finite Element Methods (L0291)		Lecture	2	3
Finite Element Methods (L0804)		Recitation Section (large)	2	3
Module Responsible	Prof. Otto von Estorff			
Admission Requirements	None			
<b>Recommended Previous</b>	Mechanics I (Statics, Mechanics of Materials	and Mechanics II (Hydrostatics, Kinematics, Dyn	amics)	
Knowledge	Mathematics I, II, III (in particular differentia	equations)		
Educational Objectives	After taking part successfully, students have	reached the following learning results		
Professional Competence	After taking part successivity, statemes nave			
	The students possess an in-depth knowled	ge regarding the derivation of the finite eleme	ant method and	are able to give
Knowledge	overview of the theoretical and methodical l			are able to give i
Skills	The students are capable to handle engine	ering problems by formulating suitable finite ele	ments, assemblir	ng the correspondi
	system matrices, and solving the resulting s	ystem of equations.		
Personal Competence				
Social Competence	Students can work in small groups on specif	c problems to arrive at joint solutions.		
Autonomy	The students are able to independently s	olve challenging computational problems and o	develop own fini	te element routine
	Problems can be identified and the results a			
	Independent Study Time 124, Study Time in	Lecture 56		
Credit points	6 Compulsory Bonus Form	Description		
Course achievement	No 20 % Midterm	Description		
Examination	Written exam			
Examination duration and				
scale				
Assignment for the	Civil Engineering: Core Qualification: Compu	lsorv		
	Energy Systems: Core Qualification: Elective			
	Aircraft Systems Engineering: Core Qualifica			
		Specialisation II. Mechatronics: Elective Compuls	ory	
		Specialisation II. Product Development and Produ		ompulsory
	Mechatronics: Core Qualification: Compulsor			. ,
	Biomedical Engineering: Specialisation Impl			
		gement and Business Administration: Elective Co	ompulsory	
		cal Technology and Control Theory: Elective Com		
		cial Organs and Regenerative Medicine: Elective		
	Product Development, Materials and Product			
	Technomathematics: Specialisation III. Engin			
	Theoretical Mechanical Engineering: Core Q			

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

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

Courses				
Title		Тур	Hrs/wk	СР
Control Systems Theory and Design	n (L0656)	Lecture	2	4
Control Systems Theory and Design	n (L0657)	Recitation Section (small)	2	2
Module Responsible	Prof. Herbert Werner			
Admission Requirements	None			
<b>Recommended Previous</b>	Introduction to Control Systems			
Knowledge				
Educational Objectives	After taking part successfully, students have re	ached the following learning results		
Professional Competence	5 - 5			
Knowledge				
Knowledge	<ul> <li>Students can explain how linear dynam</li> </ul>	ic systems are represented as state space m	odels; they can	interpret the sys
	response to initial states or external exci	tation as trajectories in state space		
	• They can explain the system properties	controllability and observability, and their rel	ationship to state	e feedback and s
	estimation, respectively			
	<ul> <li>They can explain the significance of a mi</li> </ul>	nimal realisation		
	• They can explain observer-based state fe	eedback and how it can be used to achieve tra	cking and disturk	bance rejection
	<ul> <li>They can extend all of the above to mult</li> </ul>	i-input multi-output systems		
	<ul> <li>They can explain the z-transform and its</li> </ul>			
		transfer function models of discrete-time sys	tems	
		ification of ARX models of dynamic systems, a		ification problem
	be solved by solving a normal equation			
		el can be constructed from a discrete-time im	oulse response	
			valoe reoponoe	
Skills	Charlen have been aformable and a shire	and date (when whether and a second state and a second	_	
		models into state space models and vice vers	a	
	They can assess controllability and observation			
	They can design LQG controllers for mult			
		ooth in continuous-time and discrete-time dom	ain, and decide	which is approp
	for a given sampling rate			
		Is and state space models of dynamic systems		
		g standard software tools (Matlab Control To	olbox, System Id	entification Tool
	Simulink)			
Personal Competence				
Social Competence	Students can work in small groups on specific p	roblems to arrive at joint solutions.		
A	Chudanta ann abhair infernachian farm marida	d		
Autonomy	Students can obtain information from provide	d sources (lecture notes, software document	ation, experimen	it guides) and u
	when solving given problems.			
	They can assess their knowledge in weekly on-I	ine tests and thereby control their learning pro	ogress.	
			-	
Workload in Hours	Independent Study Time 124, Study Time in Le	sturo 56		
Credit points				
Course achievement Examination				
Examination Examination duration and				
scale	120 mm			
	Electrical Engineering: Core Qualification: Comp	nulsory		
Following Curricula	5 5	,		
Following curricula	Aircraft Systems Engineering: Core Qualification			
	Computer Science in Engineering: Specialisatio			
	International Management and Engineering: Sp			
	International Management and Engineering: Sp		ory	
	Mechanical Engineering and Management: Spec	cialisation Mechatronics: Elective Compulsory		
	Mechatronics: Core Qualification: Compulsory			
	Biomedical Engineering: Specialisation Artificial	Organs and Regenerative Medicine: Elective O	Compulsory	
	Biomedical Engineering: Specialisation Implants	and Endoprostheses: Elective Compulsory		
	Biomedical Engineering: Specialisation Medical	Technology and Control Theory: Compulsory		
	Biomedical Engineering: Specialisation Manage	ment and Business Administration: Elective Co	mpulsory	
	Product Development, Materials and Production	: Core Qualification: Elective Compulsory		
	Theoretical Mechanical Engineering: Core Quali			

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

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

Courses						
Title				Тур	Hrs/wk	СР
Design and Implementation of Soft	,			Lecture	2	3
Design and Implementation of Soft	<b>,</b>			Practical Course	2	3
Module Responsible	Prof. Bernd-Christian	Renner				
Admission Requirements	None					
<b>Recommended Previous</b>	- Imperativ program	ming languages (C	, Pascal, Fortran or sim	ilar)		
Knowledge	- Simple data types (integer, double, char, boolean), arrays, if-then-else, for, while, procedure and function calls				lls	
Educational Objectives	After taking part suc	cessfully, students	have reached the follo	wing learning results		
Professional Competence						
Knowledge	Students are able to	describe mechatro	onic systems and define	e requirements.		
Skills	Students are able to	design and imple	ment mechatronic sys	tems. They are able to arg	ue the combination o	of Hard- and Softwa
	and the interfaces.					
Personal Competence						
Social Competence	Students are able to	work goal-oriente	d in small mixed group	s, learning and broadening	g teamwork abilities a	nd define task with
	the team.					
Autonomy	Students are able t	o solve individuall	v exercises related to	this lecture with instruct	ional direction Stude	nts are able to pla
hatohomy	execute and summa		•			ne and able to ple
Workload in Hours	Independent Study 1	Time 124, Study Tir	me in Lecture 56			
Credit points	6					
Course achievement		Form	Description			
	No 10 %	Attestation				
	Written exam					
Examination duration and	90 min					
scale						
Assignment for the	Mechatronics: Core (	Qualification: Comp	oulsory			
Following Curricula						

Course L1657: Design and In	nplementation 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
	This course covers software design and implementation of mechatronic systems, tools for automation in Java. Content: <ul> <li>Introduction to software techniques</li> <li>Procedural Programming</li> <li>Object oriented software design</li> <li>Java</li> <li>Event based programming</li> <li>Formal methods</li> </ul>
Literature	<ul> <li>"The Pragmatic Programmer: From Journeyman to Master"Andrew Hunt, David Thomas, Ward Cunningham</li> <li>"Core LEGO MINDSTORMS Programming: Unleash the Power of the Java Platform" Brian Bagnall Prentice Hall PTR, 1st edition (March, 2002) ISBN 0130093645</li> <li>"Objects First with Java: A Practical Introduction using Blue]" David J. Barnes &amp; Michael Kölling Prentice Hall/ Pearson Education; 2003, ISBN 0-13-044929-6</li> </ul>

Course L1658: Design and In	ourse L1658: Design and Implementation of Software Systems	
Тур	Practical Course	
Hrs/wk	2	
СР	3	
Workload in Hours	endent Study Time 62, Study Time in Lecture 28	
Lecturer	ernd-Christian Renner	
Language	EN	
Cycle	WiSe	
Content	See interlocking course	
Literature	See interlocking course	

Module M0751: Vibra	tion Theory				
Courses					
Title		Тур	Hrs/wk	СР	
Vibration Theory (L0701)		Integrated Lecture	4	6	
Module Responsible	Prof. Norbert Hoffmann				
Admission Requirements	None				
<b>Recommended Previous</b>					
Knowledge	Calculus				
	Linear Algebra     Engineering Mechanics				
	Engineering Mechanics				
Educational Objectives	After taking part successfully, students ha	ve reached the following learning results			
Professional Competence					
Knowledge			6 . I		
		and concepts of Vibration Theory and develop the		dia mandri a su a	
		g and simulation for free, driven, self-excited and	i parameter driven	vibrations.	
		near and nonlinear vibration problems.			
	• Students know basic tasks of vibrat	ion problems of discrete and continuous systems			
Skills		de eft///www.iew.Theory.co.d.dou.class.theory.foutberry			
	<ul> <li>Students are able to denote methods of Vibration Theory and develop them further.</li> <li>Students are able to apply and expand methods of modeling and simulation for free, forced, self-excited and parameters</li> </ul>				
	<ul> <li>Students are able to apply and ex driven vibrations.</li> </ul>	pand methods of modeling and simulation for f	ree, torcea, seit-ex	cited and parame	
	<ul> <li>Students are able to solve linear an</li> </ul>	d poplinger vibration problems			
		a nonimear vibration problems.			
Personal Competence					
Social Competence					
		plems, work on them, and reach working results a	also in teams or gro	ups.	
	<ul> <li>Students are able to document the</li> </ul>	results of vibration studies also in groups.			
Autonomy					
	Students are able to individually an				
	<ul> <li>Students are able to approach individual</li> </ul>	vidually research tasks in Vibration Theory.			
Workload in Hours	Independent Study Time 124, Study Time	in Lecture 56			
Credit points	6				
Course achievement	None				
Examination	Written exam				
Examination duration and	2 Hours				
scale					
Assignment for the	Energy Systems: Core Qualification: Electi	ve Compulsory			
Following Curricula	International Management and Engineerin	g: Specialisation II. Mechatronics: Elective Comp	ulsory		
	Mechanical Engineering and Management	: Specialisation Mechatronics: Elective Compulsor	гy		
	Mechatronics: Core Qualification: Compulsory				
	Biomedical Engineering: Specialisation Art	ificial Organs and Regenerative Medicine: Electiv	e Compulsory		
		plants and Endoprostheses: Elective Compulsory			
	5 5 1	cdical Technology and Control Theory: Elective Co	1 3		
		nagement and Business Administration: Elective	Compulsory		
	Product Development, Materials and Product				
	Naval Architecture and Ocean Engineering				
	Theoretical Mechanical Engineering: Core	Qualification: Elective Compulsory			
Course L0701: Vibration The	eory				
Тур	Integrated Lecture				

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

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
<b>Recommended Previous</b>	
Knowledge	Successful completion of practical modules as part of the dual Bachelor's course
	<ul> <li>Module "interlinking theory and practice as part of the dual Master's course"</li> </ul>
Educational Objectives	After taking part successfully, students have reached the following learning results
<b>Professional Competence</b>	
Knowledge	Dual students
	can describe and classify selected classic and current theories, concepts and methods
	<ul> <li>related to project management and</li> </ul>
	change and transformation management
	and apply them to specific situations, processes and plans in a personal, professional context.
Skills	Dual students
	<ul> <li> anticipate typical difficulties, positive and negative effects, as well as success and failure factors in the enginee sector, evaluate them and consider premising strategies and sources of action.</li> </ul>
	<ul> <li>sector, evaluate them and consider promising strategies and courses of action.</li> <li> develop specialised technical and conceptual skills to solve complex tasks and problems in their professional fiel</li> </ul>
	activity/work.
Personal Competence	
Social Competence	Dual students
	can responsibly lead interdisciplinary teams within the framework of complex tasks and problems.
	<ul> <li> engage in sector-specific and cross-sectoral discussions with experts, stakeholders and staff, representing t</li> </ul>
	approaches, points of view and work results.
Autonomy	Dual students
	• define, reflect and evaluate goals and measures for complex application-oriented projects and change processes.
	shape their professional area of responsibility independently and sustainably.
	take responsibility for their actions and for the results of their work.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written elaboration
	Studienbegleitende und semesterübergreifende Dokumentation: Die Leistungspunkte für das Modul werden durch die Anfertig
scale	eines digitalen Lern- und Entwicklungsberichtes (E-Portfolio) erworben. Dabei handelt es sich um eine fortlaufende Dokumenta
	und Reflexion der Lernerfahrungen und der Kompetenzentwicklung im Bereich der Personalen Kompetenz.

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

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

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Courses			
<b>Fitle</b> Practical term 1 (dual study progra	m. Master's degree) (L2887)	Hrs/wk	<b>CP</b> 10
Module Responsible			10
Admission Requirements			
Recommended Previous			
Knowledge	Successful completion of a compatible dual B.Sc. at TU Hamburg or comparable p	practical work experien	ice and competer
	<ul><li>in the area of interlinking theory and practice</li><li>Course D from the module on interlinking theory and practice as part of the dual</li></ul>	Master's course	
	After taking part successfully, students have reached the following learning results		
Professional Competence	Dual students		
Knowledge	Dual students		
	ullet combine their knowledge of facts, principles, theories and methods gained	from previous study co	ontent with acqu
	practical knowledge - in particular their knowledge of practical professional proc	edures and approaches	s, in the current f
	of activity in engineering.		
	have a critical understanding of the practical applications of their engineering	subject.	
Skills	Dual students		
	<ul> <li> apply technical theoretical knowledge to complex, interdisciplinary problem</li> </ul>		y, and evaluate
	<ul> <li>associated work processes and results, taking into account different possible cou</li> <li> implement the university's application recommendations with regard to their of</li> </ul>		
	<ul> <li> develop solutions as well as procedures and approaches in their field of activit</li> </ul>		oility
	• develop solutions as well as procedures and approaches in their field of activity	y and area or responsit	Sincy.
Personal Competence			
Social Competence	Dual students		
	work responsibly in project teams within their working area and proactively de	al with problems withir	their team.
	<ul> <li> represent complex engineering viewpoints, facts, problems and solution ap</li> </ul>		
	external stakeholders.		
Autonomy	Dual students		
	define goals for their own learning and working processes as engineers.		
	<ul> <li> reflect on learning and work processes in their area of responsibility.</li> </ul>		
	• reflect on the relevance of subject modules specialisations and specialis	ation for work as an	engineer, and
	implement the university's application recommendations and the associated c	hallenges to positively	r transfer knowle
	between theory and practice.		
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0		
Credit points	10		
Course achievement	None		
Examination	Written elaboration		
	Documentation accompanying studies and across semesters: Module credit points are e		
scale	development report (e-portfolio). This documents and reflects individual learning expe		
	interlinking theory and practice, as well as professional practice. In addition, the	1 1 3 1	ovides proof to
	dual@TUHH Coordination Office that the dual student has completed the practical phase	3.	
Assignment for the	Civil Engineering: Core Qualification: Compulsory		
Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory		
	Chemical and Bioprocess Engineering: Core Qualification: Compulsory		
	Computer Science: Core Qualification: Compulsory		
	Electrical Engineering: Core Qualification: Compulsory		
	Energy Systems: Core Qualification: Compulsory		
	Environmental Engineering: Core Qualification: Compulsory		
	Aircraft Systems Engineering: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory		
	Information and Communication Systems: Core Qualification: Compulsory		
	International Management and Engineering: Core Qualification: Compulsory		
	Logistics, Infrastructure and Mobility: Core Qualification: Compulsory		
	Materials Science: Core Qualification: Compulsory		
	Mechanical Engineering and Management: Core Qualification: Compulsory		
	Mechatronics: Core Qualification: Compulsory		
	Biomedical Engineering: Core Qualification: Compulsory		
	Microelectronics and Microsystems: Core Qualification: Compulsory		
	Product Development, Materials and Production: Core Qualification: Compulsory		
	Renewable Energies: Core Qualification: Compulsory		
	Naval Architecture and Ocean Engineering: Core Qualification: Compulsory		
	Theoretical Mechanical Engineering: Core Qualification: Compulsory		
	······································		
	Process Engineering: Core Qualification: Compulsory		

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

Courses			
<b>Fitle</b> Practical term 2 (dual study progra	m, Master's degree) (L2888)	Hrs/wk 0	<b>CP</b> 10
Module Responsible	Dr. Henning Haschke		
Admission Requirements	None		
<b>Recommended Previous</b>	<ul> <li>Successful completion of practical module 1 as part of the dual Master's course</li> </ul>		
Knowledge	<ul> <li>successful completion of practical module 1 as part of the dual Master's course</li> <li>course D from the module on interlinking theory and practice as part of the dual Master's course</li> </ul>	Master's course	
	-		
	After taking part successfully, students have reached the following learning results		
Professional Competence			
Knowledge	Dual students		
	<ul> <li> combine their knowledge of facts, principles, theories and methods gained f practical knowledge - in particular their knowledge of practical professional proce of activity in engineering.</li> <li> have a critical understanding of the practical applications of their engineering s</li> </ul>	edures and approache	
Skills	Dual students		
	<ul> <li> apply technical theoretical knowledge to complex, interdisciplinary problem associated work processes and results, taking into account different possible cour</li> <li> implement the university's application recommendations with regard to their c</li> <li> develop (new) solutions as well as procedures and approaches in their fie including in the case of frequently changing requirements (systemic skills).</li> </ul>	rses of action. urrent tasks.	
Personal Competence			
Social Competence	Dual students		
	<ul> <li> work responsibly in cross-departmental and interdisciplinary project teams a their team.</li> <li> represent complex engineering viewpoints, facts, problems and solution ap</li> </ul>		
	external stakeholders and develop these further together.		ns with internal
Autonomy	Dual students		
	define goals for their own learning and working processes as engineers.		
	<ul> <li> reflect on learning and work processes in their area of responsibility.</li> </ul>		
	<ul> <li> reflect on the relevance of subject modules specialisations and specialisations.</li> </ul>	ation for work as an	engineer, and
	implement the university's application recommendations and the associated ch	nallenges to positively	transfer knowle
	between theory and practice.		
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0		
Credit points			
Course achievement	None		
Examination	Written elaboration		
Examination duration and	Documentation accompanying studies and across semesters: Module credit points are e	arned by completing	a digital learning
scale	development report (e-portfolio). This documents and reflects individual learning expe	riences and skills dev	elopment relatin
	interlinking theory and practice, as well as professional practice. In addition, the dual@TUHH Coordination Office that the dual student has completed the practical phase		ovides proof to
Assignment for the	Civil Engineering: Core Qualification: Compulsory		
Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory		
	Chemical and Bioprocess Engineering: Core Qualification: Compulsory		
	Computer Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory		
	Energy Systems: Core Qualification: Compulsory		
	Environmental Engineering: Core Qualification: Compulsory		
	Aircraft Systems Engineering: Core Qualification: Compulsory		
	Computer Science in Engineering: Core Qualification: Compulsory		
	Information and Communication Systems: Core Qualification: Compulsory		
	International Management and Engineering: Core Qualification: Compulsory		
	Logistics, Infrastructure and Mobility: Core Qualification: Compulsory		
	Materials Science: Core Qualification: Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory		
	Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory		
	Biomedical Engineering: Core Qualification: Compulsory		
	Microelectronics and Microsystems: Core Qualification: Compulsory		
	Product Development, Materials and Production: Core Qualification: Compulsory		
	Renewable Energies: Core Qualification: Compulsory		
	Renewable Energies: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory		

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

Module M0836: Com	nunication Networks			
Courses				
		_		
Fitle	Naturatio (LOROO)	Typ	Hrs/wk 2	<b>CP</b> 2
Selected Topics of Communication Communication Networks (L0897)	Networks (L0899)	Project-/problem-based Learning Lecture	2	2
Communication Networks Excercis	e (L0898)	Project-/problem-based Learning	1	2
Module Responsible	Prof. Andreas Timm-Giel			
Admission Requirements	None			
Recommended Previous				
Knowledge	<ul> <li>Fundamental stochastics</li> </ul>			
-	<ul> <li>Basic understanding of computer networks and/or component of the standard stand Standard standard stand Standard standard stand Standard standard stand Standard standard stand Standard standard stand Standard standard stand Standard standard stand Standard standard standard sta</li></ul>	nunication technologies is benefici	al	
Educational Objectives	After taking part successfully, students have reached the follow	ving learning results		
Professional Competence	······································			
•	Students are able to describe the principles and structures	of communication networks in de	tail They car	n explain the for
	description methods of communication networks and their		-	
	communication networks work and describe the current resear			
Skills	Students are able to evaluate the performance of communication	tion networks using the learned m	ethods. They	are able to work
	problems themselves and apply the learned methods. They c	an apply what they have learned	autonomously	on further and
	communication networks.			
Personal Competence				
-	ce Students are able to define tasks themselves in small teams and solve these problems together using the learned methods.		arned methods. T	
	can present the obtained results. They are able to discuss and critically analyse the solutions.			
Autonomy	Students are able to obtain the necessary expert knowledge	for understanding the functionalit	y and perform	nance capabilitie
	new communication networks independently.			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	None			
Examination	Presentation			
Examination duration and	1.5 hours colloquium with three students, therefore about 30	min per student. Topics of the co	lloquium are t	he posters from
scale	previous poster session and the topics of the module.			
Assignment for the	Electrical Engineering: Specialisation Information and Commun	ication Systems: Elective Compuls	sory	
Following Curricula	Electrical Engineering: Specialisation Control and Power Syster	ns Engineering: Elective Compulso	iry	
	Aircraft Systems Engineering: Core Qualification: Elective Com	pulsory		
	Computer Science in Engineering: Specialisation I. Computer S	cience: Elective Compulsory		
	Information and Communication Systems: Specialisation Comm	nunication Systems: Elective Comp	oulsory	
	Information and Communication Systems: Specialisation Secur	e and Dependable IT Systems, Foo	us Networks:	Elective Compuls
	International Management and Engineering: Specialisation II. In	nformation Technology: Elective Co	ompulsory	
	Aeronautics: Core Qualification: Elective Compulsory			
	Mechatronics: Core Qualification: Elective Compulsory			
	Microelectronics and Microsystems: Specialisation Communica	tion and Signal Processing: Electiv	e Compulsory	
	Theoretical Mechanical Engineering: Specialisation Robotics an	d Computer Science: Elective Com	nula and	

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

Course L0897: Communicatio	Course L0897: Communication Networks		
Тур	Lecture		
Hrs/wk	2		
CP	2		
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28		
Lecturer	DrIng. Koojana Kuladinithi		
Language	EN		
Cycle	WiSe		
Content			
Literature	<ul> <li>Skript des Instituts f ür Kommunikationsnetze</li> <li>Tannenbaum, Computernetzwerke, Pearson-Studium</li> <li>Further literature is announced at the beginning of the lecture.</li> </ul>		

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

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

Courses				
litle		Тур	Hrs/wk	СР
Practical term 3 (dual study program	n, Master's degree) (L2889)		0	10
Module Responsible	-			
Admission Requirements	None			
Recommended Previous Knowledge	<ul><li>Successful completion of practical module</li><li>course E from the module on interlinking the</li></ul>			
Educational Objectives	After taking part successfully, students have read	hed the following learning results		
Professional Competence				
Knowledge	Dual students			
	<ul> <li> combine their comprehensive and spe strategy-oriented practical knowledge gain</li> <li> have a critical understanding of the pri implementing innovations.</li> </ul>	ed from their current field of work a	and area of responsibility.	
Skills	Dual students			
	<ul> <li> apply specialised and conceptual skills evaluate the associated work processes ar</li> <li> implement the university's application r</li> <li> develop new solutions as well as proceive when facing frequently changing requirem</li> <li> can use academic methods to develop these with regard to their usability.</li> </ul>	d results, taking into account differ ecommendations with regard to the dures and approaches to implemen ents and unpredictable changes (sy	ent possible courses of action ir current tasks. t operational projects and a stemic skills).	on. assignments - ev
Personal Competence				
Social Competence	Dual students			
Autonomy	<ul> <li>their team.</li> <li> can promote the professional developm</li> <li> represent complex and interdisciplinary with internal and external stakeholders and Dual students</li> <li> reflect on learning and work processes i</li> <li> define goals for new application-oriente company and the public.</li> </ul>	engineering viewpoints, facts, pro d develop these further together.		
	<ul> <li> reflect on the relevance of areas of university's application recommendations and practice.</li> </ul>			
Workload in Hours	Independent Study Time 300, Study Time in Lect	ure 0		
Credit points	10			
Course achievement	None			
Examination	Written elaboration			
	Documentation accompanying studies and across development report (e-portfolio). This document interlinking theory and practice, as well as p dual@TUHH Coordination Office that the dual stu-	s and reflects individual learning e rofessional practice. In addition, t	xperiences and skills devel the partner company prov	lopment relating
Assignment for the	Civil Engineering: Core Qualification: Compulsory			
	Chemical and Bioprocess Engineering: Core Quali Computer Science: Core Qualification: Compulsor Electrical Engineering: Core Qualification: Compulsory Environmental Engineering: Core Qualification: Cr Aircraft Systems Engineering: Core Qualification: Computer Science in Engineering: Core Qualification: Computer Science in Engineering: Core Qualification Information and Communication Systems: Core Qualification Logistics, Infrastructure and Mobility: Core Qualific Aeronautics: Core Qualification: Compulsory Materials Science and Engineering: Core Qualification Materials Science: Core Qualification: Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory	y Isory compulsory Compulsory ion: Compulsory ualification: Compulsory Qualification: Compulsory cation: Compulsory tion: Compulsory		
	Biomedical Engineering: Core Qualification: Comp Microelectronics and Microsystems: Core Qualific			

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

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

Courses					
Fitle Energy Efficiency in Embedded Sys Energy Efficiency in Embedded Sys	tems (L2872)		problem-based Learning	Hrs/wk 2 2	<b>CP</b> 3 2
nergy Efficiency in Embedded Sys		Recitatio	n Section (large)	1	1
Module Responsible					
Admission Requirements Recommended Previous Knowledge	None Computer Engineering (mandatory) Programming Skills in C (mandatory Computer Architecture (recommend	()			
Educational Objectives	After taking part successfully, students ha	ve reached the following learning	ng results		
Professional Competence Knowledge	Motivation: In the field of computer science we have a we are dependent on the manufacturers we are given at the system level, we ne dissipation in embedded systems. When mechanisms can I use directly/indirectly, will be elaborated and discussed in this ev Contents of teaching:	(e.g. of microcontrollers). Howe eed a deeper understanding o e does the power dissipation what is the tradeoff between flo	ever, in order to exploit f the background, proc come from, what happ	the full poten cesses and me ens at the ha	tial of the hardwa echanisms of pov ardware level, wl
Skills	<ul> <li>Motivation and power dissipation or</li> <li>Power dissipation of digital circuits,</li> <li>Power Management in Hard- and Sc</li> <li>Energy efficient system design (app</li> <li>Energy Harvesting and Transiently I</li> <li>Upon completion of this module, students</li> </ul>	inparticular CMOS oftware (Sleep Modes, DVS, FS, olications) Powered Computing (TPC)	-	ftware mechai	nisms for evaluat
	<ul> <li>and developing energy-efficient embedded</li> <li>They have a deeper understanding</li> <li>They can analyze the power dissipa</li> <li>They can use a variety of standard</li> <li>They can model, evaluate as well as</li> </ul>	of the electrotechnical basics o tion of systems at any level and techniques to achieve "Energy	d apply appropriate met Efficiency by Design"		se efficiency
Personal Competence					
Social Competence	As part of the module, concepts learned in learn to work in a team and to develop s collaboration (exchange) also takes place. efficient solutions possible in healthy cor mutual motivation, support and creativity.	olutions together. Specific task The second part is a challenge npetition with each other. This	ks are worked on withir e-based project in which	n the group, w n the groups fi	whereby cross-gro nd the most ener
Autonomy	After completing this module, students v systems based on the knowledge they hav			evaluate solu	tions for embedo
Workload in Hours	Independent Study Time 110, Study Time	in Lecture 70			
Credit points	6				
Course achievement	None				
Examination	Written exam				
Examination duration and	90 min				
scale					
-	Computer Science: Specialisation I. Compu Electrical Engineering: Specialisation Nanc Electrical Engineering: Specialisation Wire Mechatronics: Core Qualification: Elective Mechatronics: Core Qualification: Elective	electronics and Microsystems T less and Sensor Technologies: E Compulsory	Technology: Elective Co	mpulsory	

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

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

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

# **Specialization Intelligent Systems and Robotics**

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

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

Courses				
Title		Тур	Hrs/wk	СР
Approximation and Stability (L0487	7)	Lecture	3	4
Approximation and Stability (L0488	3)	Recitation Section (small)	1	2
Module Responsible	Prof. Marko Lindner			
Admission Requirements	None			
<b>Recommended Previous</b>	<ul> <li>Linear Algebra: systems of linear</li> </ul>	r equations, least squares problems, eigenvalues, s	ingular values	
Knowledge	<ul> <li>Analysis: sequences, series, diffe</li> </ul>		ingular values	
	• Analysis, sequences, series, une	rentation, integration		
Educational Objectives	After taking part successfully, students	have reached the following learning results		
Professional Competence				
Knowledge	Students are able to			
	<ul> <li>skotch and interrelate basic con</li> </ul>	cepts of functional analysis (Hilbert space, operator	rc)	
	name and understand concrete a		5),	
	<ul> <li>name and explain basic stability</li> </ul>			
		itions numbers and methods of regularisation		
Skills	Students are able to			
	<ul> <li>apply basic results from function</li> </ul>	al analysis.		
	<ul> <li>apply approximation methods,</li> </ul>			
	<ul> <li>apply stability theorems,</li> </ul>			
	<ul> <li>compute spectral quantities,</li> </ul>			
	<ul> <li>apply regularisation methods.</li> </ul>			
Personal Competence				
Social Competence	Students are able to solve specific prob	lems in groups and to present their results approp	riately (e.g. as a ser	ninar presentation).
Automore				
Autonomy	Students are capable of checking	g their understanding of complex concepts on the	eir own. They can s	pecify open questio
	precisely and know where to get	help in solving them.		
	<ul> <li>Students have developed suffic</li> </ul>	ient persistence to be able to work for longer pe	riods in a goal-orie	nted manner on ha
	problems.			
Workload in Hours	Independent Study Time 124, Study Tir	ne in Lecture 56		
Credit points	6			
Course achievement	Compulsory Bonus Form	Description		
	Yes None Presentation			
Examination	Oral exam			
Examination duration and	20 min			
scale				
Assignment for the	Electrical Engineering: Specialisation C	ontrol and Power Systems Engineering: Elective Co	mpulsory	
Following Curricula	Mechatronics: Specialisation Intelligent	Systems and Robotics: Elective Compulsory		
	Technomathematics: Specialisation I. M	lathematics: Elective Compulsory		
	Theoretical Mechanical Engineering: Sp	ecialisation Robotics and Computer Science: Electi	ve Compulsory	

Course L0487: Approximation	n and Stability	
Тур	Lecture	
Hrs/wk	3	
CP	4	
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42	
Lecturer	Prof. Marko Lindner	
Language	DE/EN	
Cycle	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.	
	umension.	
	Contents:	
	<ul> <li>crash course on Hilbert spaces: metric, norm, scalar product, completeness</li> </ul>	
	<ul> <li>crash course on operators: boundedness, norm, compactness, projections</li> </ul>	
	<ul> <li>uniform vs. strong convergence, approximation methods</li> </ul>	
	<ul> <li>applicability and stability of approximation methods, Polski's theorem</li> </ul>	
	Galerkin methods, collocation, spline interpolation, truncation	
	convolution and Toeplitz operators	
	crash course on C*-algebras     convergence of condition numbers	
	<ul> <li>convergence of condition numbers</li> <li>convergence of spectral quantities: spectrum, eigen values, singular values, pseudospectra</li> </ul>	
	<ul> <li>regularisation methods (truncated SVD, Tichonov)</li> </ul>	
Literature	R. Hagen, S. Roch, B. Silbermann: C*-Algebras in Numerical Analysis	
	<ul> <li>H. W. Alt: Lineare Funktionalanalysis</li> </ul>	
	M. Lindner: Infinite matrices and their finite sections	

Course L0488: Approximatio	urse L0488: Approximation and Stability		
Тур	Recitation Section (small)		
Hrs/wk	1		
CP	2		
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14		
Lecturer	Prof. Marko Lindner		
Language	DE/EN		
Cycle	SoSe		
Content	See interlocking course		
Literature	See interlocking course		

Module M0752: Nonli	near Dynamics				
Courses					
Title			Тур	Hrs/wk	СР
Nonlinear Dynamics (L0702)			Integrated Lecture	4	6
Module Responsible	Prof. Norbert Hoffmann				
Admission Requirements	None				
<b>Recommended Previous</b>	Calculus				
Knowledge	<ul> <li>Linear Algebra</li> </ul>				
	Engineering Mechan				
	<ul> <li>Engineering Mechani</li> </ul>				
Educational Objectives	After taking part successful	ly, students have reached the	following learning results		
Professional Competence					
Knowledge	<ul> <li>Students are able to</li> </ul>	roflect existing terms and con	cepts in Nonlinear Dynamics and	d to dovelop and res	oarch now torms
	concepts.	Tenecc existing terms and con	cepts in Nonlinear Dynamics and		earch new terms
		denote and expand methods of	of modeling and analysis for non	linear dynamical sys	tems
		achote and expand methods (	and analysis for non-	and a griannear by b	
Skills	<ul> <li>Students are able to</li> </ul>	apply existing methods and p	ocesures of Nonlinear Dynamics		
			ocedures for nonlinear dynamic		
Personal Competence					
Social Competence	<ul> <li>Students can analyze</li> </ul>	e problems of nonlinear dynam	ics also in groups		
	-		ems of nonlinear dynamical syst	ems also in groups.	
		· · · · · · · · · · · · · · ·	· · · · · · · · · · · · · · · · · · ·	5.00	
Autonomy	<ul> <li>Students are able to</li> </ul>	approach given research task	on the basis of given methods	individually.	
		identify and follow up novel re	-		
Workload in Hours		24, Study Time in Lecture 56			
Credit points	6				
Course achievement					
Examination					
Examination duration and	2 Hours				
scale	Aircraft Crasteria Englisherai		Commulation		
-		ig: Core Qualification: Elective	Compulsory n II. Mechatronics: Elective Comp	ulcon/	
Following Curricula	-		Mechatronics: Elective Compulso	-	
		n System Design: Elective Con		Jiy	
		n Intelligent Systems and Robo			
			nd Regenerative Medicine: Electi	ve Compulsory	
		-	prostheses: Elective Compulsory		
			y and Control Theory: Elective C		
		-	Business Administration: Elective		
	Product Development, Mate	erials and Production: Core Qua	alification: Elective Compulsory	-	
	Theoretical Mechanical Eng	ineering: Core Qualification: El	active 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	
	<ul> <li>One dimensional problems         <ul> <li>Linear Stability</li> <li>Local Bifurcations</li> <li>Synchronisation</li> </ul> </li> <li>Two dimensional problems         <ul> <li>Limit Cycles</li> <li>Global Bifurcations</li> </ul> </li> <li>Chaos         <ul> <li>Lorenz Equations</li> <li>Fractals and Strange Attractors</li> <li>Predictability and Horizons</li> </ul> </li> </ul>	
Literature	Steven Strogatz: Nonlinear Dynamics and Chaos.	

Co					
Courses					
<b>Title</b> Numerical Treatment of Ordinary D	ifferential Equations (LOE76)	<b>Typ</b> Lecture	Hrs/wk 2	<b>CP</b> 3	
Numerical Treatment of Ordinary D		Recitation Section (small)	2	3	
Module Responsible				-	
Admission Requirements					
Recommended Previous	None				
Knowledge	<ul> <li>Mathematik I, II, III f ür Ingenieurstudie</li> </ul>	rende (deutsch oder englisch) oder Analysis & L	ineare Algebra I	+ II sowie Analysis	
······································	für Technomathematiker				
	<ul> <li>Basic knowledge of MATLAB, Python or</li> </ul>	a similar programming language			
Educational Objectives	After taking part successfully, students have	reached the following learning results			
Professional Competence	······				
-	Students are able to				
	list numerical methods for the solution of ordinary differential equations and explain their core ideas,				
	formulate convergence statements for the treated numerical methods (including the assumptions about the underlying the statement) and the underlying the statement of the treated numerical methods (including the assumptions about the underlying the statement).				
	problem),				
	explain aspects regarding the practical realisation of a method.				
	<ul> <li>select the appropriate numerical method for concrete problems, implement the numerical algorithms efficiently ar interpret the numerical results</li> </ul>				
	interpret the numerical results				
Skills	Students are able to				
	implement, apply and compare numerical methods for the solution of ordinary differential equations,				
	<ul> <li>justify the convergence behaviour of numerical methods with respect to the posed problem and selected algorithm,</li> </ul>				
	<ul> <li>develop a suitable solution approach for a given problem, if necessary by combining of several algorithms, and to realise</li> </ul>				
	this approach and critically evaluate the results.				
Personal Competence					
Social Competence	e Students are able to				
	• work together in beteregeneously com	posed teams (i.e., teams from different study p	rograms and bac	karound knowlode	
		pport each other with practical aspects regarding			
		ppore cach other with practical aspects regurani	g the implemente		
Autonomy	Students are capable				
	• to assess whether the supporting theoretical and practical excercises are better solved individually or in a team,				
	<ul> <li>to assess their individual progress and, if necessary, to ask questions and seek help.</li> </ul>				
Workload in Hours	Independent Study Time 124, Study Time in I	Lecture 56			
Credit points	6				
Course achievement	None				
Examination	Written exam				
Examination duration and	90 min				
scale					
-		neral Bioprocess Engineering: Elective Compulso	-		
Following Curricula	a Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory				
		alisation General Process Engineering: Elective Co	ompulsory		
	Computer Science: Specialisation III. Mathema	and Power Systems Engineering: Elective Compu	lcon		
	5 5 1	, , , , , , , , , , , , , , , , , , , ,	uisory		
	Energy Systems: Core Qualification: Elective Aircraft Systems Engineering: Core Qualificat				
	, , , , , , ,	II. Numerical - Modelling Training: Compulsory			
	Mechatronics: Specialisation Intelligent Syste				
	Technomathematics: Specialisation I. Mathematics				
	Theoretical Mechanical Engineering: Core Qua				
	Process Engineering: Specialisation Chemical	Process Engineering: Elective Compulsory			

Course L0576: Numerical Tre	atment of Ordinary Differential Equations
Тур	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Daniel Ruprecht
Language	DE/EN
Cycle	SoSe
Content	Numerical methods for Initial Value Problems
Literature	<ul> <li>E. Hairer, S. Noersett, G. Wanner: Solving Ordinary Differential Equations I: Nonstiff Problems.</li> <li>E. Hairer, G. Wanner: Solving Ordinary Differential Equations II: Stiff and Differential-Algebraic Problems.</li> <li>D. Griffiths, D. Higham: Numerical Methods for Ordinary Differential Equations.</li> </ul>

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

Courses				
		_		
Title Optimal and Robust Control (L0658		<b>Typ</b> Lecture	Hrs/wk 2	<b>СР</b> 3
Optimal and Robust Control (L0659		Recitation Section (small)	2	3
Module Responsible				
Admission Requirements				
Recommended Previous	None			
Knowledge	Classical control (frequency response, root locus)			
Kilomeuge	State space methods			
	Linear algebra, singular value decomposition			
Educational Objectives	After taking part successfully, students have reached the	following learning results		
Professional Competence				
Knowledge				
landineage	<ul> <li>Students can explain the significance of the matrix</li> </ul>	Riccati equation for the solution of I	_Q problems.	
	They can explain the duality between optimal state			
	They can explain how the H2 and H-infinity norms			
	• They can explain how an LQG design problem can	•	5 1	
	They can explain how model uncertainty can be replaced on the small pair that the small pair the small pai			
	<ul> <li>They can explain how - based on the small gain the sm</li></ul>	leorem - a robust controller can gu	arantee stability	and performance
	<ul><li>an uncertain plant.</li><li>They understand how analysis and synthesis condi</li></ul>	tions on feedback loops can be repre	sontod as linoar	matrix inequalitie
	• They understand now analysis and synthesis condi-	tions on recuback loops can be repre	sented as intear	matrix mequalitie
Skills	Students are capable of designing and tuning LQG	controllors for multivariable plant m	odolc	
	<ul> <li>They are capable of representing a H2 or H-infinity</li> </ul>			nd of using stands
	software tools for solving it.	design problem in the form of a ger	ieralizeu platic, a	
	They are capable of translating time and frequence	v domain specifications for control	loops into const	raints on closed-lo
	sensitivity functions, and of carrying out a mixed-s			
	They are capable of constructing an LFT uncertain		, and of designir	ig a mixed-object
	robust controller.		-	
	They are capable of formulating analysis and synt	nesis conditions as linear matrix ine	qualities (LMI), a	nd of using standa
	LMI-solvers for solving them.			
	They can carry out all of the above using standard	software tools (Matlab robust contro	l toolbox).	
Personal Competence				
	Students can work in small groups on specific problems to	arrivo at joint colutions		
Autonomy	e Students can work in small groups on specific problems to arrive at joint solutions.			
Autonomy	y Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use i solve given problems.			
	solve given problems.			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points				
Course achievement	None			
Examination				
Examination duration and				
scale	30 min			
Scale				
Assignment for the	Electrical Engineering: Specialisation Control and Power S	ystems Engineering: Elective Compu	ulsory	
Following Curricula	Energy Systems: Core Qualification: Elective Compulsory			
	Aircraft Systems Engineering: Core Qualification: Elective			
	Mechatronics: Specialisation Intelligent Systems and Robo	1 5		
	Mechatronics: Specialisation System Design: Elective Con			
	Biomedical Engineering: Specialisation Artificial Organs a	5	Compulsory	
	Biomedical Engineering: Specialisation Implants and Endo			
	Biomedical Engineering: Specialisation Medical Technolog		-	
	Biomedical Engineering: Specialisation Management and			
	Product Development, Materials and Production: Specialis			
	Product Development, Materials and Production: Specialis Product Development, Materials and Production: Specialis		-	
	roduce Development, materials and Froduction. Specialis	ación materiais. Liective compuisors	r	

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

ourse 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	

Courses				
Title		Тур	Hrs/wk	СР
Systems Engineering (L1547)		Lecture	3	4
Systems Engineering (L1548)		Recitation Section (large)	1	2
Module Responsible	Prof. Ralf God			
Admission Requirements	None			
<b>Recommended Previous</b>	Basic knowledge in:			
Knowledge	Mathematics			
	Mechanics			
	Thermodynamics			
	Electrical Engineering			
	Control Systems			
	Previous knowledge in:			
	Aircraft Cabin Systems			
Educational Objectives	After taking part successfully, students have reacl	and the following learning results		
Professional Competence				
-	Students are able to:			
-	• understand systems engineering process model	s, methods and tools for the development o	of complex System	ns
	• describe innovation processes and the need for	technology Management		
	<ul> <li>explain the aircraft development process and th</li> </ul>	e process of type certification for aircraft		
	<ul> <li>explain the system development process, include</li> </ul>	ing requirements for systems reliability		
	<ul> <li>identify environmental conditions and test proce</li> </ul>	dures for airborne Equipment		
	<ul> <li>value the methodology of requirements-based e</li> </ul>	ngineering (RBE) and model-based require	ments engineerin	g (MBRE)
Skills	Students are able to:			
	• plan the process for the development of comple	x Systems		
	• organize the development phases and developm	nent Tasks		
	<ul> <li>assign required business activities and technical</li> </ul>	Tasks		
	<ul> <li>apply systems engineering methods and tools</li> </ul>			
Personal Competence				
Social Competence	Students are able to:			
	• understand and accept their tasks within a deve	lopment team		
	• be comfortable with their role their tasks within	the overall process		
	<ul> <li>understand and serve their suppliers and custor</li> </ul>	ners in large projects		
	<ul> <li>assume responsibility for people and technology</li> </ul>	in the development of safety-critical syste	ms	
Autonomy	Students are able to:			
	<ul> <li>interact and communicate in a development tea</li> </ul>	m with division of tasks.		
	• independently research and identify certification	specifications		
	<ul> <li>formulate requirements on their own</li> </ul>			
	• create test plans on their own and accompany c	ertification processes		
Workload in Hours	Independent Study Time 124, Study Time in Lectu	re 56		
Credit points				
-	None			
Examination	Written exam			
Examination duration and	120 Minutes			
scale				
Assignment for the	Aircraft Systems Engineering: Core Qualification: (	Compulsory		
Following Curricula	International Management and Engineering: Speci	alisation II. Aviation Systems: Elective Com	pulsory	
	International Management and Engineering: Speci	alisation II. Product Development and Prod	uction: Elective Co	ompulsory
	Mechatronics: Specialisation System Design: Elect			
	Mechatronics: Specialisation Intelligent Systems a			
	Product Development, Materials and Production: S			
	Product Development, Materials and Production: S			
	Product Development, Materials and Production: S	pecialisation Materials: Elective Compulsor	У	

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

urses			
itle	Тур	Hrs/wk	СР
Module Responsible	NN		
Admission Requirements	None		
<b>Recommended Previous</b>	See selected module according to FSPO		
Knowledge			
	After taking part successfully, students have reached the following learning results		
Professional Competence			
Knowledge	see selected module according to FSPO		
CL ///			
SKIIIS	see selected module according to FSPO		
Personal 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	Mechatronics: Specialisation System Design: Elective Compulsory		
Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory		

Courses				
Title		Тур	Hrs/wk	СР
Applied Automation (L1592)		Project-/problem-based Learning	3	3
Advanced Training Course SE-ZER	(L2739)	Project-/problem-based Learning	2	3
Development Management for Med	hatronics (L1512)	Lecture	2	3
atigue & Damage Tolerance (L03	0)	Lecture	2	3
ndustry 4.0 for engineers (L2012)		Lecture	2	3
dicrocontroller Circuits: Implement	ation in Hardware and Software (L0087)	Seminar	2	2
Aicrosystems Technology (L0724)		Lecture	2	4
Model-Based Systems Engineering	(MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Sustainable Industrial Production (I		Lecture	2	4
Process Measurement Engineering		Lecture	2	3
Process Measurement Engineering		Recitation Section (large)	1	1
Feedback Control in Medical Techn	blogy (L0664)	Lecture	2	3
Module Responsible	NN			
Admission Requirements	None			
<b>Recommended Previous</b>	None			
Knowledge				
Educational Objectives	After taking part successfully, students have reached the	following learning results		
Professional Competence				
Knowledge				
Kilowicage	<ul> <li>Students are able to express their extended know</li> </ul>	ledge and discuss the connection of di	fferent specia	l fields or applica
	areas of mechatronics			
	<ul> <li>Students are qualified to connect different special</li> </ul>	fields with each other		
Chille				
Skills	<ul> <li>Students can apply specialized solution strategies</li> </ul>	and new scientific methods in selected	areas	
	<ul> <li>Students are able to transfer learned skills to new</li> </ul>			approaches
Personal Competence				
-	No			
Social Competence	None			
Autonomy	<ul> <li>Students are able to develop their knowledge and</li> </ul>	skills by autonomous election of course	s.	
			-	
Workload in Hours	Depends on choice of courses			
Credit points				
Assignment for the	Mechatronics: Specialisation System Design: Elective Cor			
	Mechatronics: Specialisation Intelligent Systems and Rob			

Course L159	2: Applied Automation
Тур	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in	Independent Study Time 48, Study Time in Lecture 42
Hours	
Examination	Mündliche Prüfung
Form	
Examination	30 Minuten
duration	
and scale	
	Prof. Thorsten Schüppstuhl
Language	
Cycle	WiSe
Content	-Project Based Learning -Robot Operating System -Robot structure and description -Motion description -Calibration -Accuracy
Literature	John J. Craig Introduction to Robotics - Mechanics and Control ISBN: 0131236296 Pearson Education, Inc., 2005 Stefan Hesse Grundlagen der Handhabungstechnik ISBN: 3446418725 München Hanser, 2010 K. Thulasiraman and M. N. S. Swamy Graphs: Theory and Algorithms ISBN: 9781118033104 %CITAVIPICKER£9781118033104£Titel anhand dieser ISBN in Citavi-Projekt übernehmen£% John Wüey & Sons, Inc., 1992

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

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	30 Minuten		
scale			
Lecturer	NN, Dr. Johannes Nicolas Gebhardt		
Language	DE		
Cycle	SoSe		
Content	<ul> <li>Processes and methods of product development - from idea to market launch         <ul> <li>identification of market and technology potentials</li> <li>development of a common product architecture</li> <li>Synchronized product development across all engineering disciplines</li> <li>product validation incl. customer view</li> </ul> </li> <li>Steering and optimization of product development         <ul> <li>Design of processes for product development</li> <li>IT systems for product development</li> <li>Establishment of management standards</li> <li>Typical types of organization</li> </ul> </li> </ul>		
Literature	<ul> <li>Bender: Embedded Systems - qualitätsorientierte Entwicklung</li> <li>Ehrlenspiel: Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit</li> <li>Gausemeier/Ebbesmeyer/Kallmeyer: Produktinnovation - Strategische Planung und Entwicklung der Produkte von morger</li> <li>Haberfellner/de Weck/Fricke/Vössner: Systems Engineering: Grundlagen und Anwendung</li> <li>Lindemann: Methodische Entwicklung technischer Produkte: Methoden flexibel und situationsgerecht anwenden</li> <li>Pahl/Beitz: Konstruktionslehre: Grundlagen erfolgreicher Produktentwicklung. Methoden und Anwendung</li> <li>VDI-Richtlinie 2206: Entwicklungsmethodik für mechatronische Systeme</li> </ul>		

Course L0310: Fatigue & Dar	Course L0310: Fatigue & Damage Tolerance		
Тур	Lecture		
Hrs/wk	2		
CP	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Examination Form	Mündliche Prüfung		
Examination duration and	45 min		
scale			
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 f	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	120 min	
scale		
Lecturer	Prof. Thorsten Schüppstuhl	
Language	DE	
Cycle	SoSe	
Content		
Literature		

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

Course L0724: Microsystems	Technology	
Тур	Lecture	
Hrs/wk	2	
CP	4	
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28	
Examination Form	Mündliche Prüfung	
Examination duration and	) min	
scale		
Lecturer	Prof. Hoc Khiem Trieu	
Language	EN	
Cycle	WiSe	
	<ul> <li>Introduction (historical view, scientific and economic relevance, scaling laws)</li> <li>Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting)</li> <li>Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing)</li> <li>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)</li> <li>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)</li> <li>Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: hermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, IR sensor: thermopile and bolometer)</li> <li>Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: piezoresistive, capacitive and fabrication process; accelerometer: piezoresistive, piezoelectric and capacitive; angular rate sensor: operating principle and fabrication process)</li> <li>Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer)</li> <li>Chemical and Bio Sensors (thermal gas sensors: pellistor and thermal conductivity sensor; metal oxide semiconductor gas sensor, organic semiconduc</li></ul>	
	<ul> <li>micropumps, micromixer, filter, inkjet printhead, microdispenser, microfluidic switching elements, microreactor, lab-on-a-chip, microanalytics)</li> <li>MEMS in medical Engineering (wireless energy and data transmission, smart pill, implantable drug delivery system, stimulators: microelectrodes, cochlear and retinal implant; implantable pressure sensors, intelligent osteosynthesis, implant for spinal cord regeneration)</li> <li>Design, Simulation, Test (development and design flows, bottom-up approach, top-down approach, testability, modelling: multiphysics, FEM and equivalent circuit simulation; reliability test, physics-of-failure, Arrhenius equation, bath-tub relationship)</li> <li>System Integration (monolithic and hybrid integration, assembly and packaging, dicing, electrical contact: wire bonding,</li> </ul>	
Literature	<ul> <li>TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)</li> <li>M. Madou: Fundamentals of Microfabrication, CRC Press, 2002</li> <li>N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009</li> <li>T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010</li> </ul>	
	G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008	

Examination Form Examination duration and scale	3 Independent Study Time 48, Study Time in Lecture 42 Schriftliche Ausarbeitung
Workload in Hours Examination Form Examination duration and scale	Independent Study Time 48, Study Time in Lecture 42 Schriftliche Ausarbeitung
Examination Form Examination duration and scale	Schriftliche Ausarbeitung
Examination duration and scale	
scale	
	ca. 10 Seiten
Lasturer	
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 language
	SysML/UML, learning about tools for modeling and finally the implementation of a project with methods and tools of Model-Base
	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, I., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011
	· · · · · · · · · · · · · · · · · · ·

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

Course L1077: Process Meas	urement 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	45 Minuten
scale	
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	<ul> <li>Process measurement engineering in the context of process control engineering         <ul> <li>Challenges of process measurement engineering</li> <li>Instrumentation of processes</li> <li>Classification of pickups</li> </ul> </li> <li>Systems theory in process measurement engineering         <ul> <li>Generic linear description of pickups</li> <li>Mathematical description of two-port systems</li> <li>Fourier and Laplace transformation</li> </ul> </li> <li>Correlational measurement         <ul> <li>Wide band signals</li> <li>Auto- and cross-correlation function and their applications</li> <li>Fault-free operation of correlational methods</li> </ul> </li> <li>Transmission of analog and digital measurement signals</li> </ul>
Literature	<ul> <li>Modulation process (amplitude and frequency modulation)</li> <li>Multiplexing</li> <li>Analog to digital converter</li> <li>Färber: "Prozeßrechentechnik", Springer-Verlag 1994</li> <li>Kiencke, Kronmüller: "Meßtechnik", Springer Verlag Berlin Heidelberg, 1995</li> </ul>
	<ul> <li>A. Ambardar: "Analog and Digital Signal Processing" (1), PWS Publishing Company, 1995, NTC 339</li> <li>A. Papoulis: "Signal Analysis" (1), McGraw-Hill, 1987, NTC 312 (LB)</li> <li>M. Schwartz: "Information Transmission, Modulation and Noise" (3,4), McGraw-Hill, 1980, 2402095</li> <li>S. Haykin: "Communication Systems" (1,3), Wiley&amp;Sons, 1983, 2419072</li> <li>H. Sheingold: "Analog-Digital Conversion Handbook" (5), Prentice-Hall, 1986, 2440072</li> <li>J. Fraden: "AIP Handbook of Modern Sensors" (5,6), American Institute of Physics, 1993, MTB 346</li> </ul>

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

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

Courses				
Title		Тур	Hrs/wk	СР
Applied Automation (L1592)		Project-/problem-based Learning	3	3
Advanced Training Course SE-ZERT (L2739)		Project-/problem-based Learning	2	3
Development Management for Mechatronics (L1512)		Lecture	2	3
Fatigue & Damage Tolerance (L0310)		Lecture	2	3
Industry 4.0 for engineers (L2012)		Lecture	2	3
Aicrocontroller Circuits: Implement	ation in Hardware and Software (L0087)	Seminar	2	2
Microsystems Technology (L0724)		Lecture	2	4
Model-Based Systems Engineering	MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Sustainable Industrial Production (	2863)	Lecture	2	4
Process Measurement Engineering	(L1077)	Lecture	2	3
Process Measurement Engineering	(L1083)	Recitation Section (large)	1	1
Feedback Control in Medical Techn	ology (L0664)	Lecture	2	3
Module Responsible	NN			
Admission Requirements	None			
Recommended Previous	None			
Knowledge				
Educational Objectives				
Educational Objectives	After taking part successfully, students have reached the	e following learning results		
Professional Competence	After taking part successfully, students have reached the	e following learning results		
Professional Competence	Students are able to express their extended know		fferent specia	l fields or applicat
Professional Competence	<ul> <li>Students are able to express their extended know areas of mechatronics</li> </ul>	vledge and discuss the connection of dif	fferent specia	l fields or applicat
Professional Competence	Students are able to express their extended know	vledge and discuss the connection of dif	fferent specia	l fields or applicat
Professional Competence Knowledge	<ul> <li>Students are able to express their extended know areas of mechatronics</li> </ul>	vledge and discuss the connection of dif	fferent specia	l fields or applicat
Professional Competence	<ul> <li>Students are able to express their extended know areas of mechatronics</li> <li>Students are qualified to connect different special</li> </ul>	vledge and discuss the connection of dif	·	l fields or applicat
Professional Competence Knowledge	<ul> <li>Students are able to express their extended know areas of mechatronics</li> <li>Students are qualified to connect different special</li> <li>Students can apply specialized solution strategies</li> </ul>	vledge and discuss the connection of dif fields with each other and new scientific methods in selected	areas	
Professional Competence Knowledge	<ul> <li>Students are able to express their extended know areas of mechatronics</li> <li>Students are qualified to connect different special</li> </ul>	vledge and discuss the connection of dif fields with each other and new scientific methods in selected	areas	
Professional Competence Knowledge	<ul> <li>Students are able to express their extended know areas of mechatronics</li> <li>Students are qualified to connect different special</li> <li>Students can apply specialized solution strategies</li> </ul>	vledge and discuss the connection of dif fields with each other and new scientific methods in selected	areas	
Professional Competence Knowledge Skills	<ul> <li>Students are able to express their extended know areas of mechatronics</li> <li>Students are qualified to connect different special</li> <li>Students can apply specialized solution strategies</li> <li>Students are able to transfer learned skills to new</li> </ul>	vledge and discuss the connection of dif fields with each other and new scientific methods in selected	areas	
Professional Competence Knowledge Skills Personal Competence	<ul> <li>Students are able to express their extended know areas of mechatronics</li> <li>Students are qualified to connect different special</li> <li>Students can apply specialized solution strategies</li> <li>Students are able to transfer learned skills to new</li> </ul>	vledge and discuss the connection of dif fields with each other and new scientific methods in selected and unknown problems and can develop	areas p own solutior	
Professional Competence Knowledge Skills Personal Competence Social Competence	<ul> <li>Students are able to express their extended know areas of mechatronics</li> <li>Students are qualified to connect different special</li> <li>Students can apply specialized solution strategies</li> <li>Students are able to transfer learned skills to new</li> </ul>	vledge and discuss the connection of dif fields with each other and new scientific methods in selected and unknown problems and can develop	areas p own solutior	
Professional Competence Knowledge Skills Personal Competence Social Competence Autonomy	<ul> <li>Students are able to express their extended know areas of mechatronics</li> <li>Students are qualified to connect different special</li> <li>Students can apply specialized solution strategies</li> <li>Students are able to transfer learned skills to new</li> </ul>	vledge and discuss the connection of dif fields with each other and new scientific methods in selected and unknown problems and can develop	areas p own solutior	
Professional Competence Knowledge Skills Personal Competence Social Competence Autonomy	<ul> <li>Students are able to express their extended know areas of mechatronics</li> <li>Students are qualified to connect different special</li> <li>Students can apply specialized solution strategies</li> <li>Students are able to transfer learned skills to new</li> </ul> None <ul> <li>Students are able to develop their knowledge and</li> </ul>	vledge and discuss the connection of dif fields with each other and new scientific methods in selected and unknown problems and can develop	areas p own solutior	
Professional Competence Knowledge Skills Personal Competence Social Competence Autonomy Workload in Hours Credit points	<ul> <li>Students are able to express their extended know areas of mechatronics</li> <li>Students are qualified to connect different special</li> <li>Students can apply specialized solution strategies</li> <li>Students are able to transfer learned skills to new</li> </ul> None <ul> <li>Students are able to develop their knowledge and</li> </ul>	vledge and discuss the connection of dif fields with each other and new scientific methods in selected and unknown problems and can develop skills by autonomous election of courses	areas p own solutior	
Professional Competence Knowledge Skills Personal Competence Social Competence Autonomy Workload in Hours Credit points Assignment for the	<ul> <li>Students are able to express their extended know areas of mechatronics</li> <li>Students are qualified to connect different special</li> <li>Students can apply specialized solution strategies</li> <li>Students are able to transfer learned skills to new</li> </ul> None <ul> <li>Students are able to develop their knowledge and</li> </ul> Depends on choice of courses 6	vledge and discuss the connection of dif fields with each other and new scientific methods in selected and unknown problems and can develop skills by autonomous election of courses	areas p own solutior	

Course L159	2: Applied Automation
Тур	Project-/problem-based Learning
Hrs/wk	3
СР	3
Workload in	Independent Study Time 48, Study Time in Lecture 42
Hours	
Examination	Mündliche Prüfung
Form	
Examination	30 Minuten
duration	
and scale	
	Prof. Thorsten Schüppstuhl
Language	
Cycle	WiSe
Content	-Project Based Learning -Robot Operating System -Robot structure and description -Motion description -Calibration -Accuracy
Literature	John J. Craig Introduction to Robotics - Mechanics and Control ISBN: 0131236296 Pearson Education, Inc., 2005 Stefan Hesse Grundlagen der Handhabungstechnik ISBN: 3446418725 München Hanser, 2010 K. Thulasiraman and M. N. S. Swamy Graphs: Theory and Algorithms ISBN: 9781118033104 %CITAVIPICKER£9781118033104£Titel anhand dieser ISBN in Citavi-Projekt übernehmen£% John Wüey & Sons, Inc., 1992

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

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	30 Minuten
scale	
Lecturer	NN, Dr. Johannes Nicolas Gebhardt
Language	DE
Cycle	SoSe
Content	<ul> <li>Processes and methods of product development - from idea to market launch         <ul> <li>identification of market and technology potentials</li> <li>development of a common product architecture</li> <li>Synchronized product development across all engineering disciplines</li> <li>product validation incl. customer view</li> </ul> </li> <li>Steering and optimization of product development         <ul> <li>Design of processes for product development</li> <li>IT systems for product development</li> <li>Establishment of management standards</li> <li>Typical types of organization</li> </ul> </li> </ul>
Literature	<ul> <li>Bender: Embedded Systems - qualitätsorientierte Entwicklung</li> <li>Ehrlenspiel: Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit</li> <li>Gausemeier/Ebbesmeyer/Kallmeyer: Produktinnovation - Strategische Planung und Entwicklung der Produkte von morger</li> <li>Haberfellner/de Weck/Fricke/Vössner: Systems Engineering: Grundlagen und Anwendung</li> <li>Lindemann: Methodische Entwicklung technischer Produkte: Methoden flexibel und situationsgerecht anwenden</li> <li>Pahl/Beitz: Konstruktionslehre: Grundlagen erfolgreicher Produktentwicklung. Methoden und Anwendung</li> <li>VDI-Richtlinie 2206: Entwicklungsmethodik für mechatronische Systeme</li> </ul>

Course L0310: Fatigue & Damage Tolerance		
Тур	Lecture	
Hrs/wk	2	
CP	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Examination Form	Mündliche Prüfung	
Examination duration and	45 min	
scale		
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	120 min	
scale		
Lecturer	Prof. Thorsten Schüppstuhl	
Language	DE	
Cycle	SoSe	
Content		
Literature		

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

Course L0724: Microsystems	Technology
Тур	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and	30 min
scale	
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	<ul> <li>Introduction (historical view, scientific and economic relevance, scaling laws)</li> <li>Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting)</li> <li>Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, LPCVD at LECVD; screen printing)</li> <li>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)</li> <li>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)</li> <li>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, hohotmetry, radiometry, IR sensor: thermopile and bolometer)</li> <li>Mechanical Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensor, galci semiconductor gas sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip)</li> <li>Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, microvalves: passive and active, micropumps, valveless micropump, electrokinetic micropumps, micromixer, filter, inkjet printhead, microdispen</li></ul>
	<ul> <li>System Integration (monolithic and hybrid integration, assembly and packaging, dicing, electrical contact: wire bonding, TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)</li> </ul>
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

ανΤ	Project-/problem-based Learning
Hrs/wk	
CP	
	Independent Study Time 48, Study Time in Lecture 42
	Schriftliche Ausarbeitung
Examination duration and	
scale	
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
114	
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

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

Course L1077: Process Meas	urement 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	45 Minuten
scale	
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	Process measurement engineering in the context of process control engineering
	<ul> <li>Challenges of process measurement engineering</li> </ul>
	<ul> <li>Instrumentation of processes</li> </ul>
	<ul> <li>Classification of pickups</li> </ul>
	Systems theory in process measurement engineering
	Generic linear description of pickups
	<ul> <li>Mathematical description of two-port systems</li> </ul>
	Fourier and Laplace transformation
	Correlational measurement
	Wide band signals
	<ul> <li>Auto- and cross-correlation function and their applications</li> </ul>
	<ul> <li>Fault-free operation of correlational methods</li> </ul>
	<ul> <li>Transmission of analog and digital measurement signals</li> </ul>
	<ul> <li>Modulation process (amplitude and frequency modulation)</li> </ul>
	Multiplexing
	<ul> <li>Analog to digital converter</li> </ul>
Literature	- Färber: "Prozeßrechentechnik", Springer-Verlag 1994
	- Kiencke, Kronmüller: "Meßtechnik", Springer Verlag Berlin Heidelberg, 1995
	- Kiencke, Kionmuliei. "Mestechnik , Springer Venag benin neideberg, 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 Con	trol in Medical Technology		
Тур	Lecture		
Hrs/wk			
CP	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Examination Form	Mündliche Prüfung		
Examination duration and	20 min		
scale			
Lecturer	Johannes Kreuzer, Christian Neuhaus		
Language	DE		
Cycle	SoSe		
Content	Always viewed from the engineer's point of view, the lecture is structured as follows:  Introduction to the topic Fundamentals of physiological modelling Introduction to Breathing and Ventilation Physiology and Pathology in Cardiology Introduction to the Regulation of Blood Glucose kidney function and renal replacement therapy Representation of the control technology on the concrete ventilator Excursion to a medical technology company Techniques of modeling, simulation and controller development are discussed. In the models, simple equivalent block diagrams for physiological processes are derived and explained how sensors, controllers and actuators are operated. MATLAB and SIMULINK are used as development tools.		
Literature	<ul> <li>Leonhardt, S., &amp; Walter, M. (2016). Medizintechnische Systeme. Berlin, Heidelberg: Springer Vieweg.</li> <li>Werner, J. (2005). Kooperative und autonome Systeme der Medizintechnik. München: Oldenbourg.</li> <li>Oczenski, W. (2017). Atmen : Atemhilfen ; Atemphysiologie und Beatmungstechnik: Georg Thieme Verlag KG.</li> </ul>		

Courses				
Title Applied Humanoid Robotics (L1794	)	<b>Typ</b> Project-/problem-based Learning	Hrs/wk	<b>CP</b> 6
Module Responsible	Patrick Göttsch			
Admission Requirements	None			
Recommended Previous Knowledge	<ul> <li>Object oriented programming; algorithms and</li> <li>Introduction to control systems</li> <li>Control systems theory and design</li> <li>Mechanics</li> </ul>	data structures		
Educational Objectives	After taking part successfully, students have reached	I the following learning results		
Professional Competence Knowledge	<ul> <li>Students can explain humanoid robots.</li> <li>Students can explain the basic concepts, relat</li> <li>Students learn to apply basic control concepts</li> </ul>		e kinematics	
Skills	<ul> <li>Students can implement models for humanoid other tasks.</li> <li>They are capable of using models in Matlab for robot system.</li> <li>They are capable of selecting methods for seapply it successfully.</li> </ul>	r simulation and testing these models if neo	essary with C	++ code on the rea
Personal Competence Social Competence	<ul><li>Students can develop joint solutions in mixed</li><li>They can provide appropriate feedback to other</li></ul>		their own resu	lts
Autonomy	<ul> <li>Students are able to obtain required informal lecture.</li> <li>They can independently define tasks and appled to the statement of th</li></ul>		to put in into	the context of th
Workload in Hours	Independent Study Time 96, Study Time in Lecture 8	4		
Credit points	6			
Course achievement	None			
Examination	Written elaboration			
Examination duration and scale	5-10 pages			
Assignment for the	Computer Science: Specialisation II: Intelligence Engi			
Following Curricula	Electrical Engineering: Specialisation Control and Pov		ry	
	Mechatronics: Specialisation Intelligent Systems and	Robotics: Elective Compulsory		
	Theoretical Mechanical Engineering: Specialisation B			

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

Courses			
F <b>itle</b> .ab Cyber-Physical Systems (L1740	) Project-/problem-based Learning	Hrs/wk 4	<b>CP</b> 6
Module Responsible	Prof. Heiko Falk		
Admission Requirements	None		
Recommended Previous	Module "Embedded Systems"		
Knowledge			
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence			
<i>Knowledge</i> Cyber-Physical Systems (CPS) are tightly integrated with their surrounding environment, via sensors, A/D and D/A c actors. Due to their particular application areas, highly specialized sensors, processors and actors are common. Acc is a large variety of different specification approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for CPS - in contrast to classical software engineering approaches for		n. Accordingly, th	
	Based on practical experiments using robot kits and computers, the basics of specification and lab introduces into the area (basic notions, characteristical properties) and their specification tech hierarchical automata, data flow models, petri nets, imperative approaches). Since CPS frequent experiments will base on simple control applications. The experiments will use state-of-the- (MATLAB/Simulink, LabVIEW, NXC) in order to model cyber-physical models that interact with t actors.	chniques (mod ly perform co -art industrial	dels of computation ntrol tasks, the la l specification to
Skills	After successful attendance of the lab, students are able to develop simple CPS. They understand CPS and its surrounding processes which stem from the fact that a CPS interacts with the environ digital processors, D/A converters and actors. The lab enables students to compare modellir advantages and limitations, and to decide which technique to use for a concrete task. They will be to practical problems. They obtain first experiences in hardware-related software development, tools and in the area of simple control applications.	ment via sens ng approache pe able to app	sors, A/D converte s, to evaluate the oly these techniq
Personal Competence			
Social Competence	Students are able to solve similar problems alone or in a group and to present the results accordin	ngly.	
Autonomy	Students are able to acquire new knowledge from specific literature and to associate this knowledge	lge with other	classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Course achievement	None		
Examination	Written elaboration		
Examination duration and	Execution and documentation of all lab experiments		
scale			
Assignment for the	General Engineering Science (German program, 7 semester): Specialisation Computer Science: El	ective Compu	llsory
Following Curricula	Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory		
	Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective (	Compulsory	
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory		
	Mechatronics: Specialisation System Design: Elective Compulsory		

Course L1740: Lab Cyber-Physical Systems		
Тур	Project-/problem-based Learning	
Hrs/wk	4	
CP	6	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56	
Lecturer	Prof. Heiko Falk	
Language	DE/EN	
Cycle	SoSe	
Content	<ul> <li>Experiment 1: Programming in NXC</li> <li>Experiment 2: Programming the Robot in Matlab/Simulink</li> <li>Experiment 3: Programming the Robot in LabVIEW</li> </ul>	
Literature	<ul> <li>Peter Marwedel. Embedded System Design - Embedded System Foundations of Cyber-Physical Systems. 2 <sup>nd</sup> Edition, Springer, 2012.</li> <li>Begleitende Foliensätze</li> </ul>	

Module M1306: Contr	ol Lab C			
Courses				
<b>Fitle</b>		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. Herbert Werner			
Admission Requirements	None			
<b>Recommended Previous</b>	Chata and a matheda			
Knowledge	State space methods			
	LQG control			
	H2 and H-infinity optimal control			
	<ul> <li>uncertain plant models and robus</li> </ul>	st control		
	LPV control			
Educational Objectives	After taking part successfully, students	have reached the following learning results		
Professional Competence				
Knowledge				
	Students can explain the different	nce between validation of a control lop in simulati	on and experimental	alidation
Skills				
51.115	<ul> <li>Students are capable of applying</li> </ul>	ng basic system identification tools (Matlab Sys	stem Identification To	olbox) to identif
	dynamic model that can be used	for controller synthesis		
	They are capable of using stand	dard software tools (Matlab Control Toolbox) fo	r the design and imp	elementation of L
	controllers			
	They are capable of using standa	ard software tools (Matlab Robust Control Toolbo>	() for the mixed-sensit	tivity design and
	implementation of H-infinity optin	mal controllers		
	They are capable of representing	model uncertainty, and of designing and implem	enting a robust control	oller
	They are capable of using standa	ard software tools (Matlab Robust Control Toolbox	) for the design and th	e implementation
	LPV gain-scheduled controllers			
Personal Competence				
Social Competence	<ul> <li>Students can work in teams to co</li> </ul>	onduct experiments and document the results		
Autonomy	<ul> <li>Students can independently carry</li> </ul>	y out simulation studies to design and validate co	ntrol loons	
	• Students can independently carry	y out simulation studies to design and validate co		
Workload in Hours	Independent Study Time 48, Study Time	e in Lecture 42		
Credit points	3			
Course achievement	None			
Examination	Written elaboration			
Examination duration and	1			
scale				
Assignment for the	Electrical Engineering: Specialisation Co	ontrol and Power Systems Engineering: Elective C	ompulsory	
Following Curricula	Mechatronics: Specialisation Intelligent	Systems and Robotics: Elective Compulsory		
	Mechatronics: Specialisation System De	esign: Elective Compulsory		
	Theoretical Mechanical Engineering: Co	re Qualification: Elective Compulsory		

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

Course L1834: Control Lab V	11
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 V	urse L1835: Control Lab VIII	
Тур	Practical Course	
Hrs/wk	1	
CP	1	
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14	
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch	
Language	EN	
Cycle	WiSe/SoSe	
Content	One of the offered experiments in control theory.	
Literature	Experiment Guides	

Module M1281: Adva	nced Topics in Vibration
Courses	
Title	Typ Hrs/wk CP
Advanced Topics in Vibration (L174	13) Project-/problem-based Learning 4 6
Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	None
<b>Recommended Previous</b>	Vibration Theory
Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
	Students are able to reflect existing terms and concepts of Advanced Vibrations.
	<ul> <li>Students are able to identify the need to develop and research new terms and concepts in vibrations.</li> </ul>
Skills	
	Students are able to apply existing methods and procesures of Advanced Vibrations.
	<ul> <li>Students are able to develop novel methods and procedures for advanced vibration problems.</li> </ul>
Personal Competence	
Social Competence	
	Students can reach working results also in groups.
	Students can present working results also in groups.
Autonomy	
	<ul> <li>Students are able to approach given research tasks individually</li> </ul>
	<ul> <li>Students are able to identify and follow up novel research tasks by themselves.</li> </ul>
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and	2 Hours
scale	
Assignment for the	Mechatronics: Specialisation System Design: Elective Compulsory
Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory
	Mechatronics: Technical Complementary Course: Elective Compulsory
	Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory
	Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory
	Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L1743: Advanced Top	Course L1743: Advanced Topics in Vibration	
Тур	Project-/problem-based Learning	
Hrs/wk	4	
CP	6	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56	
Lecturer	Prof. Norbert Hoffmann	
Language	DE/EN	
Cycle	SoSe	
	Advanced and Research Topics in Vibrations   Rotor Dynamics  Modal Analysis  Model Order Reduction  Stability of Periodic Solutions  Random Vibrations  Advanced and Research Periodic Solutions  Random Vibrations	
Literature	Aktuelle Veröffentlichungen / Recent research publications Bücher/Books: Gasch, Nordmann, Pfützner: Rotordynamik Gasch, Knothe, Liebich: Strukturdynamik	

Courses				
Title		Turn		СР
Humanoid Robotics (L0663)		<b>Typ</b> Seminar	Hrs/wk 2	2
Module Responsible	Patrick Göttsch			
Admission Requirements	None			
<b>Recommended Previous</b>				
Knowledge				
	Introduction to control systems			
	Control theory and design			
Educational Objectives	After taking part successfully, students have	e reached the following learning results		
Professional Competence				
Knowledge	. Chudanta can avalain humanaid vahat			
	Students can explain humanoid robot		abatian	
	<ul> <li>Students learn to apply basic control</li> </ul>	concepts for different tasks in humanoid ro	obotics.	
Skills				
		elected aspects of humanoid robotics, base	d on specified literature	
	Students generalize developed result			
	<ul> <li>Students practice to prepare and give</li> </ul>	e a presentation		
Personal Competence				
Social Competence				
	<ul> <li>Students are capable of developing solutions in interdisciplinary teams and present them</li> </ul>			
	<ul> <li>They are able to provide appropriate</li> </ul>	feedback and handle constructive criticism	n of their own results	
Autonomy				
	-	drawbacks of different forms of presente	ation for specific tasks	and select the be
	solution			
		a scientific field, are able of introduce it	and follow presentation	ns of other studen
	such that a scientific discussion deve	lops		
Workload in Hours	Independent Study Time 32, Study Time in	Lecture 28		
Credit points	2			
Course achievement	None			
Examination	Presentation			
Examination duration and	30 min			
scale				
-	Mechatronics: Specialisation Intelligent Syst			
Following Curricula	Mechatronics: Specialisation System Design			
	Biomedical Engineering: Specialisation Artifi			
	Biomedical Engineering: Specialisation Impl			
	Biomedical Engineering: Specialisation Medi			
	Biomedical Engineering: Specialisation Mana Theoretical Mechanical Engineering: Special	-		

Course L0663: Humanoid Rol	botics
Тур	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Patrick Göttsch
Language	DE
Cycle	SoSe
Content	<ul> <li>Grundlagen der Regelungstechnik</li> <li>Control systems theory and design</li> </ul>
	- B. Siciliano, O. Khatib. "Handbook of Robotics. Part A: Robotics Foundations", Springer (2008).

Courses				
Title		Тур	Hrs/wk	СР
Linear and Nonlinear System Ident	ification (L0660)	Lecture	2	3
Module Responsible	Prof. Herbert Werner			
Admission Requirements	None			
<b>Recommended Previous</b>				
Knowledge	Classical control (frequency respon	nse, root locus)		
	State space methods			
	Discrete-time systems			
	<ul> <li>Linear algebra, singular value deco</li> <li>Basic knowledge about stochastic</li> </ul>			
	Basic knowledge about stornastic	processes		
Educational Objectives	After taking part successfully, students ha	ave reached the following learning results		
Professional Competence				
Knowledge	<ul> <li>Students can explain the general</li> </ul>	framework of the prediction error method a	and its application to a	variety of linear a
	nonlinear model structures	framework of the prediction error method a		variety of infear a
		erceptron networks are used to model nonline	ear dynamics	
		ate predictive control scheme can be based		ls
		ace identification and its relation to Kalman r		
			,	
Skills	<ul> <li>Students are capable of applying</li> </ul>	the predicition error method to the experi	mental identification of	linear and nonline
	models for dynamic systems			
		a nonlinear predictive control scheme based	on a neural network mo	del
		pace algorithms to the experimental identific		
	They can do the above using stand	lard software tools (including the Matlab Syst	em Identification Toolbo	x)
Personal Competence				
-	Students can work in mixed groups on sp	ecific problems to arrive at joint solutions.		
Social competence	Students can work in mixed groups on sp			
Autonomy	my Students are able to find required information in sources provided (lecture notes, literature, software documentation) and us		ntation) and use it	
	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	30 min			
scale				
Assignment for the	Electrical Engineering: Specialisation Con	trol and Power Systems Engineering: Elective	e Compulsory	
Following Curricula		ystems and Robotics: Elective Compulsory		
	Mechatronics: Specialisation System Desi			
		tificial Organs and Regenerative Medicine: El		
		plants and Endoprostheses: Elective Compul	-	
		edical Technology and Control Theory: Comp	-	
		anagement and Business Administration: Elec	ctive Compulsory	
	Theoretical Mechanical Engineering: Core	Qualification: Elective Compulsory		

Course L0660: Linear and No	nlinear System Identification
Тур	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	SoSe
Content	<ul> <li>Prediction error method</li> <li>Linear and nonlinear model structures</li> <li>Nonlinear model structure based on multilayer perceptron network</li> <li>Approximate predictive control based on multilayer perceptron network model</li> <li>Subspace identification</li> </ul>
Literature	<ul> <li>Lennart Ljung, System Identification - Theory for the User, Prentice Hall 1999</li> <li>M. Norgaard, O. Ravn, N.K. Poulsen and L.K. Hansen, Neural Networks for Modeling and Control of Dynamic Systems, Springer Verlag, London 2003</li> <li>T. Kailath, A.H. Sayed and B. Hassibi, Linear Estimation, Prentice Hall 2000</li> </ul>

Module M0939: Contr	ol Lab A			
Courses				
Title		Тур	Hrs/wk	СР
Control Lab I (L1093)		Practical Course	1	1
Control Lab II (L1291)		Practical Course	1	1
Control Lab III (L1665)		Practical Course	1	1
Control Lab IV (L1666)		Practical Course	1	1
Module Responsible	Prof. Herbert Werner			
Admission Requirements	None			
<b>Recommended Previous</b>				
Knowledge	<ul> <li>State space methods</li> </ul>			
	LQG control			
	<ul> <li>H2 and H-infinity optimal control</li> </ul>			
	<ul> <li>uncertain plant models and robust control</li> </ul>			
	LPV control			
Educational Objectives	After taking part successfully, students have read	hed the following learning results		
Professional Competence		····· ································		
Knowledge				
	Students can explain the difference between	en validation of a control lop in simulatio	n and experimental v	alidation
Skills Personal Competence Social Competence	<ul> <li>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</li> <li>They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers</li> <li>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</li> <li>They are capable of representing model uncertainty, and of designing and implementing a robust controller</li> <li>They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of H-infinity optimal controllers</li> <li>They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers</li> </ul>			
Social Competence	Students can work in teams to conduct exp	periments and document the results		
Autonomy	Students can independently carry out simu	lation studies to design and validate cor	ntrol loops	
Workload in Hours	Independent Study Time 64, Study Time in Lectu	re 56		
Credit points	4			
Course achievement	None			
Examination	Written elaboration			
Examination duration and scale	1			
	Flashring Engineering Crassic listing Cont.	Deuron Curchama Englistantian Election	mmulaam	
	Electrical Engineering: Specialisation Control and		mpulsory	
Following Curricula	Mechatronics: Specialisation System Design: Elec			
	Mechatronics: Specialisation Intelligent Systems			
	Theoretical Mechanical Engineering: Specialisatic	n Robotics and Computer Science: Electi	ve Compulsory	

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

## Module Manual M.Sc. "Mechatronics"

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

purse L1665: Control Lab III	
Practical Course	
1	
1	
Independent Study Time 16, Study Time in Lecture 14	
Prof. Herbert Werner, Adwait Datar, Patrick Göttsch	
EN	
WiSe/SoSe	
One of the offered experiments in control theory.	
Experiment Guides	

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

Module M0924: Softw	are 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. Bernd-Christian Renne	er				
Admission Requirements	None					
<b>Recommended Previous</b>						
Knowledge			ce in programming in the C language			
	Basic knowledge in s					
	<ul> <li>Basic understanding</li> </ul>	of assembly language				
Educational Objectives	After taking part successfu	lly, students have reache	d the following learning results			
Professional Competence						
Knowledge	Students know the basic p	rinciples and procedures	of software engineering for embedded s	systems. They are	able to describe the	
	usage and pros of event	based programming ι	ising interrupts. They know the comp	onents and fund	tions of a concre	
	microcontroller. The partic	microcontroller. The participants explain requirements of real time systems. They know at least three scheduling algorithm				
	real time operating system	s including their pros and	l cons.			
Skills	ills Students build interrupt-based programs for a concrete microcontroller. They build and use a preemptive sch					
	peripheral components (timer, ADC, EEPROM) to realize complex tasks for embedded systems. To interface wi				erface with externa	
	components they utilize serial protocols.					
Personal Competence						
Social Competence						
Autonomy						
Workload in Hours	Independent Study Time 1	10, Study Time in Lecture	2 70			
Credit points	6					
Course achievement	Compulsory Bonus Form	n I	Description			
	No 10 % Atte	estation				
Examination	Written exam					
Examination duration and	90 min					
scale						
Assignment for the	Computer Science: Special	isation I. Computer and S	oftware Engineering: Elective Compulsor	У		
Following Curricula	Electrical Engineering: Spe	cialisation Information an	d Communication Systems: Elective Com	npulsory		
	Information and Communic	ation Systems: Specialisa	ation Communication Systems, Focus Sof	tware: Elective Co	ompulsory	
	Mechatronics: Technical Co	mplementary Course: Ele	ective Compulsory			
	Mechatronics: Specialisatio	n Intelligent Systems and	d Robotics: Elective Compulsory			
	Mechatronics: Specialisation System Design: Elective Compulsory					
	Microelectronics and Micro	systems, Enocialisation E	mbedded Systems: Elective Compulsory			

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

Course L1070: Software for I	urse L1070: Software for Embdedded Systems		
Тур	Recitation Section (small)		
Hrs/wk	3		
CP	3		
Workload in Hours	ndent Study Time 48, Study Time in Lecture 42		
Lecturer	Prof. Bernd-Christian Renner		
Language	I		
Cycle			
Content	interlocking course		
Literature	See interlocking course		

Courses					
Title		Тур	Hrs/wk	СР	
Compilers for Embedded Systems (	(L1692)	Lecture	3	4	
Compilers for Embedded Systems (	(L1693)	Project-/problem-based Lear	ning 1	2	
Module Responsible	Prof. Heiko Falk				
Admission Requirements	None				
<b>Recommended Previous</b>	Module "Embedded Systems"				
Knowledge	C/C++ Programming skills				
Educational Objectives	After taking part successfully, students	have reached the following learning results			
<b>Professional Competence</b>					
Knowledge	embedded processors grows continuou of embedded systems, highly optimizi impose high demands on compilers whi the students are able • to illustrate the structure and orc • to distinguish and explain interm • to assess optimizations and their The high demands on compilers for e particular, • which kinds of optimizations are • how the translation from source of • which kinds of optimizations are • how register allocation is perform • how memory hierarchies can be Since compilers for embedded systems	ediate representations of various abstraction levels, runderlying problems in all compiler phases. embedded systems make effective code optimizat applicable at the source code level, code to assembly code is performed, applicable at the assembly code level, ned, and exploited effectively. often have to optimize for multiple objectives (e.g.,	ause of the particu ed. Such highly sp le successful atten and ons mandatory. T average- or worst	alar application are pecialized processo idance of this cours he students learn -case execution tin	
Skills	After successful completion of the cours be enabled to assess which kind of cod assembly code) within a compiler.	ents learn to evaluate the influence of optimizations se, students shall be able to translate high-level pro e optimization should be applied most effectively at will learn to implement a fully functional compiler ind	gram code into ma which abstraction	achine code. They v level (e.g., source	
Personal Competence					
-	Students are able to solve similar proble	ems alone or in a group and to present the results a	ccordingly.		
Autonomy	Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.				
Workload in Hours	Independent Study Time 124, Study Tin	ne in Lecture 56			
Credit points	6				
Course achievement	None				
Examination	Oral exam				
Examination duration and	30 min				
scale					
Assignment for the	Computer Science: Specialisation I. Con	nputer and Software Engineering: Elective Compulso	ry		
Following Curricula	Electrical Engineering: Specialisation In	formation and Communication Systems: Elective Co	mpulsory		
	Aircraft Systems Engineering: Core Qua	lification: Elective Compulsory			
		Custome and Debatics, Floating Commulasmy			
	Mechatronics: Specialisation Intelligent				
	Mechatronics: Specialisation Intelligent Mechatronics: Specialisation System De Mechatronics: Technical Complementar	sign: Elective Compulsory			

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

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	aiko Falk	
Language		
Cycle		
Content	See interlocking course	
Literature	See interlocking course	

Courses						
Title			Тур	Hrs/wk	СР	
Robotics and Navigation in Medicir			Lecture	2	3	
Robotics and Navigation in Medicir Robotics and Navigation in Medicir			Project Seminar Recitation Section (small	2	2	
		ofor	Recitation Section (Small	) 1	T	
Module Responsible Admission Requirements		leier				
Recommended Previous	None					
Knowledge	<ul> <li>principles of m</li> </ul>	ath (algebra, analysis/calc	ulus)			
		rogramming, e.g., in Java c	or C++			
	<ul> <li>solid R or Matl</li> </ul>	ab skills				
Educational Objectives	After taking part succ	cessfully, students have re	ached the following learning results			
Professional Competence		· ·				
Knowledge	The students can ex	plain kinematics and trac	king systems in clinical contexts and il	lustrate systems and	their component	
	detail. Systems can	be evaluated with respec	t to collision detection and safety and	l regulations. Studen	ts can assess typ	
	systems regarding de	esign and limitations.				
Skille	The students are able	e to design and evaluate n	avigation systems and robotic systems for	r medical application	c	
SKIIIS	The students are able		avigation systems and robotic systems it	interical application	3.	
Personal Competence						
	The students are abl	le to grasp practical tasks	in groups, develop solution strategies	independently, define	work processes	
	work on them collabo					
	The students are able to collaboratively organize their work processes and software solutions using virtual communication ar					
	software management tools.					
	The students can critically reflect on the results of other groups, make constructive suggestions for improvement, and al					
	incorporate them into their own work.					
A	The students are a	and the indexed of the surf-				
Autonomy			edge and independently control their le y evaluate the results achieved and pres			
	manner to the other		y evaluate the results achieved and pres		priate argumenta	
		9.00p51				
Werkland in Herre	Independent Chudu T	ina 110 Chudu Tima in La	atura 70			
Credit points		ime 110, Study Time in Le				
Course achievement		Form	Description			
	Yes 10 %	Written elaboration				
	Yes 10 %	Presentation				
Examination	Written exam					
Examination duration and	90 minutes					
scale						
5			e Engineering: Elective Compulsory			
Following Curricula			echnology: Elective Compulsory			
	International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory					
	-		ecialisation II. Process Engineering and B s and Robotics: Elective Compulsory	iotechnology: Elective	compulsory	
		5 ,		tive Compulsory		
	Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory					
	5	5 1 1	Technology and Control Theory: Elective	5		
	5	5 1	ment and Business Administration: Elective			
	-		: Specialisation Product Development: El			
	Product Development	t, Materials and Production	: Specialisation Production: Elective Com	pulsory		
			a: Specialisation Production: Elective Com a: Specialisation Materials: Elective Comp			

Тур	ture				
Hrs/wk					
CP	3				
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28				
Lecturer	Prof. Alexander Schlaefer				
Language	EN				
Cycle	SoSe				
Content	- kinematics				
	- calibration				
	acking systems				
	avigation and image guidance				
	notion 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	urse L0338: Robotics and Navigation in Medicine			
Тур	Project Seminar			
Hrs/wk	2			
CP	2			
Workload in Hours	pendent Study Time 32, Study Time in Lecture 28			
Lecturer	Prof. Alexander Schlaefer			
Language				
Cycle	2			
Content	See interlocking course			
Literature	See interlocking course			

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

Courses						
Title		Тур	Hrs/wk	СР		
Lab Applied Dynamics (L1631)		Practical Course	2	2		
Applied Dynamics (L1630)		Lecture	4	4		
Module Responsible	Prof. Robert Seifried					
Admission Requirements	None					
Recommended Previous	Mathematics I, II, III, Mechanics I, II, III, IV					
Knowledge	Numerical Treatment of Ordinary Differential Eq	uations				
Educational Objectives	After taking part successfully, students have rea	ached the following learning results				
Professional Competence						
Knowledge	Students can represent the most important me and have a good understanding of the main con		letion of the module	e Technical dynami		
Skills	Students are able					
	+ to think holistically					
	+ to independently, securly and critically analyze and optimize basic problems of the dynamics of rigid and flexible multibod systems					
	+ to describe dynamics problems mathematically					
	+ to investigate dynamics problems both exper	mentally and numerically				
Personal Competence						
Social Competence	Students are able to					
	+ solve problems in heterogeneous groups and	to document the corresponding results.				
Autonomy	Students are able to					
	+ assess their knowledge by means of exercises and experiments.					
	+ acquaint themselves with the necessary knowledge to solve research oriented tasks.					
Workload in Hours	Independent Study Time 96, Study Time in Lect	ure 84				
Credit points	6					
Course achievement	Compulsory         Bonus         Form           Yes         None         Subject         theoretical           practical work	Description andVersuche Fachlabor				
Examination	Written exam					
Examination duration and	90 min					
scale						
Assignment for the	Mechatronics: Specialisation Intelligent Systems	and Robotics: Elective Compulsory				
Following Curricula	Mechatronics: Specialisation System Design: Ele	ective Compulsory				
	Theoretical Mechanical Engineering: Core Qualification: Compulsory					

Course L1631: Lab Applied Dynamics	
Тур	Practical Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Marc-André Pick
Language	DE
Cycle	SoSe
	Practical exercises are performed in groups. The examples are taken from different areas of applied dynamics, such as numerical simulation, experimental validation and experimental vibration analysis.
Literature	Schiehlen, W.; Eberhard, P.: Technische Dynamik, 4. Auflage, Vieweg+Teubner: Wiesbaden, 2014.

Course L1630: Applied Dynamics	
Тур	Lecture
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Prof. Robert Seifried, Dr. Marc-André Pick
Language	DE
Cycle	SoSe
Content	<ol> <li>Modelling of Multibody Systems</li> <li>Basics from kinematics and kinetics</li> <li>Constraints</li> <li>Multibody systems in minimal coordinates</li> <li>State space, linearization and modal analysis</li> <li>Multibody systems with kinematic constraints</li> <li>Multibody systems as DAE</li> <li>Non-holonomic multibody systems</li> <li>Experimental Methods in Dynamics</li> </ol>
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.

Courses							
Title				Тур		Hrs/wk	СР
Embedded Systems (L0805)				Lecture		3	3
Embedded Systems (L2938)				Project-/	problem-based Learning	1	1
Embedded Systems (L0806)				Recitatio	n Section (small)	1	2
Module Responsible	Prof. Heiko Falk						
Admission Requirements	None						
	Computer Engineering	g					
Knowledge							
Educational Objectives	After taking part succ	essfully, students	have reached t	the following learning	ig results		
Professional Competence							
Knowledge	Embedded systems ca	an be defined as	nformation pro	cessing systems en	nbedded into enclosing	products. Thi	s course teaches
					nto these systems (not		
					mata, specification of	distributed sy	/stems, task grap
	specification of real-ti	me applications,	ranslations bet	ween different mod	els).		
	Another part covers	the hardware of	embedded sys	tems: Sonsors, A/D	and D/A converters,	real-time cap	able communicat
	hardware, embedded	processors, men	ories, energy	dissipation, reconfig	jurable logic and actua	ators. The cou	urse also features
	introduction into real	i-time operating	ystems, middle	eware and real-tim	e scheduling. Finally,	the implemen	tation of embed
	systems using hardwa	are/software co-d	esign (hardwar	e/software partitior	ing, high-level transfo	rmations of sp	pecifications, ener
	efficient realizations,	compilers for emb	edded process	ors) is covered.			
Chille	After beying attended	d the second stu	danta chall ha	abla ta vaaliza sina			
SKIIIS	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 able to compare different models of computations and feasible techniques for system-level design. They shall be able to judge						
	which areas of embed				es for system-level des	agn. mey sna	
Personal Competence	which dreas of embed	laca system acsig	in specific fisits	exist.			
-	Students are able to s	solve similar prob	ems alone or in	a group and to pre	sent the results accord	linaly	
Social competence		forve similar prob		a group and to pre		inigiy.	
Autonomy	Students are able to a	acquire new know	edge from spec	cific literature and t	o associate this knowle	dge with othe	r classes.
Workload in Hours	Independent Study Tir	me 110 Study Ti	ne in Lecture 7	0			
	6	ine 110, Study In	The In Lecture 7	0			
Course achievement	Compulsory Bonus	Form	Des	cription			
course achievement	Yes 10 %	Subject theor	etical and				
		practical work					
Examination	Written exam						
Examination duration and	90 minutes, contents of course and labs						
scale							
Assignment for the	General Engineering 9	Science (German	program, 7 sem	ester): Specialisatio	on Computer Science: (	Compulsory	
Following Curricula	Computer Science: Sp	oecialisation I. Cor	nputer and Soft	ware Engineering:	Elective Compulsory		
	Electrical Engineering: Core Qualification: Elective Compulsory						
	Engineering Science: Specialisation Mechatronics: Elective Compulsory						
	Engineering Science: Specialisation Electrical Engineering: Elective Compulsory						
	Aircraft Systems Engineering: Core Qualification: Elective Compulsory						
	General Engineering Science (English program, 7 semester): Specialisation Mechatronics: Elective Compulsory						
	Computer Science in Engineering: Core Qualification: Compulsory						
			Mechatronics: Specialisation System Design: Elective Compulsory				
		-	-				

Course L0805: Embedded Sy	stems
Тур	Lecture
Hrs/wk	3
СР	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	EN
Cycle	SoSe
Content	<ul> <li>Introduction</li> <li>Specifications and Modeling</li> <li>Embedded/Cyber-Physical Systems Hardware</li> <li>System Software</li> <li>Evaluation and Validation</li> <li>Mapping of Applications to Execution Platforms</li> <li>Optimization</li> </ul>
Literature	<ul> <li>Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2 <sup>nd</sup> Edition, Springer, 2012., Springer, 2012.</li> </ul>

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

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

Courses				
Title		Тур	Hrs/wk	СР
Machine Learning and Data Mining (L0340)		Lecture	2	4
Machine Learning and Data Mining		Recitation Section (small)	2	2
Module Responsible				
Admission Requirements				
Recommended Previous Knowledge	<ul><li>Calculus</li><li>Stochastics</li></ul>			
Educational Objectives	After taking part successfully, students I	nave reached the following learning results		
Professional Competence				
Skills	algorithms. Students are also able to sketch different clustering techniques. They depict how the performance of learned classif can be improved by ensemble learning, and they can summarize how this influences computational learning theory. Algorithms reinforcement learning can also be explained by students. Student derive decision trees and, in turn, propositional rule sets from simple and static data tables and are able to name explain basic optimization techniques. They present and apply the basic idea of first-order inductive leaning. Students apply BME, MAP, ML, and EM algorithms for learning parameters of Bayesian networks and compare the different algorithms. They a know how to carry out Gaussian mixture learning. They can contrast kNN classifiers, neural networks, and support ver machines, and name their basic application areas and algorithmic properties. Students can describe basic clustering techniques, e.g., k-me clustering and nearest neighbor classification. They can distinguish various ensemble learning techniques and compare different goals of those techniques.			
Personal Competence				
Personal Competence Social Competence				
Social Competence Autonomy	Independent Study Time 124, Study Tim	ie in Lecture 56		
Social Competence Autonomy Workload in Hours	Independent Study Time 124, Study Tim	e in Lecture 56		
Social Competence Autonomy Workload in Hours	Independent Study Time 124, Study Tim	e in Lecture 56		
Social Competence Autonomy Workload in Hours Credit points Course achievement	Independent Study Time 124, Study Tim 6 None	ie in Lecture 56		
Social Competence Autonomy Workload in Hours Credit points Course achievement Examination	Independent Study Time 124, Study Tim 6 None Written exam	e in Lecture 56		
Social Competence Autonomy Workload in Hours Credit points Course achievement Examination	Independent Study Time 124, Study Tim 6 None Written exam	e in Lecture 56		
Social Competence Autonomy Workload in Hours Credit points Course achievement Examination Examination duration and scale Assignment for the	Independent Study Time 124, Study Tim 6 None Written exam 90 minutes Computer Science: Specialisation II: Inte	lligence Engineering: Elective Compulsory		
Social Competence Autonomy Workload in Hours Credit points Course achievement Examination Examination duration and scale	Independent Study Time 124, Study Tim 6 None Written exam 90 minutes Computer Science: Specialisation II: Inter International Management and Engineer	lligence Engineering: Elective Compulsory ing: Specialisation II. Information Technology: Ele	ective Compulsory	
Social Competence Autonomy Workload in Hours Credit points Course achievement Examination Examination duration and scale Assignment for the	Independent Study Time 124, Study Tim 6 None Written exam 90 minutes Computer Science: Specialisation II: Inter International Management and Engineer Mechatronics: Technical Complementary	lligence Engineering: Elective Compulsory ing: Specialisation II. Information Technology: Ele / Course: Elective Compulsory	ective Compulsory	
Social Competence Autonomy Workload in Hours Credit points Course achievement Examination Examination duration and scale Assignment for the	Independent Study Time 124, Study Tim 6 None Written exam 90 minutes Computer Science: Specialisation II: Inter International Management and Engineer Mechatronics: Technical Complementary Mechatronics: Specialisation System Des	lligence Engineering: Elective Compulsory ing: Specialisation II. Information Technology: Ele / Course: Elective Compulsory	ective Compulsory	

Course L0510: Machine Lear	ourse L0510: Machine Learning and Data Mining			
Тур	Recitation Section (small)			
Hrs/wk	2			
СР	2			
Workload in Hours	ependent Study Time 32, Study Time in Lecture 28			
Lecturer	ner Marrone			
Language	EN			
Cycle	SoSe			
Content	See interlocking course			
Literature	See interlocking course			

Module M1173: Appli	ed Statistics				
Courses					
Title	Тур		Hrs/wk	СР	
Applied Statistics (L1584)	Lecture	2	2	3	
Applied Statistics (L1586)	-	-/problem-based Learning	2	2	
Applied Statistics (L1585)		ion Section (small)	1	1	
Module Responsible					
Admission Requirements	None				
<b>Recommended Previous</b>	Basic knowledge of statistical methods				
Knowledge					
Educational Objectives	After taking part successfully, students have reached the following learn	ning results			
Professional Competence					
Knowledge	Students can explain the statistical methods and the conditions of their use.				
Skills	Students are able to use the statistics program to solve statistics problems and to interpret and depict the results				
Personal Competence					
Social Competence	Team Work, joined presentation of results				
A					
Autonomy	To understand and interpret the question and solve				
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70				
Credit points	6				
Course achievement	None				
Examination	Written exam				
Examination duration and	90 minutes, 28 questions				
scale					
Assignment for the	Mechanical Engineering and Management: Specialisation Management:	Elective Compulsory			
Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective (	Compulsory			
	Mechatronics: Specialisation System Design: Elective Compulsory				
	Mechatronics: Core Qualification: Elective Compulsory				
	Biomedical Engineering: Core Qualification: Compulsory				
	Product Development, Materials and Production: Core Qualification: Elec	tive Compulsory			
	Theoretical Mechanical Engineering: Specialisation Bio- and Medical Tec	hnology: Elective Compul	sory		

Course L1584: Applied Statis	tics
Тур	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
	<ul> <li>The goal is to introduce students to the basic statistical methods and their application to simple problems. The topics include:</li> <li>Chi square test</li> <li>Simple regression and correlation</li> <li>Multiple regression and correlation</li> <li>One way analysis of variance</li> <li>Two way analysis of variance</li> <li>Discriminant analysis</li> <li>Analysis of categorial data</li> <li>Chossing the appropriate statistical method</li> <li>Determining critical sample sizes</li> </ul>
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 Statis	stics
Тур	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
Content	The students receive a problem task, which they have to solve in small groups ( $n=5$ ). They do have to collect their own data and work with them. The results have to be presented in an executive summary at the end of the course.
Literature	Selbst zu finden

Course L1585: Applied Statis	stics
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

Courses					
Title		Тур	Hrs/wk	СР	
Formulas and Vehicles - Dynamics	and Control of Autonomous Vehicles (L2869)	Integrated Lecture	1	1	
Formulas and Vehicles - Introduction	n into Mobile Underwater Robotics (L1981)	Project-/problem-based Learning	4	5	
Module Responsible	Prof. Robert Seifried				
Admission Requirements	None				
<b>Recommended Previous</b>	Mechanics IV, Applied Dynamics or Robotics				
Knowledge	Numerical Treatment of Ordinary Differential Equati	ons			
	Control Systems Theory and Design				
Educational Objectives	After taking part successfully, students have reache	d the following learning results			
Professional Competence					
Knowledge	After successful completion of the module studen areas of multibody dynamics and robotics	s demonstrate deeper knowledge and und	erstanding in	selected applicati	
Skills	Students are able				
	+ to think holistically				
	+ to independently, securly and critically analyze and optimize basic problems of the dynamics of rigid and flexible multibod systems				
	+ to describe dynamics problems mathematically				
	+ to implement dynamical problems on hardware				
Personal Competence					
Social Competence	Students are able to				
	+ solve problems in heterogeneous groups and to d	ocument the corresponding results and prese	ent them		
Autonomy	Students are able to				
	+ assess their knowledge by means of exercises and projects.				
	+ acquaint themselves with the necessary knowled	ge to solve research oriented tasks.			
Workload in Hours	Independent Study Time 110, Study Time in Lecture	70			
Credit points	6				
Course achievement	None				
Examination	Presentation				
Examination duration and	ТВА				
scale					
	Mechatronics: Specialisation Intelligent Systems and				
Following Curricula	Mechatronics: Specialisation System Design: Electiv				
	Mechatronics: Core Qualification: Elective Compulso Theoretical Mechanical Engineering: Core Qualificat	•			

Course L2869: Formulas and	ourse L2869: Formulas and Vehicles - Dynamics and Control of Autonomous Vehicles		
Тур	Integrated Lecture		
Hrs/wk	1		
CP	1		
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14		
Lecturer	Prof. Robert Seifried, Daniel-André Dücker		
Language	DE		
Cycle	WiSe		
Content			
Literature			

Course L1981: Formulas and Vehicles - Introduction into Mobile Underwater Robotics		
Тур	Project-/problem-based Learning	
Hrs/wk	4	
СР	5	
Workload in Hours	Independent Study Time 94, Study Time in Lecture 56	
Lecturer	Prof. Robert Seifried, Daniel-André Dücker	
Language	DE	
Cycle	WiSe	
Content		
Literature	Seifried, R.: Dynamics of underactuated multibody systems, Springer, 2014	
	Popp, K.; Schiehlen, W.: Ground vehicle dynamics, Springer, 2010	

Module M0832: Adva	nced Topics in Control			
Courses				
Title		Тур	Hrs/wk	СР
Advanced Topics in Control (L0661)	)	Lecture	2	3
Advanced Topics in Control (L0662)	)	Recitation Section (small)	2	3
Module Responsible	NN			
Admission Requirements	None			
<b>Recommended Previous</b>	H-infinity optimal control, mixed-sensitivity design, linear matrix i	nequalities		
Knowledge				
Educational Objectives	After taking part successfully, students have reached the following	g learning results		
Professional Competence				
Knowledge Skills	<ul> <li>Students can explain the advantages and shortcomings of 1</li> <li>They can explain the representation of nonlinear systems ii</li> <li>They can explain how stability and performance conditions</li> <li>They can explain how gridding techniques can be used to s</li> <li>They are familiar with polytopic and LFT representation: associated with each of these model structures</li> <li>Students can explain how graph theoretic concepts are systems</li> <li>They can explain the convergence properties of first order</li> <li>They can explain analysis and synthesis conditions for form</li> <li>Students can explain concepts behind linear and qLPV Mod</li> <li>Students can construct LPV models of nonlinear plants controllers; they can do this using polytopic, LFT or general</li> <li>They can use standard software tools (Matlab robust control</li> <li>Students can design distributed formation controllers for tools provided</li> </ul>	n the form of quasi-LPV syst for LPV systems can be forn solve analysis and synthesis is of LPV systems and som used to represent the co- consensus protocols nation control loops involvin lel Predictive Control (MPC) is and carry out a mixed- l LPV models ol toolbox) for these tasks	nulated as LMI co problems for LPV e of the basic s mmunication top g either LTI or LPV sensitivity design	systems ynthesis techniqu ology of multiage / agent models
Personal Competence	• Students can design MPC controllers for linear and non-line	ear systems using Matlab too	bls	
	s Students can work in small groups and arrive at joint results.			
Autonomy	Students can find required information in sources provided (lectu	ure notes, literature, softwa	re documentation	) and use it to sol
	given problems.			
	Independent Study Time 124, Study Time in Lecture 56			
Credit points				
Course achievement	None			
Examination	Oral exam			
Examination duration and scale	30 min			
Assignment for the	Electrical Engineering: Specialisation Control and Power Systems	Engineering: Elective Comp	ulsory	
Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compul	sory		
	Aeronautics: Core Qualification: Elective Compulsory			
	Mechatronics: Specialisation Intelligent Systems and Robotics: Ele	ective Compulsory		
	Mechatronics: Specialisation System Design: Elective Compulsory			
	Mechatronics: Core Qualification: Elective Compulsory			
	Biomedical Engineering: Specialisation Implants and Endoprosthe	ses: Elective Compulsory		
	Biomedical Engineering: Specialisation Medical Technology and Co	ontrol Theory: Elective Com	pulsory	
	Biomedical Engineering: Specialisation Management and Business	s Administration: Elective Co	ompulsory	
	Biomedical Engineering: Specialisation Artificial Organs and Rege	nerative Medicine: Elective	Compulsory	
	Theoretical Mechanical Engineering: Specialisation Robotics and C	Computer Science: Elective	Compulsory	

Тур	Lecture	
Hrs/wk		
CP	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Lecturer	NN	
Language	EN	
Cycle	WiSe	
Content	Linear Parameter-Varying (LPV) Gain Scheduling	
	- Linearizing gain scheduling, hidden coupling	
	- Jacobian linearization vs. quasi-LPV models	
	- Stability and induced L2 norm of LPV systems	
	- Synthesis of LPV controllers based on the two-sided projection lemma	
	- Simplifications: controller synthesis for polytopic and LFT models	
	- Experimental identification of LPV models	
	- Controller synthesis based on input/output models	
	- Applications: LPV torque vectoring for electric vehicles, LPV control of a robotic manipulator	
	Control of Multi-Agent Systems	
	- Communication graphs	
	- Spectral properties of the graph Laplacian	
	- First and second order consensus protocols	
	- Formation control, stability and performance	
	- LPV models for agents subject to nonholonomic constraints	
	- Application: formation control for a team of quadrotor helicopters	
	Linear and Nonlinear Model Predictive Control based on LMIs	
Literature	Werner, H., Lecture Notes "Advanced Topics in Control"	
	<ul> <li>Selection of relevant research papers made available as pdf documents via StudIP</li> </ul>	

Course L0662: Advanced Top	ourse L0662: Advanced Topics in Control	
Тур	Recitation Section (small)	
Hrs/wk	2	
CP		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Lecturer	NN	
Language	EN	
Cycle	Cycle WiSe	
Content	See interlocking course	
Literature	See interlocking course	

Module M1748: Const	ruction Robotics
Courses	
Fitle Construction Robotics (L2867)	Typ     Hrs/wk     CP       Project-/problem-based Learning     6     6
Module Responsible	
Admission Requirements	
Recommended Previous	
Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Basics of robotics
	Applications in civil engineering
	Kinematics
	Kindidas
Skills	Use of specific hardware
	Development of software routines
	Python programming language
	Image processing
	Basics of localization (LIDAR, SLAM)
Personal Competence	
Social Competence	Teamwork
	Communication skills
Autonomy	Independent work
	Independent decisions
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and	ca. 10 Seiten
scale	
	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory
Following Curricula	
	Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory
	Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory
	Civil Engineering: Specialisation Computational Engineering: Elective Compulsory
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory
	Mechatronics: Core Qualification: Elective Compulsory
	Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

ourse L2867: Construction Robotics		
Тур	Project-/problem-based Learning	
Hrs/wk		
CP	6	
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84	
Lecturer	Prof. Kay Smarsly, Jan Stührenberg, Mathias Worm	
Language	DE/EN	
Cycle	WiSe	
Content	<ol> <li>Introduction: Robotics in civil engineering</li> <li>Presentation of potential topics</li> <li>Programming of algorithms in Python</li> <li>Application of software systems: LINUX distribution, ROS, CloudCompare,</li> <li>Application of hardware systems: Petoi Bittle Dog, Raspberry Pi, Arduino, sensing</li> <li>Topics considered for robotics using the Petoi Bittle Dog:         <ol> <li>Movement</li> <li>Use of sensors (camera, infrared,)</li> <li>Data structures/data acquisition</li> <li>Programming</li> </ol> </li> <li>Topics technically relevant to building inspection:         <ol> <li>Geodetic evaluations</li> <li>Image processing</li> <li>Localization</li> </ol> </li> </ol>	
Literature	Bock/Linner: Construction Robotics Verl et al.: Soft Robotics	
	Pasquale: New Laws of robotics	

Courses				
Title		Тур	Hrs/wk	CP
Image Processing (L2443) Image Processing (L2444)		Lecture Recitation Section (small)	2	4 2
	Prof. Tobias Knopp	Reclation Section (Sinally	2	2
Module Responsible				
Admission Requirements	None			
Recommended Previous Knowledge	Signal and Systems			
-	After taking part successfully, students have reache	d the following learning results		
Professional Competence	After taking part successiony, students have reache	a the following learning results		
•	The students know about			
Knowledge	The students know about			
	<ul> <li>visual perception</li> </ul>			
	<ul> <li>multidimensional signal processing</li> </ul>			
	<ul> <li>sampling and sampling theorem</li> </ul>			
	filtering			
	<ul> <li>image enhancement</li> </ul>			
	edge detection			
	<ul> <li>multi-resolution procedures: Gauss and Lapla</li> </ul>	ce pyramid, wavelets		
	image compression			
	image segmentation			
	<ul> <li>morphological image processing</li> </ul>			
Skills	The students can			
	analyze, process, and improve multidimensio	nal image data		
	<ul> <li>implement simple compression algorithms</li> <li>design custom filters for specific applications</li> </ul>			
	design custom inters for specific applications			
Personal Competence				
Social Competence	Students can work on complex problems both indep	endently and in teams. They can exchang	e ideas with each	n other and use th
	individual strengths to solve the problem.			
Autonomy	Students are able to independently investigate a co	mploy problem and assess which compate	ancios aro roquiro	d to colvo it
Autonomy	Students are able to independently investigate a col	inplex problem and assess which compete	encies are require	a to solve it.
Workload in Hours	Independent Study Time 124, Study Time in Lecture	56		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and	90 min			
scale				
Assignment for the	Data Science: Core Qualification: Elective Compulso	ry		
Following Curricula	Data Science: Specialisation I. Mathematics/Comput	er Science: Elective Compulsory		
	Data Science: Specialisation II. Computer Science: E	lective Compulsory		
	Data Science: Specialisation IV. Special Focus Area:	Elective Compulsory		
	Electrical Engineering: Specialisation Information an	d Communication Systems: Elective Com	oulsory	
	Electrical Engineering: Specialisation Medical Techn	ology: Elective Compulsory		
	Information and Communication Systems: Specia	lisation Secure and Dependable IT Sy	/stems, Focus S	oftware and Sig
	Processing: Elective Compulsory			
	Information and Communication Systems: Specialisa			ective Compulsory
	International Management and Engineering: Special		e Compulsory	
	Mechatronics: Specialisation Intelligent Systems and			
	Mechatronics: Specialisation System Design: Electiv			
	Mechatronics: Core Qualification: Elective Compulso		tive Course 1	
	Microelectronics and Microsystems: Specialisation C			
	Theoretical Mechanical Engineering: Specialisation F	lobolics and computer science: Elective (	Jonnpulsory	

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

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

Courses				
Title		Тур	Hrs/wk	СР
Digital Signal Processing and Digita		Lecture	3	4
Digital Signal Processing and Digita		Recitation Section (large)	2	2
Module Responsible	Prof. Gerhard Bauch			
Admission Requirements	None			
Recommended Previous	Mathematics 1-3			
Knowledge	Signals and Systems			
	<ul> <li>Fundamentals of signal and system</li> </ul>	theory as well as random processes.		
	Fundamentals of spectral transform	s (Fourier series, Fourier transform, Laplace tra	nsform)	
	After taking part successfully, students ha	ve reached the following learning results		
Professional Competence				
Knowledge		algorithms of digital signal processing. They ar		
	-	scribe and analyse signals and systems in tin	-	-
		entify and assess important properties inclu oefficients and signals. They are familiar with		
		ds of spectrum estimation, also taking a limited		-
	perform traditional and parametric metric	as of spectrum estimation, also taking a minicu		into account.
	The students are familiar with the contents of lecture and tutorials. They can explain and apply them to new problems		problems.	
Skills	The students are able to apply methods o	of digital signal processing to new problems. Th	ey can choose and	parameterize suita
	filter striuctures. In particular, the can design adaptive filters according to the minimum mean squared error (MMSE) criterion an			
	develop an efficient implementation, e.c.	. based on the LMS or RLS algorithm. Furth	ermore, the studer	nts are able to app
	methods of spectrum estimation and to ta	ke the effects of a limited observation window in	nto account.	
Personal Competence				
Social Competence	The students can jointly solve specific pro	blems.		
Autonomy	The students are able to acquire relev	ant information from appropriate literature s	aureas Thoy can	control their lovel
Autonomy		lving tutorial problems, software tools, clicker s	-	control their level
			, sternin	
Workload in Hours	Independent Study Time 110, Study Time	in Lecture 70		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and	90 min			
scale				
-		rol and Power Systems Engineering: Elective Co		
Following Curricula		sation II. Engineering Science: Elective Compuls		
	-	Specialisation Communication Systems, Focus		lective Compulsory
		: Specialisation Mechatronics: Elective Compulso	ory	
	Mechatronics: Specialisation Intelligent Sy			
	Mechatronics: Core Qualification: Elective			
		alisation Communication and Signal Processing:		У
	Theoretical Mechanical Engineering: Spec	alisation Robotics and Computer Science: Electi	ve Compulsory	

Course L0446: Digital Signal	Processing and Digital Filters	
Тур	Lecture	
Hrs/wk	3	
СР	4	
Workload in Hours	ndependent Study Time 78, Study Time in Lecture 42	
	Prof. Gerhard Bauch	
Language		
Cycle	Wise	
content	Transforms of discrete-time signals:	
	• Discrete-time Fourier Transform (DTFT)	
	<ul> <li>Discrete Fourier-Transform (DFT), Fast Fourier Transform (FFT)</li> </ul>	
	• Z-Transform	
	Correspondence of continuous-time and discrete-time signals, sampling, sampling theorem	
	Fast convolution, Overlap-Add-Method, Overlap-Save-Method	
	Fundamental structures and basic types of digital filters	
	Characterization of digital filters using pole-zero plots, important properties of digital filters	
	Quantization effects	
	Design of linear-phase filters	
	Fundamentals of stochastic signal processing and adaptive filters	
	MMSE criterion	
	Wiener Filter	
	LMS- and RLS-algorithm	
	Traditional and parametric methods of spectrum estimation	
Literature	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.	
	Oppenheim, R. W. Schafer: Digital signal processing. Prentice Hall.	
	S. Haykin: Adaptive flter theory.	
	L. B. Jackson: Digital filters and signal processing. Kluwer.	
	T.W. Parks, C.S. Burrus: Digital filter design. Wiley.	

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

Module M1552: Adva	nced Machine Learning			
Courses				
Title		Тур	Hrs/wk	СР
Advanced Machine Learning (L2322 Advanced Machine Learning (L2322		Lecture Recitation Section (small)	2	3 3
		Recitation Section (Smail)	Z	5
Module Responsible				
Admission Requirements	None			
Recommended Previous	1. Mathematics I-III			
Knowledge	2. Numerical Mathematics 1/ Numerics			
	3. Programming skills, preferably in Python			
Educational Objectives	After taking part successfully, students have rea	ched the following learning results		
Professional Competence	5 p			
•	Students are able to name, state and classify si	ate-of-the-art neural networks and their corr	esponding mathe	ematical basics. The
	can assess the difficulties of different neural net			
Skills	Students are able to implement, understand, an	d, tailored to the field of application, apply ne	eural networks.	
Personal Competence		.,		
Social Competence	Students can			
,				
	<ul> <li>develop and document joint solutions in s</li> </ul>			
		and transfer them to other areas of applicabil	lity;	
	<ul> <li>form a team to develop, build, and advan</li> </ul>	ce a software library.		
Autonomy	Students are able to			
	<ul> <li>correctly assess the time and effort of sel</li> </ul>	f-defined work:		
		I and practical excercises are better solved in	idividually or in a	team;
	<ul> <li>define test problems for testing and expa</li> </ul>		2	
	<ul> <li>assess their individual progess and, if neo</li> </ul>	essary, to ask questions and seek help.		
Workload in Hours	Independent Study Time 124, Study Time in Lec	ture 56		
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and	25 min			
scale				
Assignment for the	Computer Science: Specialisation III. Mathemati	cs: Elective Compulsory		
Following Curricula	Data Science: Core Qualification: Compulsory			
	Computer Science in Engineering: Specialisation	III. Mathematics: Elective Compulsory		
	Mechatronics: Specialisation Intelligent Systems	and Robotics: Elective Compulsory		
	Mechatronics: Specialisation System Design: Ele	ctive Compulsory		
	Mechatronics: Core Qualification: Elective Comp	ulsory		
	Technomathematics: Specialisation I. Mathemat	ics: Elective Compulsory		
	Theoretical Mechanical Engineering: Specialisati	on Robotics and Computer Science: Elective	Compulsory	

Course L2322: Advanced Ma	chine Learning
Тур	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jens-Peter Zemke
Language	DE/EN
Cycle	WiSe
Content	<ol> <li>Basics: analogy; layout of neural nets, universal approximation, NP-completeness</li> <li>Feedforward nets: backpropagation, variants of Stochastistic Gradients</li> <li>Deep Learning: problems and solution strategies</li> <li>Deep Belief Networks: energy based models, Contrastive Divergence</li> <li>CNN: idea, layout, FFT and Winograds algorithms, implementation details</li> <li>RNN: idea, relation to neural ODEs</li> <li>Standard libraries: Tensorflow, Keras, PyTorch</li> <li>Recent trends</li> </ol>
Literature	<ol> <li>Skript</li> <li>Online-Werke:         <ul> <li>http://neuralnetworksanddeeplearning.com/</li> <li>https://www.deeplearningbook.org/</li> </ul> </li> </ol>

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

Module M1596: Engin	eering Haptic S	ystems			
Courses					
Гitle			Тур	Hrs/wk	СР
Haptic Technology for Human-Mach	nine-Interfaces (HMI) (L243	39)	Lecture	4	3
Haptic Technology for Human-Mach	nine-Interfaces (HMI) (L28	59)	Project-/problem-based L	earning 2	3
Module Responsible	Prof. Thorsten Kern				
Admission Requirements	None				
Recommended Previous	We recommend knowle	edge in the areas of g	eneral engineering sciences, mechatronics	and/or control-end	aineering. However a
			engineering or even process-engineers ca		
	the content properly.			,	
Educational Objectives		ssfully, students have	reached the following learning results		
Professional Competence	, area taking part sacce	ssiany, stadents nave			
-	This course is an intro	duction to the decign	methods and design requirements to see	sidor when creati	an hantic systems fr
Kilowieuge			methods and design-requirements to con		
			tuator development part, and goes up to a		
			re complex projects. Beside design-relate		
	laboratories of M-4.		that field with many examples. This is	supported by on-	site experiments in
	Iddoratories of M-4.				
	<ul> <li>Motivation and a</li> </ul>	application of haptic sy	stems		
	<ul> <li>Haptic perception</li> </ul>	n			
		iser in direct system in	teraction		
	Development of haptic systems				
	Identification of requirements				
	System-structure and control				
	Kinematic fundamentals				
	Actuation & Sensors technology for haptic applications				
	Control and system-design aspects				
		nsiderations in simulat	ing haptics		
Skills	Executing the course the competency will be developed to apply the general engineering capabilities of the individual cours				
	towards the design and application of active haptic systems. The resulting competencies will open an entry into specialize				
	position in avionic-indu	stries, automotive-indu	ustry and consumer-device-development.		
Personal Competence					
Social Competence	As a side-effect this n	nodule teaches basics	of a general design for human-machine-	interfaces, indepe	ndent from the spec
	application of "haptics". It teaches methods to execute user-studies, judge on user-feedback and how to deal with soft design				
	requirements which are	e common when dealin	g with subjective perception.		
Autonomy	Independent design-ca	pability of haptic syste	ms, general competency in engineering fro	om a design-perspe	ctive
Workload in Hours	Independent Study Tim	ne 96, Study Time in Le	cture 84		
Credit points	6				
Course achievement	Compulsory Bonus	Form	Description		
	Yes 20 %	Subject theoretical	andDurchführung von Laborversuchen		
		practical work			
Examination	Subject theoretical and	l practical work			
	30 min				
scale					
	Mechatronics: Specialis	sation Intelligent System	ms and Robotics: Elective Compulsory		
-	Mechatronics: Specialis				
i onowing curricula	Mechatronics: Core Qu				
	meenacionics. core qu	anneation. Liective COI	iipuisoi y		

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

course 12059. haptic recillo	biogy for numan-machine-interfaces (nmi)
Тур	Project-/problem-based Learning
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Courses					
<b>Fitle</b> Mathematical Image Processing (L	0001)		Гур .ecture	Hrs/wk 3	<b>CP</b> 4
Mathematical Image Processing (L			Recitation Section (small)	1	2
Module Responsible					
Admission Requirements					
Recommended Previous					
Knowledge	<ul> <li>Analysis: partial derivatives</li> </ul>	, gradient, directional derivative			
Kitowieuge		, least squares solution of a linea	ar system		
Educational Objectives	After taking part successfully, stu	lanta hava yaashad tha fallowing			
Educational Objectives		ents have reached the following	learning results		
Professional Competence					
Knowledge	Students are able to				
	characterize and compare of	iffusion equations			
	<ul> <li>explain elementary method</li> </ul>	s of image processing			
	<ul> <li>explain methods of image s</li> </ul>	egmentation and registration			
	<ul> <li>sketch and interrelate basic</li> </ul>	concepts of functional analysis			
Skille	Students are able to				
SKIIIS					
	<ul> <li>implement and apply element</li> </ul>	entary methods of image process	sing		
	<ul> <li>explain and apply modern r</li> </ul>	nethods of image processing			
Personal Competence					
	Students are able to work tog	other in beterogeneously com	nosed teams (i.e. teams	from different of	tudy programs a
Social Competence	background knowledge) and to ex		josed teams (i.e., teams	nom unerent s	study programs a
	buckground knowledge, and to ex	Juin theoretical foundations.			
Autonomy	Students are capable of ch	ocking their understanding of c	omploy concepts on their (	wn Thoy can ch	ocify open questio
	<ul> <li>Students are capable of checking their understanding of complex concepts on their own. They can specify open question precisely and know where to get help in solving them.</li> </ul>				
		sufficient persistence to be able	to work for longer period	ls in a goal-orien	ted manner on ha
		unicient persistence to be usie	, to work for longer period	is in a goar orien	
	problems.				
Workload in Hours	problems.	ly Time in Lecture 56			
Workload in Hours Credit points	problems. Independent Study Time 124, Stu	ly Time in Lecture 56			
	problems. Independent Study Time 124, Stur 6	ly Time in Lecture 56			
Credit points	problems. Independent Study Time 124, Stud 6 None	ly Time in Lecture 56			
Credit points Course achievement	problems. Independent Study Time 124, Stur 6 None Oral exam	ly Time in Lecture 56			
Credit points Course achievement Examination	problems. Independent Study Time 124, Stur 6 None Oral exam 20 min	ly Time in Lecture 56			
Credit points Course achievement Examination Examination duration and	problems. Independent Study Time 124, Stur 6 None Oral exam 20 min		ineering: Elective Compulso	ory	
Credit points Course achievement Examination Examination duration and scale	problems. Independent Study Time 124, Stur 6 None Oral exam 20 min Bioprocess Engineering: Specialisa	tion A - General Bioprocess Engi		ory	
Credit points Course achievement Examination Examination duration and scale Assignment for the	problems. Independent Study Time 124, Stur 6 None Oral exam 20 min Bioprocess Engineering: Specialisa Computer Science: Specialisation Computer Science in Engineering:	ition A - General Bioprocess Engi II. Mathematics: Elective Compu Specialisation III. Mathematics: f	llsory Elective Compulsory		
Credit points Course achievement Examination Examination duration and scale Assignment for the	problems. Independent Study Time 124, Stur 6 None Oral exam 20 min Bioprocess Engineering: Specialiss Computer Science: Specialisation Computer Science in Engineering: Interdisciplinary Mathematics: Specialiss	tion A - General Bioprocess Engi II. Mathematics: Elective Compu Specialisation III. Mathematics: I cialisation Computational Metho	llsory Elective Compulsory ods in Biomedical Imaging:		
Credit points Course achievement Examination Examination duration and scale Assignment for the	problems. Independent Study Time 124, Stur 6 None Oral exam 20 min Bioprocess Engineering: Specialisation Computer Science: Specialisation Computer Science in Engineering: Interdisciplinary Mathematics: Spe Mechatronics: Specialisation Intell	tion A - General Bioprocess Engi II. Mathematics: Elective Compu Specialisation III. Mathematics: f cialisation Computational Metho gent Systems and Robotics: Elec	llsory Elective Compulsory ods in Biomedical Imaging:		
Credit points Course achievement Examination Examination duration and scale Assignment for the	problems. Independent Study Time 124, Stur 6 None Oral exam 20 min Bioprocess Engineering: Specialisation Computer Science: Specialisation Computer Science in Engineering: Interdisciplinary Mathematics: Spe Mechatronics: Specialisation Intell Mechatronics: Specialisation Systemetry Mechatronics: Specialisation	tion A - General Bioprocess Engi II. Mathematics: Elective Compu Specialisation III. Mathematics: f cialisation Computational Metho gent Systems and Robotics: Elec m Design: Elective Compulsory	llsory Elective Compulsory ods in Biomedical Imaging:		
Credit points Course achievement Examination Examination duration and scale Assignment for the	problems. Independent Study Time 124, Stur 6 None Oral exam 20 min Bioprocess Engineering: Specialisation Computer Science: Specialisation Computer Science in Engineering: Interdisciplinary Mathematics: Spe Mechatronics: Specialisation Intell Mechatronics: Specialisation Syste Mechatronics: Core Qualification:	tion A - General Bioprocess Engi II. Mathematics: Elective Compu Specialisation III. Mathematics: f cialisation Computational Metho gent Systems and Robotics: Elec m Design: Elective Compulsory Elective Compulsory	Ilsory Elective Compulsory ods in Biomedical Imaging: ctive Compulsory		
Credit points Course achievement Examination Examination duration and scale Assignment for the	problems. Independent Study Time 124, Stur 6 None Oral exam 20 min Bioprocess Engineering: Specialisation Computer Science: Specialisation Computer Science in Engineering: Interdisciplinary Mathematics: Spe Mechatronics: Specialisation Intell Mechatronics: Specialisation Systemetry Mechatronics: Specialisation	tion A - General Bioprocess Engi II. Mathematics: Elective Compu Specialisation III. Mathematics: f cialisation Computational Metho gent Systems and Robotics: Elec m Design: Elective Compulsory Elective Compulsory n I. Mathematics: Elective Comp	Ilsory Elective Compulsory ods in Biomedical Imaging: ctive Compulsory ulsory	Compulsory	

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

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

Module M0629: Intelli	gent Autonomous Agents and	Cognitive Robotics		
Courses				
Title		Тур	Hrs/wk	СР
Intelligent Autonomous Agents and	Cognitive Robotics (L0341)	Lecture	2	4
Intelligent Autonomous Agents and	Cognitive Robotics (L0512)	Recitation Section (small)	2	2
Module Responsible	Rainer Marrone			
Admission Requirements	None			
<b>Recommended Previous</b>	Vectors, matrices, Calculus			
Knowledge				
Educational Objectives	After taking part successfully, students have	reached the following learning results		
Professional Competence				
	Students can explain the agent abstraction, ( (goals, utilities, environments). They can desi- can be discussed in terms of decision proble world scenarios, students can summarize how formalism in static and dynamic settings. In settings, with and with complete access to solving (partially observable) Markov decisio Students can identify techniques for simulta desired states. Students can explain coordina of equilibria, social choice functions, voting pr Students can select an appropriate agent ar students can derive decision trees and apply networks/dynamic Bayesian networks and a different sampling techniques for simplified a best action or policies for concrete settings. I states,e.g., Nash equilibria. For multi-agent du the results.	cribe the main features of environments. The ems and algorithms for solving these proble w Bayesian networks can be employed as a addition, students can define decision mak the state of the environment. In this contex n problems, and they can recall techniques neous localization and mapping, and can e ation problems and decision making in a mul rotocol, and mechanism design techniques. chitecture for concrete agent application so basic optimization techniques. For those ap apply bayesian reasoning for simple queri- agent scenarios. For simple and complex de In multi-agent situations students will apply	e notion of adversar ms. For dealing wit knowledge represer ing procedures in s kt, students can de for measuring the kplain planning tecl i-agent setting in to enarios. For simplif plications they can as. Students can a cision making stude techniques for findi	tial agent cooperati th uncertainty in re- ntation and reason simple and sequen- scribe techniques value of informati- hniques for achiev erm of different typ fied agent applicat also create Bayes also name and ap ents can compute to ng different equiliti
Devecuel Commetence				
Personal Competence	Students are able to discuss their solutions to	problems with others. They communicate in	English	
Social competence		prosients with others. They communicate in	Lightin	
Autonomy	Students are able of checking their understan	nding of complex concepts by solving varaints	of concrete proble	ms
Workload in Hours	Independent Study Time 124, Study Time in L	Lecture 56		
Credit points	6			
Course achievement				
Examination	Written exam			
Examination duration and	90 minutes			
scale				
Assignment for the	Computer Science: Specialisation II: Intelligen	ce Engineering: Elective Compulsory		
Following Curricula	International Management and Engineering: S	Specialisation II. Information Technology: Elec	tive Compulsory	
	Mechatronics: Specialisation Intelligent System	ms and Robotics: Elective Compulsory		
	Mechatronics: Core Qualification: Elective Cor			
	Biomedical Engineering: Specialisation Artifici			
	Biomedical Engineering: Specialisation Implar			
	Biomedical Engineering: Specialisation Medica			
	Biomedical Engineering: Specialisation Manag	gement and business Administration: Elective	compuisory	

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

Course L0512: Intelligent Au	ourse L0512: Intelligent Autonomous Agents and Cognitive Robotics				
Тур	Recitation Section (small)				
Hrs/wk	2				
CP	2				
Workload in Hours	ent Study Time 32, Study Time in Lecture 28				
Lecturer	Marrone				
Language	EN				
Cycle	WiSe				
Content	See interlocking course				
Literature	See interlocking course				

Courses							
Title			Тур	Hrs/	wk	СР	
Intelligent Systems in Medicine (L0	331)		Lecture	2		3	
Intelligent Systems in Medicine (L0334)			Project Seminar	2		2	
Intelligent Systems in Medicine (L0333)			Recitation Section (sm	nall) 1		1	
Module Responsible	Prof. Alexander Schl	laefer					
Admission Requirements	None						
<b>Recommended Previous</b>							
Knowledge		math (algebra, analysis/o	calculus)				
	<ul> <li>principles of s</li> </ul>						
		programming, Java/C++	and R/Matlab				
	<ul> <li>advanced pro</li> </ul>	ogramming skills					
Educational Objectives	After taking part suc	ccessfully. students have	reached the following learning results				
Professional Competence	5 1 5 1 1 1 1	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,					
-	The students are al	ole to analyze and solve	clinical treatment planning and decision	support problem	s usina -	methods for sea	
Knowledge			explain methods for classification and th				
			re different methods for representing me				
			challenges due to the clinical nature of th	-	-		
					quisición		
	and safety requirements.						
Skills	The students can give reasons for selecting and adapting methods for classification, regression, and prediction. They can asses						
	the methods based on actual patient data and evaluate the implemented methods.						
Personal Competence							
•	The students are a	ble to grace practical ta	ske in groune, doublen colution strategie	ac independently	dofino	work processes	
Social Competence	The students are able to grasp practical tasks in groups, develop solution strategies independently, define work processes a work on them collaboratively.						
	The students can critically reflect on the results of other groups, make constructive suggestions for improvement and al						
	incorporate them into their own work.						
	incorporate them in	to their own work.					
Automore	The students can assess their level of knowledge and document their work results. They can critically evaluate the results achiev						
Autonomy				ley can critically e	valuate	the results achie	
	and present them in	i an appropriate argume	ntative manner to the other groups.				
Workload in Hours	Independent Ctudy	Times 110 Chudu Times in	Lesture 70				
		Time 110, Study Time in	Lecture 70				
Credit points		Form	Description				
Course achievement	Yes 10 %	Presentation					
	Yes 10 %	Written elaboration					
Examination	Written exam						
Examination duration and	90 minutes						
scale	50 minutes						
	Computer Science:	Specialisation II: Intellige	nce Engineering: Elective Compulsory				
-							
i onowing curricula	Data Science: Specialisation III. Applications: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory						
	Electrical Engineering: Specialisation Medical Technology: Elective Compulsory						
	Interdisciplinary Mathematics: Specialisation Computational Methods in Biomedical Imaging: Compulsory						
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory						
			cial Organs and Regenerative Medicine: E	lective Compulsor	rv		
	5	5	5 5		у		
	Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory						
	Riomodical Engineer	ring: Specialization Mana	appoint and Business Administration, Fla	ctive Compulsers			
	-		gement and Business Administration: Ele cal Technology and Control Theory: Comp				

Course L0331: Intelligent Sys	stems in Medicine
Тур	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	<ul> <li>methods for search, optimization, planning, classification, regression and prediction in a clinical context</li> <li>representation of medical knowledge</li> <li>understanding challenges due to clinical and patient related data and data acquisition</li> <li>The students will work in groups to apply the methods introduced during the lecture using problem based learning.</li> </ul>
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 Sy	urse L0334: Intelligent Systems in Medicine			
Тур	Project Seminar			
Hrs/wk	2			
CP	2			
Workload in Hours	endent 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 Sy	urse L0333: Intelligent Systems in Medicine		
Тур	Recitation Section (small)		
Hrs/wk	1		
CP	1		
Workload in Hours	rs Independent Study Time 16, Study Time in Lecture 14		
Lecturer	Lecturer Prof. Alexander Schlaefer		
Language	EN		
Cycle	WiSe		
Content	See interlocking course		
Literature	See interlocking course		

Courses						
Title		Тур	Hrs/wk	СР		
Flexible Multibody Systems (L1632)		Lecture	2	3		
Optimization of dynamical systems		Lecture	2	3		
Module Responsible	Prof. Robert Seifried					
Admission Requirements	None					
Recommended Previous						
Knowledge	Mathematics I, II, III					
	Mechanics I, II, III, IV     Simulation of dynamical Systems					
	<ul> <li>Simulation of dynamical Systems</li> </ul>					
Educational Objectives	After taking part successfully, students have re-	ached the following learning results				
Professional Competence						
Knowledge	Students demonstrate basic knowledge and u	nderstanding of modeling, simulation	n and analysis of comp	lex rigid and flexib		
	multibody systems and methods for optimizing	dynamic systems after successful con	npletion of the module.			
Skille	Students are able					
JKIIIS						
	+ to think holistically					
	+ to independently, securly and critically ana	vze and optimize basic problems of	the dynamics of rigid a	nd flexible multibo		
	+ to independently, securly and critically analyze and optimize basic problems of the dynamics of rigid and flexible multiboc systems					
	-					
	+ to describe dynamics problems mathematically					
	+ to optimize dynamics problems					
Personal Competence	Chudonka ana abla ta					
Social Competence	Students are able to					
	+ solve problems in heterogeneous groups and	to document the corresponding result	ts.			
Autonomy	Students are able to					
	+ assess their knowledge by means of exercise	5.				
	+ acquaint themselves with the necessary know	ledge to solve research oriented task	S.			
	Indexedent Church Time 124 Church Time 1	hun 50				
Workload in Hours	Independent Study Time 124, Study Time in Lee	LUIE 20				
Credit points	6 Nore					
Course achievement	None					
Examination	Oral exam					
Examination duration and scale	30 mm					
	Aircraft Systems Engineering: Core Qualification	Elective Compulsory				
Following Curricula	Aircraft Systems Engineering: Core Qualification Aeronautics: Core Qualification: Elective Compu					
. cthing carricula	Mechatronics: Specialisation Intelligent Systems					
	Mechatronics: Specialisation Intelligent System					
	Mechatronics: Core Qualification: Elective Comp					
	Product Development, Materials and Production		ory			
	Theoretical Mechanical Engineering: Core Quali	ication: Elective Compulsory				

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

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

Courses						
Title		Тур	Hrs/wk	СР		
Matrix Algorithms (L0984)		Lecture	2	3		
Matrix Algorithms (L0985)		Recitation Section (small)	2	3		
Module Responsible	Dr. Jens-Peter Zemke					
Admission Requirements	None					
Recommended Previous	Mathematics I - III					
Knowledge	Numerical Mathematics 1/ Numerics					
	<ul> <li>Basic knowledge of the programming</li> </ul>	g languages Matlab and C				
Educational Objectives	After taking part successfully, students hav	e reached the following learning results				
Professional Competence						
Knowledge	Students are able to					
	1 name state and classify state-of-the	e-art Krylov subspace methods for the solution	of the core probler	ns of the engineerir		
		ms, solution of linear systems, and model redu		is of the engineerin		
		matrix equations (Sylvester, Lyapunov, Riccati)				
Skills	Students are capable to					
	1. implement and assess basic Krylov	subspace methods for the solution of eigenva	lue problems, linea	r systems, and mod		
	reduction;					
	2. assess methods used in modern software with respect to computing time, stability, and domain of applicability;					
	<ol><li>adapt the approaches learned to nev</li></ol>	v, unknown types of problem.				
Personal Competence						
Social Competence	Students can					
	<ul> <li>develop and document joint solution:</li> </ul>	s in small teams.				
		leas and transfer them to other areas of applic	ability;			
	<ul> <li>form a team to develop, build, and a</li> </ul>		-			
Autonomy	Students are able to					
	<ul> <li>correctly assess the time and effort of</li> </ul>	of self-defined work				
	-	etical and practical excercises are better solve	d individually or in a	a team;		
	<ul> <li>define test problems for testing and</li> </ul>					
	<ul> <li>assess their individual progess and, i</li> </ul>	if necessary, to ask questions and seek help.				
Workload in Hours	Independent Study Time 124, Study Time ir	n Lecture 56				
Credit points	6					
Course achievement	None					
Examination	Oral exam					
Examination duration and	25 min					
scale						
-	Computer Science: Specialisation III. Mathe					
Following Curricula	Data Science: Specialisation IV. Special Foc					
	Data Science: Specialisation I. Mathematics					
	Mechatronics: Specialisation Intelligent Syst					
	Mechatronics: Specialisation System Desigr Mechatronics: Core Qualification: Elective C					
	Technomathematics: Specialisation I. Mathe					

Course L0984: Matrix Algorit	hms
Тур	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jens-Peter Zemke
Language	DE/EN
Cycle	WiSe
Content	<ul> <li>Part A: Krylov Subspace Methods:         <ul> <li>Basics (derivation, basis, Ritz, OR, MR)</li> <li>Arnoldi-based methods (Arnoldi, GMRes)</li> <li>Lanczos-based methods (Lanczos, CG, BiCG, QMR, SymmLQ, PvL)</li> <li>Sonneveld-based methods (IDR, BiCGStab, TFQMR, IDR(s))</li> </ul> </li> <li>Part B: Matrix Equations:         <ul> <li>Sylvester Equation</li> <li>Lyapunov Equation</li> <li>Algebraic Riccati Equation</li> </ul> </li> </ul>
Literature	<ol> <li>Skript (224 Seiten)</li> <li>Ergänzend können die folgenden Lehrbücher herangezogen werden:         <ol> <li>Saad, Yousef. Numerical methods for large eigenvalue problems: revised edition. Society for Industrial and Applied Mathematics, 2011.</li> <li>Saad, Yousef. Iterative methods for sparse linear systems. Society for Industrial and Applied Mathematics, 2003.</li> <li>Van der Vorst, Henk A. Iterative Krylov methods for large linear systems. No. 13. Cambridge University Press, 2003.</li> <li>Liesen, Jörg, and Zdenek Strakos. Krylov subspace methods: principles and analysis. Oxford University Press, 2013.</li> </ol> </li> </ol>

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

Courses						
Title				Тур	Hrs/wk	СР
Optics for Engineers (L2437)				Lecture	3	3
Optics for Engineers (L2438)				Project-/problem-based Learning	3	3
Module Responsible	Prof. Thorsten Kern					
Admission Requirements	None					
<b>Recommended Previous</b>	- Basics of physics					
Knowledge						
Educational Objectives	After taking part succ	cessfully, students have	e reached the followin	ig learning results		
Professional Competence						
Knowledge	Teaching subject ist t	he design of simple op	tical systems for illum	nination and imaging optics		
		or optical systems and I				
		ck-bodies, color-percep				
	-	und their characterizati	on			
	<ul> <li>Photometrics</li> </ul>					
	Ray-Optics					
	<ul> <li>Matrix-Optics</li> </ul>					
	<ul> <li>Stops, Pupils a</li> </ul>					
	<ul> <li>Light-field Tech</li> </ul>					
	Introduction to					
	<ul> <li>Introduction to</li> </ul>	Holography				
Skills	Understandings of op	tics as part of light and	l electromagnetic spe	ectrum. Design rules, approach t	o designing o	ptics
Personal Competence						
Social Competence						
Autonomy						
Workload in Hours	Independent Study Ti	ime 96, Study Time in l	_ecture 84			
Credit points	6					
Course achievement	Compulsory Bonus	Form	Description			
	Yes None	Subject theoretica	l andTeilnahme an	Laborübungen und Simulation		
		practical work				
Examination	Oral exam					
Examination duration and	30 min					
scale						
Assignment for the	Electrical Engineering	g: Specialisation Microw	vave Engineering, Opt	tics, and Electromagnetic Comp	atibility: Electi	ive Compulsory
Following Curricula	Mechatronics: Specia	lisation Intelligent Syst	ems and Robotics: Ele	ective Compulsory		
-	Mechatronics: Specia	lisation System Design	: Elective Compulsory	/		
	Mechatronics: Core Q	ualification: Elective Co	ompulsory			
	1		ualification: Elective (			

Course L2437: Optics for Eng	gineers
Тур	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	WiSe
Content	<ul> <li>Basic values for optical systems and lighting technology</li> <li>Spectrum, black-bodies, color-perception</li> <li>Light-Sources und their characterization</li> <li>Photometrics</li> <li>Ray-Optics</li> <li>Matrix-Optics</li> <li>Stops, Pupils and Windows</li> <li>Light-field Technology</li> <li>Introduction to Wave-Optics</li> <li>Introduction to Holography</li> </ul>
Literature	

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

Courses				
Title		Тур	Hrs/wk	СР
Industrial Process Automation (L03	44)	Lecture	2	3
Industrial Process Automation (L03	45)	Recitation Section (small)	2	3
Module Responsible	Prof. Alexander Schlaefer			
Admission Requirements	None			
<b>Recommended Previous</b>	mathematics and optimization methods			
Knowledge	principles of automata			
	principles of algorithms and data structures			
	programming skills			
Educational Objectives	After taking part successfully, students have	e reached the following learning results		
Professional Competence				
Knowledge	The students can evaluate and assess discre	ete event systems. They can evaluate propertie	es of processes and	d explain methods
		e methods for process modelling and select an a		
	They can discuss scheduling methods in t	the context of actual problems and give a d	etailed explanatior	n of advantages a
	disadvantages of different programming m	nethods. The students can relate process auto	omation to method	ds from robotics a
	sensor systems as well as to recent topics lil	ke 'cyberphysical systems' and 'industry 4.0'.		
Skills	The students are able to develop and mode	el processes and evaluate them accordingly. Th	nis involves taking	into account optir
	scheduling, understanding algorithmic comp	plexity, and implementation using PLCs.		
Deveryal Commetence				
Personal Competence	The shudents are independently define would			
Social Competence		< processes within their groups, distribute tasks	s within the group a	and develop soluti
	collaboratively.			
Autonomy	The students are able to assess their level o	f knowledge and to document their work result	s adequately.	
	Independent Study Time 124, Study Time in	Lecture 56		
Credit points Course achievement	o Compulsory Bonus Form	Description		
course acmevement	No 10 % Excercises			
Examination	Written exam			
Examination duration and	90 minutes			
scale				
Assignment for the	Bioprocess Engineering: Specialisation A - G	eneral Bioprocess Engineering: Elective Compu	lsory	
-		ialisation Chemical Process Engineering: Electiv	-	
Ū.		ialisation General Process Engineering: Elective		
	Computer Science: Specialisation II: Intellige	ence Engineering: Elective Compulsory		
	Electrical Engineering: Specialisation Contro	l and Power Systems Engineering: Elective Con	npulsory	
	Aircraft Systems Engineering: Core Qualifica	tion: Elective Compulsory		
	International Management and Engineering:	Specialisation II. Mechatronics: Elective Compu	lsory	
	International Management and Engineering:	Specialisation II. Product Development and Pro	duction: Elective C	ompulsory
	Aeronautics: Core Qualification: Elective Con	npulsory		
	Mechanical Engineering and Management: S	Specialisation Mechatronics: Elective Compulsor	У	
	Mechatronics: Specialisation Intelligent Syste	ems and Robotics: Elective Compulsory		
	Mechatronics: Core Qualification: Elective Co	ompulsory		
	Theoretical Mechanical Engineering: Special	isation Robotics and Computer Science: Electiv	e Compulsory	
	Theoretical Mechanical Engineering: Special Process Engineering: Specialisation Chemica		e Compulsory	

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

Course L0345: Industrial Pro	urse 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			Тур	Hrs/wk	СР
Control Lab V (L1667)			Practical Course	1	1
Control Lab VI (L1668)			Practical Course	1	1
Module Responsible	NN				
Admission Requirements	None				
<b>Recommended Previous</b>	Charles and an and	the state			
Knowledge	State space me	thods			
	LQG control	· · · · · · · · · · · · · · · · · · ·			
	H2 and H-infinit				
		models and robust control			
	LPV control				
Educational Objectives	After taking part succe	essfully, students have reach	ed the following learning results		
Professional Competence					
Knowledge	. Chudanta con a	alain the difference between	validation of a control lon in simulat	ion and overering enterly	volidation
	<ul> <li>Students can es</li> </ul>	cplain the difference betweer	n validation of a control lop in simulat	ion and experimental	Validation
Skills					
			stem identification tools (Matlab Sy	stem Identification To	oolbox) to identify
		that can be used for controll			
		ole of using standard softwa	are tools (Matlab Control Toolbox) fo	or the design and imp	plementation of L
	controllers				
		-	e tools (Matlab Robust Control Toolbo	x) for the mixed-sensi	tivity design and t
		of H-infinity optimal controll			
			ertainty, and of designing and implen	-	
		-	tools (Matlab Robust Control Toolbox	<ol> <li>for the design and the</li> </ol>	ne implementation
	LPV gain-sched	uled controllers			
Personal Competence					
Social Competence					
Social competence	<ul> <li>Students can w</li> </ul>	ork in teams to conduct expe	riments and document the results		
A					
Autonomy	Students can in	dependently carry out simula	ation studies to design and validate co	ontrol loops	
Workload in Hours	Indopondont Study Tir	ne 32, Study Time in Lecture	20		
Credit points		ne 52, Study Time in Lecture	20		
Course achievement					
Examination					
Examination duration and					
scale	Ţ				
	Electrical Engineering	Specialisation Control and P	ower Systems Engineering: Elective (	Compulsory	
		alification: Elective Compuls		1	
			d Robotics: Elective Compulsory		
		sation System Design: Electi			

Course L1667: Control Lab V		
Тур	Practical Course	
Hrs/wk	1	
CP	1	
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14	
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch	
Language	EN	
Cycle	WiSe/SoSe	
Content	One of the offered experiments in control theory.	
Literature	Experiment Guides	

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

Courses						
Title				Тур	Hrs/wk	СР
Advanced Topics in Control (L1803)				Seminar	2	2
Module Responsible	NN					
Admission Requirements	None					
Recommended Previous Knowledge	٠	Introduction to control Control theory and des optimal and robust cor	sign			
Educational Objectives	After t	aking part successfully	, students have reache	d the following learning results		
Professional Competence Knowledge		Students can explain n Students learn to apply		s for different tasks		
Skills	•		eveloped results and pr	spects of modern control, based esent them to the participants entation	on specified literature	
Personal Competence Social Competence		Students are capable of They are able to provide		and present them k and handle constructive criticis	m of their own results	
Autonomy	•	solution	nemselves with a scier	ks of different forms of present	·	
Workload in Hours	Indepe	endent Study Time 32,	Study Time in Lecture 2	28		
Credit points	2					
Course achievement	None					
Examination	Preser	ntation				
Examination duration and	90 mir	<u></u> ו				
scale						
-				Robotics: Elective Compulsory		
Following Curricula		tronics: Specialisation	System Design: Electiv ion: Elective Compulso			

Course L1803: Advanced Top	
Тур	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	NN
Language	EN
Cycle	WiSe/SoSe
Content	Seminar on selected topics in modern control
Literature	To be specified

Courses						
Title		Тур	Hrs/wk	СР		
Fundamentals of Maintenance, Rej	pair and Overhaul (MRO) (L3160)	Lecture	3	4		
Fundamentals of Maintenance, Re	pair and Overhaul (MRO) (L3161)	Recitation Section (large)	1	2		
Module Responsible	Prof. Gerko Wende					
Admission Requirements	None					
<b>Recommended Previous</b>	We recommend knowledge in the areas of general	engineering sciences, aeronautics and air	rcraft systems er	ngineering. Techni		
Knowledge	fields like mechanical engineering, mechatronics a	and production engineering will be intro	duced into the	relevant aeronauti		
	content.					
Educational Objectives	After taking part successfully, students have reache	d the following learning results				
Professional Competence						
Knowledge	The students are able to describe fundamental corre	elations for the sustainable operation of te	chnical assets ar	nd to identify solut		
	approaches for complex optimization problems.					
Skills	s The students are enabled to apply the general engineering capabilities of the individual course towards the optimization of th					
	sustainability in operation of technical assets. The resulting competencies will open an entry into positions in the development production and technical operation of sustainable products in the mobility and engineering industries.					
	production and technical operation of sustainable pr	oducts in the mobility and engineering ind	lustries.			
Personal Competence						
Social Competence	The students are able to work in mixed groups with a clear focus on the approached solutions by respecting the comple					
	environment of multiple stakeholders.					
Autonom	The students are enabled to find colutions for a	atinization problems and to take your	ined decision for	the eccentration		
Autonomy	The students are enabled to find solutions for optimization problems and to take required decision for the assessment determining factors independently.					
	determining factors independently.					
Workload in Hours	Independent Study Time 124, Study Time in Lecture	2 56				
Credit points	6					
Course achievement	None					
Examination	Oral exam					
Examination duration and	30 min					
scale						
Assignment for the	Aircraft Systems Engineering: Core Qualification: Ele	ective Compulsory				
Following Curricula	Aeronautics: Core Qualification: Elective Compulsory	/				
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory					
	Mechatronics: Specialisation System Design: Elective	e Compulsory				
	Mechatronics: Core Qualification: Elective Compulso	ry				
	Product Development, Materials and Production: Spe					
	Product Development, Materials and Production: Spe		-			
	Product Development, Materials and Production: Spe					
	Theoretical Mechanical Engineering: Specialisation F		1 3			
	Theoretical Mechanical Engineering: Specialisation A	Aircraft Systems Engineering: Elective Con	npulsory			

Course L3160: Fundamentals	s of Maintenance, Repair and Overhaul (MRO)
Тур	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Gerko Wende
Language	DE
Cycle	WiSe
Content	Fundamentals for the sustainable operation of technical assets by means of maintenance, repair and overhaul (MRO):
	<ul> <li>Life cycle analytics</li> <li>Material circularity and service products</li> <li>Rules and regulations</li> <li>Processes and production methods</li> <li>Tools and technologies</li> <li>Data handling and usage</li> <li>Design for maintenance</li> <li>Self-healing technical systems</li> </ul>
Literature	-

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

## **Specialization System Design**

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

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

Module M0752: Nonli	near Dynamics				
Courses					
Title		Тур	Hrs/wk	СР	
Nonlinear Dynamics (L0702)		Integrated Lecture	4	6	
Module Responsible	Prof. Norbert Hoffmann				
Admission Requirements	None				
Recommended Previous	Calculus				
Knowledge	Linear Algebra				
	Engineering Mechanics				
Educational Objectives	After taking part successfully, students have reache	d the following learning results			
Professional Competence					
Knowledge	<ul> <li>Students are able to reflect existing terms an</li> </ul>	d concepts in Nonlinear Dynamics and	to develop and rese	earch new terms and	
	concepts.				
	Students are able to denote and expand meth	nods of modeling and analysis for nonlin	near dynamical syst	ems.	
Chille					
Skills	Students are able to apply existing methods a	nd procesures of Nonlinear Dynamics.			
	<ul> <li>Students are able to develop novel methods a</li> </ul>	and procedures for nonlinear dynamica	l systems.		
Personal Competence					
Social Competence					
Social Competence	<ul> <li>Students can analyze problems of nonlinear d</li> </ul>	ynamics also in groups.			
	Students can achieve solution procedures for	problems of nonlinear dynamical syste	ems also in groups.		
Autonomy					
	• Students are able to approach given research tasks on the basis of given methods individually.				
	<ul> <li>Students are able to identify and follow up no</li> </ul>	vel 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	2 Hours				
scale					
Assignment for the					
Following Curricula					
	Mechanical Engineering and Management: Specialis		ry		
	Mechatronics: Specialisation System Design: Elective				
	Mechatronics: Specialisation Intelligent Systems and Biomedical Engineering: Specialisation Artificial Orga		e Compulsory		
	Biomedical Engineering: Specialisation Artificial orga Biomedical Engineering: Specialisation Implants and		e compuisory		
	Biomedical Engineering: Specialisation Medical Tech		mpulsory		
	Biomedical Engineering: Specialisation Management				
	Product Development, Materials and Production: Cor				
	Theoretical Mechanical Engineering: Core Qualificati	on: Elective Compulsory			

Course L0702: Nonlinear Dyr	namics		
Тур	tegrated 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		
	<ul> <li>One dimensional problems <ul> <li>Linear Stability</li> <li>Local Bifurcations</li> <li>Synchronisation</li> </ul> </li> <li>Two dimensional problems <ul> <li>Limit Cycles</li> <li>Global Bifurcations</li> </ul> </li> <li>Chaos <ul> <li>Lorenz Equations</li> <li>Fractals and Strange Attractors</li> <li>Predictability and Horizons</li> </ul> </li> </ul>		
Literature	Steven Strogatz: Nonlinear Dynamics and Chaos.		

Courses						
Title				Тур	Hrs/wk	СР
Embedded Systems (L0805)				Lecture	3	3
Embedded Systems (L2938)				Project-/problem-based Learning	1	1
Embedded Systems (L0806)	Recitation Section (small) 1 2					2
Module Responsible	Prof. Heiko Falk					
Admission Requirements	None					
<b>Recommended Previous</b>	Computer Engineering	J				
Knowledge						
Educational Objectives	After taking part succe	essfully, students ha	ave reached the following	ng learning results		
Professional Competence						
Knowledge	Embedded systems ca	an be defined as infe	ormation processing sys	stems embedded into enclosing	products. Thi	s course teaches t
				duction into these systems (not		
	their specification languages (models of computation, hierarchical automata, specification of distributed systems, task graphs					
	specification of real-ti	me applications, tra	nslations between differ	rent models).		
	Another part covers	the hardware of en	nbedded systems: Son	sors, A/D and D/A converters,	real-time cap	able communicati
	hardware, embedded	processors, memor	ries, energy dissipation	, reconfigurable logic and actua	ators. The cou	irse also features
	introduction into real-	-time operating sys	tems, middleware and	real-time scheduling. Finally,	the implemen	tation of embedd
	systems using hardware/software co-design (hardware/software partitioning, high-level transformations of specifications, energy					
	efficient realizations, o	compilers for embed	ded processors) is cove	ered.		
Skille	After baying attended	d the course stude	nto chall ha able to re-	liza cimpla ambaddad systems	The student	c chall realize wh
<i>SKIIIS</i>	After having attended the course, students shall be able to realize simple embedded systems. The students shall realize which relevant parts of technological competences to use in order to obtain a functional embedded systems. In particular, they shall be					
	able to compare different models of computations and feasible techniques for system-level design. They shall be able to judge					
which areas of embedded system design specific risks exist.				ii be able to judge		
Personal Competence			specific fibito chiber			
-	Students are able to solve similar problems alone or in a group and to present the results accordingly.					
boerar competence		one sinnar prosien	is alone of in a group a			
Autonomy	Students are able to a	cquire new knowled	lge from specific literati	ure and to associate this knowle	dge with othe	r classes.
Workload in Hours	Independent Study Tir	me 110. Study Time	in Lecture 70			
Credit points						
Course achievement	Compulsory Bonus	Form	Description			
	Yes 10 %	Subject theoreti	cal and			
		practical work				
Examination	Written exam					
Examination duration and	90 minutes, contents of course and labs					
scale						
Assignment for the	General Engineering S	science (German pro	gram, 7 semester): Spe	ecialisation Computer Science: O	Compulsory	
Following Curricula	Computer Science: Sp	ecialisation I. Comp	uter and Software Engin	neering: Elective Compulsory		
	Electrical Engineering	: Core Qualification:	Elective Compulsory			
	Engineering Science: S	Specialisation Mecha	atronics: Elective Comp	ulsory		
	Engineering Science: S	Specialisation Electr	ical Engineering: Electiv	ve Compulsory		
		-	ication: Elective Compu	-		
	General Engineering S		-	cialisation Mechatronics: Electiv	e Compulsory	
		Enaineerina: Core O	ualification: Compulsory	4		
	Mechatronics: Special	lisation System Desi	gn: Elective Compulsory			

Course L0805: Embedded Sy	stems		
Тур	Lecture		
Hrs/wk			
СР	3		
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42		
Lecturer	Prof. Heiko Falk		
Language	EN		
Cycle	SoSe		
Content	<ul> <li>Introduction</li> <li>Specifications and Modeling</li> <li>Embedded/Cyber-Physical Systems Hardware</li> <li>System Software</li> <li>Evaluation and Validation</li> <li>Mapping of Applications to Execution Platforms</li> <li>Optimization</li> </ul>		
Literature	<ul> <li>Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2 <sup>nd</sup> Edition, Springer, 2012., Springer, 2012.</li> </ul>		

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

Course L0806: Embedded Sy	rse L0806: Embedded Systems			
Тур	Recitation Section (small)			
Hrs/wk	1			
CP				
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14			
Lecturer	rof. Heiko Falk			
Language	l			
Cycle	joSe			
Content	See interlocking course			
Literature	See interlocking course			

es, Noise Protection, Psycho Acoustics ) (L0516) es, Noise Protection, Psycho Acoustics ) (L0518) Prof. Otto von Estorff None Mechanics I (Statics, Mechanics of Materials) and Mech	<b>Typ</b> Lecture Recitation Section (large)	Hrs/wk 2 2	<b>СР</b> 3 3	
ss, Noise Protection, Psycho Acoustics ) (L0518) Prof. Otto von Estorff None				
Prof. Otto von Estorff None	Recitation Section (large)	2	3	
None				
Mechanics I (Statics, Mechanics of Materials) and Mech				
	nanics II (Hydrostatics, Kinematics, Dyna	amics)		
Mathematics I, II, III (in particular differential equations	5)			
After taking part successfully, students have reached t	he following learning results			
The students possess an in-depth knowledge in acoust	stics regarding acoustic waves, noise p	protection, and p	sycho acoustics a	
are able to give an overview of the corresponding the	pretical and methodical basis.			
The students are canable to bandle engineering	problems in accustics by theory ba	and application	of the domandi	
nethodologies and measurement procedures treated	within the module.			
Students can work in small groups on specific problems to arrive at joint solutions.				
The students are able to independently solve challenging acoustical problems in the areas treated within the module. Possible				
· · · · · · · · · · · · · · · · · · ·	,			
ndependent Study Time 124, Study Time in Lecture 5	6			
6				
None				
Written exam				
90 min				
Energy Systems: Core Qualification: Elective Compulso	pry			
Aircraft Systems Engineering: Core Qualification: Elect	ive Compulsory			
		oulsory		
	The students possess an in-depth knowledge in acou are able to give an overview of the corresponding theo The students are capable to handle engineering methodologies and measurement procedures treated of Students can work in small groups on specific problem The students are able to independently solve challer conflicting issues and limitations can be identified and independent Study Time 124, Study Time in Lecture 5 5 None Written exam 20 min Energy Systems: Core Qualification: Elective Compulso Aircraft Systems Engineering: Core Qualification: Elect international Management and Engineering: Specialisa Mechatronics: Specialisation System Design: Elective Cor Forduct Development, Materials and Production: Core Fechnomathematics: Specialisation III. Engineering Sci Theoretical Mechanical Engineering: Specialisation Pro	are able to give an overview of the corresponding theoretical and methodical basis. The students are capable to handle engineering problems in acoustics by theory-bar methodologies and measurement procedures treated within the module. Students can work in small groups on specific problems to arrive at joint solutions. The students are able to independently solve challenging acoustical problems in the areas conflicting issues and limitations can be identified and the results are critically scrutinized. Independent Study Time 124, Study Time in Lecture 56 S None Written exam 20 min Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Fechnomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Specialisation Product Development and Production: Elective Compulsory Specialisation Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Developm	The students possess an in-depth knowledge in acoustics regarding acoustic waves, noise protection, and p are able to give an overview of the corresponding theoretical and methodical basis. The students are capable to handle engineering problems in acoustics by theory-based application methodologies and measurement procedures treated within the module. Students can work in small groups on specific problems to arrive at joint solutions. The students are able to independently solve challenging acoustical problems in the areas treated within t conflicting issues and limitations can be identified and the results are critically scrutinized. Independent Study Time 124, Study Time in Lecture 56 5 None Nritten exam 20 min Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Ore Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory	

ourse L0516: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics )			
Lecture			
2			
3			
Independent Study Time 62, Study Time in Lecture 28			
Prof. Benedikt Kriegesmann, DrIng. Sören Keuchel			
EN			
SoSe			
- 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			
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 Aco	rse L0518: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics )			
Тур	Recitation Section (large)			
Hrs/wk	2			
CP	3			
Workload in Hours	dependent Study Time 62, Study Time in Lecture 28			
Lecturer	of. Benedikt Kriegesmann, DrIng. Sören Keuchel			
Language	J			
Cycle	SoSe			
Content	See interlocking course			
Literature	See interlocking course			

Courses						
Title				Тур	Hrs/wk	СР
Boundary Element Methods (L0523	)			Lecture	2	3
Boundary Element Methods (L0524	.)			Recitation Section (large)	2	3
Module Responsible	Prof. Otto von Estorff					
Admission Requirements	None					
<b>Recommended Previous</b>	Mechanics I (Statics, M	Mechanics of Mate	rials) and Mechanics II (	(Hydrostatics, Kinematics, Dyr	namics)	
Knowledge	Mathematics I, II, III (in	n particular differ	ential equations)			
Educational Objectives	After taking part succe	essfully students	have reached the follow	ving learning results		
Professional Competence	Filter taking part succe	costany, scadence		ing learning results		
	The students possess	an in-denth know	wledge regarding the d	erivation of the boundary ele	ment method an	d are able to give
Kilomeage			lical basis of the method		ment method an	a are able to give
	overview of the theore					
Skills	The students are ca	apable to handle	e engineering problem	ns by formulating suitable	boundary eleme	nts, assembling
	corresponding system	n matrices, and so	lving the resulting syste	em of equations.		
Personal Competence						
	Students can work in small groups on specific problems to arrive at joint solutions.					
Jocial competence	Students can work in sman groups on specific problems to arrive at joint Solutions.					
Autonomy	The students are able to independently solve challenging computational problems and develop own boundary element routines					
	Problems can be identified and the results are critically scrutinized.					
			,			
Workload in Hours	Independent Study Tin	me 124, Study Tir	ne in Lecture 56			
Credit points	6					
Course achievement	Compulsory Bonus	Form	Description			
	No 20 %	Midterm				
Examination	Written exam					
Examination duration and	90 min					
scale						
Assignment for the	Civil Engineering: Spe-	cialisation Structu	ural Engineering: Electiv	e Compulsory		
-			chnical Engineering: Elec			
			I Engineering: Elective (			
	Energy Systems: Core		5 5	· · · ······		
				uct Development and Producti	on: Elective Com	oulcony
	-		esign: Elective Compulso	•	on. Liecuve Comp	Juisony
	mechatronics: Special	iisation System De	sign: Elective Compuis	ui y		
		-	-	tion floating C 1		
	Product Development,	, Materials and Pr	oduction: Core Qualifica	tion: Elective Compulsory		
	Product Development, Technomathematics: S	, Materials and Pr Specialisation III.	oduction: Core Qualifica Engineering Science: Ele	1 3		

Course L0523: Boundary Element Methods				
Тур	Lecture			
Hrs/wk	2			
CP	3			
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28			
Lecturer	Prof. Otto von Estorff			
Language	EN			
Cycle	SoSe			
Content	- Boundary value problems			
	- Integral equations			
	- Fundamental Solutions			
	- Element formulations			
	- Numerical integration			
	- Solving systems of equations (statics, dynamics)			
	- Special BEM formulations			
	- Coupling of FEM and BEM			
	- Hands-on Sessions (programming of BE routines)			
	- Applications			
Literature	Gaul, L.; Fiedler, Ch. (1997): Methode der Randelemente in Statik und Dynamik. Vieweg, Braunschweig, Wiesbaden			
	Bathe, KJ. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin			

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

Courses			
ſitle	Тур	Hrs/wk	СР
Module Responsible	NN		
Admission Requirements	None		
<b>Recommended Previous</b>	See selected module according to FSPO		
Knowledge			
,	After taking part successfully, students have reached the following learning results		
Professional Competence			
Knowledge	see selected module according to FSPO		
C1-111-	and a last diversity of a second in a tar FCDO		
SKIIIS	see selected module according to FSPO		
Personal 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	Mechatronics: Specialisation System Design: Elective Compulsory		
Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory		

Courses				
litle		Тур	Hrs/wk	СР
Systems Engineering (L1547)		Lecture	3	4
systems Engineering (L1548)		Recitation Section (la	rge) 1	2
Module Responsible	Prof. Ralf God			
Admission Requirements	None			
<b>Recommended Previous</b>	Basic knowledge in:			
Knowledge	Mathematics			
	Mechanics			
	Thermodynamics			
	Electrical Engineering			
	Control Systems			
	Previous knowledge in:			
	Aircraft Cabin Systems			
Educational Objectives	After taking part successfully, students	have reached the following learning results		
Professional Competence	, and a subsection of the subs			
-	Students are able to:			
5		ess models, methods and tools for the develo	pment of complex Syst	ems
	• describe innovation processes and the	e need for technology Management		
	• explain the aircraft development proce	ess and the process of type certification for a	ircraft	
	• explain the system development proce	ess, including requirements for systems relia	oility	
	<ul> <li>identify environmental conditions and</li> </ul>	test procedures for airborne Equipment		
	<ul> <li>value the methodology of requirement</li> </ul>	ts-based engineering (RBE) and model-based	requirements engineer	ing (MBRE)
Skills	Students are able to:			
	• plan the process for the development	of complex Systems		
	<ul> <li>organize the development phases and</li> </ul>	l development Tasks		
	<ul> <li>assign required business activities and</li> </ul>	d technical Tasks		
	<ul> <li>apply systems engineering methods a</li> </ul>	nd tools		
Personal Competence				
	Students are able to:			
	• understand and accept their tasks with	hin a development team		
	• be comfortable with their role their tas	sks within the overall process		
	• understand and serve their suppliers a	and customers in large projects		
	<ul> <li>assume responsibility for people and t</li> </ul>	echnology in the development of safety-critic	al systems	
Autonomy	Students are able to:			
naconomy	<ul> <li>interact and communicate in a develo</li> </ul>	pment team with division of tasks.		
	• independently research and identify c	•		
	• formulate requirements on their own			
	<ul> <li>create test plans on their own and acc</li> </ul>	company certification processes		
Workload in Hours	Independent Study Time 124, Study Tim	ae in Lecture 56		
Credit points				
Course achievement				
Examination				
Examination duration and				
scale				
Assignment for the	Aircraft Systems Engineering: Core Qua	lification: Compulsory		
-		ring: Specialisation II. Aviation Systems: Elect	ive Compulsory	
	International Management and Engineer	ring: Specialisation II. Product Development a	nd Production: Elective	Compulsory
	Mechatronics: Specialisation System De	sign: Elective Compulsory		
	Mechatronics: Specialisation Intelligent	Systems and Robotics: Elective Compulsory		
	Product Development, Materials and Pro	oduction: Specialisation Product Development	: Compulsory	
	Product Development, Materials and Pro	oduction: Specialisation Product Development oduction: Specialisation Production: Elective C oduction: Specialisation Materials: Elective Co	Compulsory	

ourse 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 (RBE) • Model-based requirements engineering (MBRE)	
Literature	<ul> <li>Skript zur Vorlesung</li> <li>diverse Normen und Richtlinien (EASA, FAA, RTCA, SAE)</li> <li>Hauschildt, J., Salomo, S.: Innovationsmanagement. Vahlen, 5. Auflage, 2010</li> <li>NASA Systems Engineering Handbook, National Aeronautics and Space Administration, 2007</li> <li>Hinsch, M.: Industrielles Luftfahrtmanagement: Technik und Organisation luftfahrttechnischer Betriebe. Springer, 2010</li> <li>De Florio, P.: Airworthiness: An Introduction to Aircraft Certification. Elsevier Ltd., 2010</li> <li>Pohl, K.: Requirements Engineering. Grundlagen, Prinzipien, Techniken. 2. korrigierte Auflage, dpunkt.Verlag, 2008</li> </ul>	

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

Courses				
Title		Тур	Hrs/wk	СР
Applied Automation (L1592)		Project-/problem-based Learning	3	3
Advanced Training Course SE-ZERT	(L2739)	Project-/problem-based Learning	2	3
Development Management for Mec	hatronics (L1512)	Lecture	2	3
Fatigue & Damage Tolerance (L031	.0)	Lecture	2	3
ndustry 4.0 for engineers (L2012)		Lecture	2	3
Microcontroller Circuits: Implement	ation in Hardware and Software (L0087)	Seminar	2	2
Microsystems Technology (L0724)		Lecture	2	4
Model-Based Systems Engineering	(MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3
Sustainable Industrial Production (L	.2863)	Lecture	2	4
Process Measurement Engineering		Lecture	2	3
Process Measurement Engineering		Recitation Section (large)	1	1
Feedback Control in Medical Technol	ology (L0664)	Lecture	2	3
Module Responsible	NN			
Admission Requirements	None			
<b>Recommended Previous</b>	None			
Knowledge				
Educational Objectives	After taking part successfully, students have reache	d the following learning results		
Professional Competence				
Knowledge	<ul> <li>Students are able to express their extended areas of mechatronics</li> <li>Students are qualified to connect different sport</li> </ul>	-	fferent specia	l fields or applicat
Skills	<ul> <li>Students can apply specialized solution strate</li> <li>Students are able to transfer learned skills to</li> </ul>	-		n approaches
<b>Personal Competence</b> Social Competence Autonomy	None  • Students are able to develop their knowledge	and skills by autonomous election of course	S.	
Workload in Hours	Depends on choice of courses			
Credit points	12			
	12 Mechatronics: Specialisation System Design: Elective	e Compulsory		

Course L1592	2: Applied Automation
Тур	Project-/problem-based Learning
Hrs/wk	3
СР	3
Workload in	Independent Study Time 48, Study Time in Lecture 42
Hours	
Examination	Mündliche Prüfung
Form	
Examination	30 Minuten
duration	
and scale	
	Prof. Thorsten Schüppstuhl
Language	
Cycle	WiSe
Content	-Project Based Learning -Robot Operating System -Robot structure and description -Motion description -Calibration -Accuracy
Literature	John J. Craig Introduction to Robotics - Mechanics and Control ISBN: 0131236296 Pearson Education, Inc., 2005 Stefan Hesse Grundlagen der Handhabungstechnik ISBN: 3446418725 München Hanser, 2010 K. Thulasiraman and M. N. S. Swamy Graphs: Theory and Algorithms ISBN: 9781118033104 %CITAVIPICKER£9781118033104£Titel anhand dieser ISBN in Citavi-Projekt übernehmen£% John Wüey & Sons, Inc., 1992

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

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	30 Minuten		
scale			
Lecturer	NN, Dr. Johannes Nicolas Gebhardt		
Language	DE		
Cycle	SoSe		
Content	<ul> <li>Processes and methods of product development - from idea to market launch         <ul> <li>identification of market and technology potentials</li> <li>development of a common product architecture</li> <li>Synchronized product development across all engineering disciplines</li> <li>product validation incl. customer view</li> </ul> </li> <li>Steering and optimization of product development         <ul> <li>Design of processes for product development</li> <li>IT systems for product development</li> <li>Establishment of management standards</li> <li>Typical types of organization</li> </ul> </li> </ul>		
Literature	<ul> <li>Bender: Embedded Systems - qualitätsorientierte Entwicklung</li> <li>Ehrlenspiel: Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit</li> <li>Gausemeier/Ebbesmeyer/Kallmeyer: Produktinnovation - Strategische Planung und Entwicklung der Produkte von morger</li> <li>Haberfellner/de Weck/Fricke/Vössner: Systems Engineering: Grundlagen und Anwendung</li> <li>Lindemann: Methodische Entwicklung technischer Produkte: Methoden flexibel und situationsgerecht anwenden</li> <li>Pahl/Beitz: Konstruktionslehre: Grundlagen erfolgreicher Produktentwicklung. Methoden und Anwendung</li> <li>VDI-Richtlinie 2206: Entwicklungsmethodik für mechatronische Systeme</li> </ul>		

Course L0310: Fatigue & Damage Tolerance		
Тур	Lecture	
Hrs/wk	2	
CP	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Examination Form	Mündliche Prüfung	
Examination duration and	45 min	
scale		
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 f	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	120 min	
scale		
Lecturer	Prof. Thorsten Schüppstuhl	
Language	DE	
Cycle	SoSe	
Content		
Literature		

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

Course L0724: Microsystems	Technology
Тур	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and	30 min
scale	
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	
	<ul> <li>Introduction (historical view, scientific and economic relevance, scaling laws)</li> <li>Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting)</li> <li>Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing)</li> <li>Etching and Bulk Micromachining (definitions, wet chemical etching, lisotropic etch with HNA, electrochemical etching, anisotropic etching with K0H/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)</li> <li>Surface Micromachining and alternative Techniques (sacrificial etching, film stress, Stition: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping)</li> <li>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, R sensor: thermopile and bolometer)</li> <li>Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: spiezoresistive, angaeto-transistor; magnetoresistive sensors: spenting principle and fabrication process)</li> <li>Magnetic Sensors (galvanomagnetic sensors: splining current Hall sensor and magneto-transistor; magnetoresistive sensors; colaris esensor, cipanic semiconductor gas sensor, Lambda probe, MOSFET gas sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip)</li> <li>Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulat</li></ul>
	TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002
	N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009
	T. M. Adams, R. A. Layton: Introductory MEMS, Springer, 2010
	G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Тур	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Schriftliche Ausarbeitung
Examination duration and	ca. 10 Seiten
scale	
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 language
	SysML/UML, learning about tools for modeling and finally the implementation of a project with methods and tools of Model-Base
	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
Literature	- Skipt zur Vollesung - Weilkiens, T.: Systems Engineering mit SysML/UML: Modellierung, Analyse, Design. 2. Auflage, dpunkt.Verlag, 2008
	- Weintens, T.: Systems Engineering mit Sysmi, one. Modellering, Analyse, Design. 2. Aurage, dpunkt. verag, 2008 - Holt, J., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011
	- noit, J., reny, S.A., brownsword, M.: Model-based Requirements Engineering. Institution Engineering & Tech, 2011

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

Course L1077: Process Meas	urement 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	45 Minuten
scale	
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	Process measurement engineering in the context of process control engineering
	<ul> <li>Challenges of process measurement engineering</li> </ul>
	<ul> <li>Instrumentation of processes</li> </ul>
	<ul> <li>Classification of pickups</li> </ul>
	Systems theory in process measurement engineering
	Generic linear description of pickups
	<ul> <li>Mathematical description of two-port systems</li> </ul>
	Fourier and Laplace transformation
	Correlational measurement
	Wide band signals
	<ul> <li>Auto- and cross-correlation function and their applications</li> </ul>
	<ul> <li>Fault-free operation of correlational methods</li> </ul>
	Transmission of analog and digital measurement signals
	<ul> <li>Modulation process (amplitude and frequency modulation)</li> </ul>
	• Multiplexing
	<ul> <li>Analog to digital converter</li> </ul>
Literature	- Färber: "Prozeßrechentechnik", Springer-Verlag 1994
	- Kiencke, Kronmüller: "Meßtechnik", Springer Verlag Berlin Heidelberg, 1995
	- Kiencke, Kionmunei, "Mestechnik", Springer Venag benin neideberg, 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 Meas	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 Con	trol in Medical Technology	
Тур	Lecture	
Hrs/wk	2	
CP	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Examination Form	ündliche Prüfung	
Examination duration and	20 min	
scale		
Lecturer	Johannes Kreuzer, Christian Neuhaus	
Language	DE	
Cycle	SoSe	
Content	Always viewed from the engineer's point of view, the lecture is structured as follows:  Introduction to the topic Fundamentals of physiological modelling Introduction to Breathing and Ventilation Physiology and Pathology in Cardiology Introduction to the Regulation of Blood Glucose kidney function and renal replacement therapy Representation of the control technology on the concrete ventilator Excursion to a medical technology company Techniques of modeling, simulation and controller development are discussed. In the models, simple equivalent block diagrams for physiological processes are derived and explained how sensors, controllers and actuators are operated. MATLAB and SIMULINK are used as development tools.	
Literature	<ul> <li>Leonhardt, S., &amp; Walter, M. (2016). Medizintechnische Systeme. Berlin, Heidelberg: Springer Vieweg.</li> <li>Werner, J. (2005). Kooperative und autonome Systeme der Medizintechnik. München: Oldenbourg.</li> <li>Oczenski, W. (2017). Atmen : Atemhilfen ; Atemphysiologie und Beatmungstechnik: Georg Thieme Verlag KG.</li> </ul>	

Courses			
Title	Тур	Hrs/wk	СР
Applied Automation (L1592)	Project-/problem-based Learning	3	3
Advanced Training Course SE-ZERT	(L2739) Project-/problem-based Learning	2	3
Development Management for Mec	hatronics (L1512) Lecture	2	3
atigue & Damage Tolerance (L031	.0) Lecture	2	3
ndustry 4.0 for engineers (L2012)	Lecture	2	3
Microcontroller Circuits: Implement	ation in Hardware and Software (L0087) Seminar	2	2
Microsystems Technology (L0724)	Lecture	2	4
Model-Based Systems Engineering	(MBSE) with SysML/UML (L1551) Project-/problem-based Learning	3	3
Sustainable Industrial Production (L	.2863) Lecture	2	4
Process Measurement Engineering	(L1077) Lecture	2	3
Process Measurement Engineering	(L1083) Recitation Section (large)	1	1
eedback Control in Medical Techn	ology (L0664) Lecture	2	3
Module Responsible	NN		
Admission Requirements	None		
<b>Recommended Previous</b>	None		
Knowledge			
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence			
Knowledge			
	<ul> <li>Students are able to express their extended knowledge and discuss the connection of difareas of mechatronics</li> <li>Students are qualified to connect different special fields with each other</li> </ul>	fferent specia	l fields or applicat
Skills	areas of mechatronics	areas	
Skills Personal Competence	<ul> <li>areas of mechatronics</li> <li>Students are qualified to connect different special fields with each other</li> <li>Students can apply specialized solution strategies and new scientific methods in selected</li> </ul>	areas	
	<ul> <li>areas of mechatronics</li> <li>Students are qualified to connect different special fields with each other</li> <li>Students can apply specialized solution strategies and new scientific methods in selected</li> <li>Students are able to transfer learned skills to new and unknown problems and can develop</li> </ul>	areas	
Personal Competence	<ul> <li>areas of mechatronics</li> <li>Students are qualified to connect different special fields with each other</li> <li>Students can apply specialized solution strategies and new scientific methods in selected</li> <li>Students are able to transfer learned skills to new and unknown problems and can develop</li> </ul>	areas p own solutior	
<b>Personal Competence</b> Social Competence Autonomy	<ul> <li>areas of mechatronics</li> <li>Students are qualified to connect different special fields with each other</li> <li>Students can apply specialized solution strategies and new scientific methods in selected</li> <li>Students are able to transfer learned skills to new and unknown problems and can develop</li> </ul> None	areas p own solutior	
<b>Personal Competence</b> Social Competence Autonomy	<ul> <li>areas of mechatronics</li> <li>Students are qualified to connect different special fields with each other</li> <li>Students can apply specialized solution strategies and new scientific methods in selected</li> <li>Students are able to transfer learned skills to new and unknown problems and can develop</li> <li>None</li> <li>Students are able to develop their knowledge and skills by autonomous election of courses</li> </ul>	areas p own solutior	
Personal Competence Social Competence Autonomy Workload in Hours Credit points	<ul> <li>areas of mechatronics</li> <li>Students are qualified to connect different special fields with each other</li> <li>Students can apply specialized solution strategies and new scientific methods in selected</li> <li>Students are able to transfer learned skills to new and unknown problems and can develop</li> <li>None</li> <li>Students are able to develop their knowledge and skills by autonomous election of courses</li> </ul>	areas p own solutior	
Personal Competence Social Competence Autonomy Workload in Hours Credit points Assignment for the	<ul> <li>areas of mechatronics</li> <li>Students are qualified to connect different special fields with each other</li> <li>Students can apply specialized solution strategies and new scientific methods in selected</li> <li>Students are able to transfer learned skills to new and unknown problems and can develop</li> <li>None <ul> <li>Students are able to develop their knowledge and skills by autonomous election of courses</li> </ul> </li> <li>Depends on choice of courses</li> <li>6</li> </ul>	areas p own solutior	

Course L1592	2: Applied Automation
Тур	Project-/problem-based Learning
Hrs/wk	3
СР	3
Workload in	Independent Study Time 48, Study Time in Lecture 42
Hours	
Examination	Mündliche Prüfung
Form	
Examination	30 Minuten
duration	
and scale	
	Prof. Thorsten Schüppstuhl
Language	
Cycle Content	
content	-Project Based Learning -Robot Operating System -Robot structure and description -Motion description -Calibration -Accuracy
Literature	John J. Craig Introduction to Robotics - Mechanics and Control ISBN: 0131236296 Pearson Education, Inc., 2005 Stefan Hesse Grundlagen der Handhabungstechnik ISBN: 3446418725 München Hanser, 2010 K. Thulasiraman and M. N. S. Swamy Graphs: Theory and Algorithms ISBN: 9781118033104 %CITAVIPICKER£9781118033104£Titel anhand dieser ISBN in Citavi-Projekt übernehmen£% John Wüey & Sons, Inc., 1992

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

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	30 Minuten	
scale		
Lecturer	NN, Dr. Johannes Nicolas Gebhardt	
Language	DE	
Cycle	SoSe	
Content	<ul> <li>Processes and methods of product development - from idea to market launch         <ul> <li>identification of market and technology potentials</li> <li>development of a common product architecture</li> <li>Synchronized product development across all engineering disciplines</li> <li>product validation incl. customer view</li> </ul> </li> <li>Steering and optimization of product development         <ul> <li>Design of processes for product development</li> <li>IT systems for product development</li> <li>Establishment of management standards</li> <li>Typical types of organization</li> </ul> </li> </ul>	
Literature	<ul> <li>Bender: Embedded Systems - qualitätsorientierte Entwicklung</li> <li>Ehrlenspiel: Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit</li> <li>Gausemeier/Ebbesmeyer/Kallmeyer: Produktinnovation - Strategische Planung und Entwicklung der Produkte von morger</li> <li>Haberfellner/de Weck/Fricke/Vössner: Systems Engineering: Grundlagen und Anwendung</li> <li>Lindemann: Methodische Entwicklung technischer Produkte: Methoden flexibel und situationsgerecht anwenden</li> <li>Pahl/Beitz: Konstruktionslehre: Grundlagen erfolgreicher Produktentwicklung. Methoden und Anwendung</li> <li>VDI-Richtlinie 2206: Entwicklungsmethodik für mechatronische Systeme</li> </ul>	

Course L0310: Fatigue & Damage Tolerance		
Тур	Lecture	
Hrs/wk	2	
CP	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Examination Form	Mündliche Prüfung	
Examination duration and	45 min	
scale		
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	120 min
scale	
Lecturer	Prof. Thorsten Schüppstuhl
Language	DE
Cycle	SoSe
Content	
Literature	

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

Course L0724: Microsystems	Technology
Тур	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and	30 min
scale	
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	
	<ul> <li>Introduction (historical view, scientific and economic relevance, scaling laws)</li> <li>Semiconductor Technology Basics, Lihography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting)</li> <li>Deposition Technology Basics, Lihography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting)</li> <li>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, roy process, XeF2 etching)</li> <li>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)</li> <li>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, clarain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: piezoresistive, capacitive and fabrication process; celerometer: piezoresistive, piezoelectric and capacitive; angular rate sensor: sengento resistance, AMR and GMR, fluxgate magnetometer)</li> <li>Chemical and Bio Sensors (thermal gas sensors: pellistor and thermal conductivity sensor; metal oxide semiconductor gas sensor, cambda probe, MOSFET gas sensor, pri-FET, SAW sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip)</li> <li>Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, m</li></ul>
	and silicon fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002
	N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009
	T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010
	G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

ανΤ	Project-/problem-based Learning
Hrs/wk	
CP	
	Independent Study Time 48, Study Time in Lecture 42
	Schriftliche Ausarbeitung
Examination duration and	
scale	
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
114	
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

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

Course L1077: Process Measu	Irement 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	45 Minuten
scale	
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	<ul> <li>Process measurement engineering in the context of process control engineering</li> </ul>
	<ul> <li>Challenges of process measurement engineering</li> </ul>
	<ul> <li>Instrumentation of processes</li> </ul>
	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
	<ul> <li>Auto- and cross-correlation function and their applications</li> </ul>
	<ul> <li>Fault-free operation of correlational methods</li> </ul>
	Transmission of analog and digital measurement signals
	<ul> <li>Modulation process (amplitude and frequency modulation)</li> </ul>
	Multiplexing
	<ul> <li>Analog to digital converter</li> </ul>
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 Con	strol in Medical Technology		
	p Lecture		
Hrs/wk			
CP			
	Independent Study Time 62, Study Time in Lecture 28		
Examination Form			
Examination duration and			
scale			
Lecturer	Johannes Kreuzer, Christian Neuhaus		
Language	DE		
Cycle	SoSe		
Content	Always viewed from the engineer's point of view, the lecture is structured as follows: <ul> <li>Introduction to the topic</li> <li>Fundamentals of physiological modelling</li> <li>Introduction to Breathing and Ventilation</li> <li>Physiology and Pathology in Cardiology</li> <li>Introduction to the Regulation of Blood Glucose</li> <li>kidney function and renal replacement therapy</li> <li>Representation of the control technology on the concrete ventilator</li> <li>Excursion to a medical technology company</li> </ul> Techniques of modeling, simulation and controller development are discussed. In the models, simple equivalent block diagrams for physiological processes are derived and explained how sensors, controllers and actuators are operated. MATLAB and SIMULINK are used as development tools.		
Literature	<ul> <li>Leonhardt, S., &amp; Walter, M. (2016). Medizintechnische Systeme. Berlin, Heidelberg: Springer Vieweg.</li> <li>Werner, J. (2005). Kooperative und autonome Systeme der Medizintechnik. München: Oldenbourg.</li> <li>Oczenski, W. (2017). Atmen : Atemhilfen ; Atemphysiologie und Beatmungstechnik: Georg Thieme Verlag KG.</li> </ul>		

Courses			
F <b>itle</b> .ab Cyber-Physical Systems (L1740	) Project-/problem-based Learning	Hrs/wk 4	<b>CP</b> 6
Module Responsible	Prof. Heiko Falk		
Admission Requirements	None		
Recommended Previous	Module "Embedded Systems"		
Knowledge			
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence			
Knowledge	Ge Cyber-Physical Systems (CPS) are tightly integrated with their surrounding environment, via sensors, A/D and D/A converse control of their particular application areas, highly specialized sensors, processors and actors are common. Accordi is a large variety of different specification approaches for CPS - in contrast to classical software engineering approaches.		n. Accordingly, th
	Based on practical experiments using robot kits and computers, the basics of specification and lab introduces into the area (basic notions, characteristical properties) and their specification tech hierarchical automata, data flow models, petri nets, imperative approaches). Since CPS frequent experiments will base on simple control applications. The experiments will use state-of-the- (MATLAB/Simulink, LabVIEW, NXC) in order to model cyber-physical models that interact with t actors.	chniques (mod ly perform co -art industrial	dels of computation ntrol tasks, the la l specification to
Skills	After successful attendance of the lab, students are able to develop simple CPS. They understand CPS and its surrounding processes which stem from the fact that a CPS interacts with the environ digital processors, D/A converters and actors. The lab enables students to compare modellir advantages and limitations, and to decide which technique to use for a concrete task. They will be to practical problems. They obtain first experiences in hardware-related software development, tools and in the area of simple control applications.	ment via sens ng approache pe able to app	sors, A/D converte s, to evaluate the oly these techniq
Personal Competence			
Social Competence	Students are able to solve similar problems alone or in a group and to present the results accordin	ngly.	
Autonomy	Students are able to acquire new knowledge from specific literature and to associate this knowledge	lge with other	classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Course achievement	None		
Examination	Written elaboration		
Examination duration and	Execution and documentation of all lab experiments		
scale			
Assignment for the	General Engineering Science (German program, 7 semester): Specialisation Computer Science: El	ective Compu	llsory
Following Curricula	Computer Science: Specialisation II. Mathematics and Engineering Science: Elective Compulsory		
	Computer Science in Engineering: Specialisation II. Mathematics & Engineering Science: Elective (	Compulsory	
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory		
	Mechatronics: Specialisation System Design: Elective Compulsory		

Course L1740: Lab Cyber-Physical Systems			
Тур	Project-/problem-based Learning		
Hrs/wk	4		
CP	6		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Lecturer	Prof. Heiko Falk		
Language	DE/EN		
Cycle	SoSe		
Content	<ul> <li>Experiment 1: Programming in NXC</li> <li>Experiment 2: Programming the Robot in Matlab/Simulink</li> <li>Experiment 3: Programming the Robot in LabVIEW</li> </ul>		
Literature	<ul> <li>Peter Marwedel. Embedded System Design - Embedded System Foundations of Cyber-Physical Systems. 2 <sup>nd</sup> Edition, Springer, 2012.</li> <li>Begleitende Foliensätze</li> </ul>		

Module M1306: Conti	rol Lab C			
Courses				
<b>Fitle</b>		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. Herbert Werner			
Admission Requirements	None			
<b>Recommended Previous</b>				
Knowledge				
	LQG control			
	H2 and H-infinity optimal control			
	<ul> <li>uncertain plant models and robus</li> </ul>	st control		
	LPV control			
Educational Objectives	After taking part successfully, students	have reached the following learning results		
Professional Competence				
Knowledge	,			
	Students can explain the different	nce between validation of a control lop in simulati	on and experimental v	validation
Skills				
54113	<ul> <li>Students are capable of applying</li> </ul>	ng basic system identification tools (Matlab System)	stem Identification To	olbox) to identif
	dynamic model that can be used	for controller synthesis		
	They are capable of using stand	dard software tools (Matlab Control Toolbox) fo	r the design and imp	lementation of L
	controllers			
	They are capable of using standa	ard software tools (Matlab Robust Control Toolbo>	<li>k) for the mixed-sensit</li>	ivity design and
	implementation of H-infinity optin	mal controllers		
	They are capable of representing	model uncertainty, and of designing and implem	nenting a robust contro	oller
	They are capable of using standa	ard software tools (Matlab Robust Control Toolbox	) for the design and th	e implementation
	LPV gain-scheduled controllers			
Personal Competence				
Social Competence	<ul> <li>Students can work in teams to co</li> </ul>	onduct experiments and document the results		
Autonomy	<ul> <li>Students can independently carry</li> </ul>	y out simulation studies to design and validate co	ntrol loons	
	• Students can independently can	y out simulation studies to design and valuate ce		
Workload in Hours	Independent Study Time 48, Study Time	e in Lecture 42		
Credit points	3			
Course achievement	None			
Examination	Written elaboration			
Examination duration and	1			
scale				
Assignment for the	Electrical Engineering: Specialisation Co	ontrol and Power Systems Engineering: Elective C	ompulsory	
Following Curricula	Mechatronics: Specialisation Intelligent	Systems and Robotics: Elective Compulsory		
	Mechatronics: Specialisation System De	esign: Elective Compulsory		
	Theoretical Machanical Engineering, Co	re Qualification: Elective Compulsory		

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

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

Courses	
Title	Typ Hrs/wk CP
Advanced Topics in Vibration (L174	Project-/problem-based Learning         4         6
Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	None
<b>Recommended Previous</b>	Vibration Theory
Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
	Students are able to reflect existing terms and concepts of Advanced Vibrations.
	<ul> <li>Students are able to identify the need to develop and research new terms and concepts in vibrations.</li> </ul>
Skills	
	<ul> <li>Students are able to apply existing methods and procesures of Advanced Vibrations.</li> </ul>
	<ul> <li>Students are able to develop novel methods and procedures for advanced vibration problems.</li> </ul>
Personal Competence	
Social Competence	
	Students can reach working results also in groups.
	Students can present working results also in groups.
Autonomy	
	<ul> <li>Students are able to approach given research tasks individually</li> </ul>
	<ul> <li>Students are able to identify and follow up novel research tasks by themselves.</li> </ul>
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and	2 Hours
scale	
Assignment for the	Mechatronics: Specialisation System Design: Elective Compulsory
Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory
	Mechatronics: Technical Complementary Course: Elective Compulsory
	Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory
	Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory
	Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L1743: Advanced Top	ourse L1743: Advanced Topics in Vibration	
Тур	Project-/problem-based Learning	
Hrs/wk	4	
CP	6	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56	
Lecturer	Prof. Norbert Hoffmann	
Language	DE/EN	
Cycle	SoSe	
	Advanced and Research Topics in Vibrations   Rotor Dynamics  Modal Analysis  Model Order Reduction  Stability of Periodic Solutions  Random Vibrations	
Literature	Aktuelle Veröffentlichungen / Recent research publications Bücher/Books: Gasch, Nordmann, Pfützner: Rotordynamik Gasch, Knothe, Liebich: Strukturdynamik	

Courses Title Titl					
Humanoid Robotics (L0563)         Seminar         2         2           Module Responsible         Parick Gdtsch         Admission Requirements         None           Recommended Previous         None         Control theory and design         Control theory and design           Educational Objective         After taking part successfully, students have reached the following learning results         Professional Competence           Professional Competence         Students can explain humanoid robots.         Students can explain humanoid robots.         Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature           Skills         Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature         Students are capable of developed results and present them to the participants         Students are capable of developed results and present them           Personal Competence         Students are capable of developing solutions in interdisciplinary teams and present them         They are able to provide appropriate feedback and handle constructive criticism of their own results           Autonomy         Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studer solution           Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studer solution           Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other stu	Courses				
Humanoid Robotics (LO653)         Seminar         2         2           Module Responsible         Patck & Göttsch         Admission Requirements         None           Recommended Previous Knowledge         Introduction to control systems         - </th <th>Title</th> <th></th> <th>Түр</th> <th>Hrs/wk</th> <th>СР</th>	Title		Түр	Hrs/wk	СР
Admission Requirements       None         Recommended Previous Knowledge <ul> <li>Introduction to control systems</li> <li>Control theory and design</li> </ul> Educational Objectives       After taking part successfully, students have reached the following learning results         Professional Competence Knowledge <ul> <li>Students can explain humanoid robots.</li> <li>Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature</li> <li>Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature</li> <li>Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature</li> <li>Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature</li> <li>Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature</li> <li>Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature</li> <li>Students acquire knowledge about selected appects of humanoid robotics, based on specified literature</li> <li>Students are capable of developing solutions in interdisciplinary teams and present them</li> <li>They are able to provide appropriate feedback and handle constructive criticism of their own results</li> <li>Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studer such that a scientific discussion develops</li> </ul> <li>Workload in Hours</li> <li>Independent Study Time 32, Study Time in Lecture 28         <ul> <li>Credit point 2</li></ul></li>	Humanoid Robotics (L0663)				2
Recommended Previous Knowledge <ul> <li>Introduction to control systems</li> <li>Control theory and design</li> <li>Educational Objectives</li> <li>After taking part successfully, students have reached the following learning results</li> <li>Professional Competence Knowledge</li> <li>Students can explain humanoid robots.</li> <li>Students is acquire knowledge about selected aspects of humanoid robotics, based on specified literature</li> <li>Students generalize developed results and present them to the participants</li> <li>Students practice to prepare and give a presentation</li> <li>Students are capable of developing solutions in interdisciplinary teams and present them</li> <li>They are able to provide appropriate feedback and handle constructive criticism of their own results</li> <li>Students revaluate advantages and drawbacks of different forms of presentation for specific tasks and select the bisolution</li> <li>Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other student such that a scientific discussion develops</li> </ul> <li>Workload in Hours Indepent Study Time 32, Study Time in Lecture 28         <ul> <li>Course achievement None</li> <li>Examination</li> <li>Presentation</li> <li>Stealisation Intelligent Systems and Robotics: Elective Compulsory</li> <li>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Artificial Tregenerand Buscines Aministraton: Elective Compulsory</li></ul></li>	Module Responsible	Patrick Göttsch			
Knowledge. Introduction to control systems . Control theory and designEducational ObjectivesAtter taking part successfully, students have reached the following learning resultsProfessional Competence KnowledgeAtter taking part successfully, students have reached the following learning resultsProfessional Competence Social Competence. Students can explain humanoid robots. . Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature . Students generalize developed results and present them to the participants . Students are capable of developing solutions in interdisciplinary teams and present them . They are able to provide appropriate feedback and handle constructive criticism of their own resultsAutonomyIntegrate developed . Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the bisolution . Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other student . Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other student . Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other student . Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other student . Students accentific discussion developsWorkload in HoursIndependent Study Time 32, Study Time in Lecture 28Course achievementRoneAssignment for tha Biomedical Engineering: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Intelligent System Seerementive Medicine: Elective Compulsory 	Admission Requirements	None			
• Introduction to control systems           • Control theory and design           Educational Objectives           Professional Competence           knowledge           • Students can explain humanoid robots.           • Students can explain humanoid robots.           • Students can explain humanoid robots.           • Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature           • Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature           • Students generalize developed results and present them to the participants           • Students are capable of developing solutions in interdisciplinary teams and present them           • They are able to provide appropriate feedback and handle constructive criticism of their own results           Autonomy           • Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studer solution           • Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studer such that a scientific discussion develops           Workload in Hours         Independent Study Time 32, Study Time in Lecture 28           Course achievement         None           Examination         Presentation           Examination duration and somin         Students intelligent Systems and Robotics: Elective Compulsory	<b>Recommended Previous</b>				
e. Control theory and design         Educational Objective       After taking part successfully, students have reached the following learning results         Professional Competence <ul> <li>Students can explain humanoid robots.</li> <li>Students is can explain humanoid robots.</li> <li>Students learn to apply basic control concepts for different tasks in humanoid robotics, based on specified literature</li> <li>Students generalize developed results and present them to the participants</li> <li>Students practice to prepare and give a presentation</li> </ul> Personal Competence <ul> <li>Students are capable of developing solutions in interdisciplinary teams and present them</li> <li>They are able to provide appropriate feedback and handle constructive criticism of their own results</li> <li>Autonomy</li> <li>Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other students such that a scientific discussion develops</li> </ul> Workload in Hours <ul> <li>Resentation</li> <li>Presentation</li> <li>Resentation</li> <li>Resentation intelligent System Sand Robotics: Elective Compulsory</li> <li>Biomed</li></ul>	Knowledge	<ul> <li>Introduction to control systems</li> </ul>			
Educational Objective         After taking part successfully, students have reached the following learning results           Professional Competence         Knowledge           Knowledge              • Students can explain humanoid robots.            Skills              • Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature            Skills              • Students generalize developed results and present them to the participants            Science              • Students are capable of developing solutions in interdisciplinary teams and present them            Autonomy              • Students are capable of developing solutions in interdisciplinary teams and present them            Autonomy              • Students ramiliarize themselves with a scientific field, are able of introduce it and follow presentations of other studer             solution            Vorkload in Hours              independent Study Time in Lecture 28            Course achievement              None            Examination              Presentation            Restration              Presentation            Examination Breactive Specialisation intelligent Systems and Robotics: Elective Compulsory            Biomedical Engineering: Specialisation implants and Endoprostheses: Elective Compulsory            Biomedical Engineering: Specia					
Professional Competence       Students can explain humanoid robots.         Students can explain humanoid robots.       Students can explain humanoid robots.         Students learn to apply basic control concepts for different tasks in humanoid robotics.         Stills         Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature         Students generalize developed results and present them to the participants         Students practice to prepare and give a presentation         Personal Competence         Students are capable of developing solutions in interdisciplinary teams and present them         They are able to provide appropriate feedback and handle constructive criticism of their own results         Autonomy         Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studer solution         Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studer such that a scientific discussion develops         Workload in Hours       Independent Study Time 32, Study Time in Lecture 28         Credit points 2       Course achievement         Course achievement       None         Examination duration and 30 min       Students         scale       Assignment for the         Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory         Biome					
Knowledge       - Students can explain humanoid robots.         Skills       - Students learn to apply basic control concepts for different tasks in humanoid robotics.         Skills       - Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature         Skills       - Students generalize developed results and present them to the participants         Students generalize developed results and present them to the participants       - Students practice to prepare and give a presentation         Personal Competence       - Students are capable of developing solutions in interdisciplinary teams and present them         Autonomy       - Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the bisolution         Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studen such that a scientific discussion develops         Workload in Hours       Independent Study Time 32, Study Time in Lecture 28         Course achievement       None         Examination       Presentation         Following Curricula       Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory         Following Curricula       Mechatronics: Specialisation Actificial Organs and Regenerative Medicine: Elective Compulsory         Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory       Biomedical Engineering: Specialisation Mandeical Technology	Educational Objectives	After taking part successfully, students have	reached the following learning results		
<ul> <li>Students can explain humanoid robots.</li> <li>Students learn to apply basic control concepts for different tasks in humanoid robotics.</li> <li>Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature</li> <li>Students generalize developed results and present them to the participants</li> <li>Students practice to prepare and give a presentation</li> <li>Personal Competence</li> <li>Students are capable of developing solutions in interdisciplinary teams and present them</li> <li>They are able to provide appropriate feedback and handle constructive criticism of their own results</li> <li>Autonomy</li> <li>Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other student such that a scientific discussion develops</li> <li>Workload in Hours</li> <li>Independent Study Time 32, Study Time in Lecture 28</li> <li>Credit points</li> <li>Z</li> <li>Course achievement</li> <li>None</li> <li>Examination</li> <li>Presentation</li> <li>Presentation</li> <li>Presentation</li> <li>Mechatronics: Specialisation Intelligent Systems and Regonerative Medicine: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory</li> </ul>	Professional Competence				
skills       - Students learn to apply basic control concepts for different tasks in humanoid robotics.         skills       - Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature         Skills       - Students generalize developed results and present them to the participants         Social Competence       - Students are capable of developing solutions in interdisciplinary teams and present them         Autonomy       - Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the bisolution         Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other students auch that a scientific discussion develops         Workload in Hours       Independent Study Time 32, Study Time in Lecture 28         Course achievement       Ione         Examination duration and scientific discussion intelligent Systems and Robotics: Elective Compulsory         Following Curricut       Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory         Biomedical Engineering: Specialisation Mandagement and Business Administration: Elective Compulsory         Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory	Knowledge	<ul> <li>Students can explain humanoid robots</li> </ul>			
Skills <ul> <li>Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature - Students generalize developed results and present them to the participants - Students practice to prepare and give a presentation</li> </ul> Personal Competence <ul> <li>Students practice to prepare and give a presentation</li> <li>Students practice to prepare and give a presentation</li> <li>Students are capable of developing solutions in interdisciplinary teams and present them             <ul> <li>They are able to provide appropriate feedback and handle constructive criticism of their own results</li> <li>Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the busicultion</li> <li>Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other student such that a scientific discussion develops</li> </ul> </li> <li>Workload in Hours         <ul> <li>Independent Study Time 32, Study Time in Lecture 28</li> <li>Course achievement</li> <li>None</li> <li>Examination duration and 30 min</li> <li>Rechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation System Design: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory</li></ul></li></ul>				obotics	
<ul> <li>Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature</li> <li>Students generalize developed results and present them to the participants</li> <li>Students practice to prepare and give a presentation</li> <li>Students are capable of developing solutions in interdisciplinary teams and present them</li> <li>They are able to provide appropriate feedback and handle constructive criticism of their own results</li> <li>Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the br solution</li> <li>Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studen such that a scientific discussion develops</li> <li>Workload in Hours</li> <li>Independent Study Time 32, Study Time in Lecture 28</li> <li>Course achievement</li> <li>None</li> <li>Examination duration and 30 min</li> <li>Assignment for the Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory</li> </ul>					
<ul> <li>Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature</li> <li>Students generalize developed results and present them to the participants</li> <li>Students practice to prepare and give a presentation</li> <li>Students are capable of developing solutions in interdisciplinary teams and present them</li> <li>They are able to provide appropriate feedback and handle constructive criticism of their own results</li> <li>Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the br solution</li> <li>Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studen such that a scientific discussion develops</li> <li>Workload in Hours</li> <li>Independent Study Time 32, Study Time in Lecture 28</li> <li>Course achievement</li> <li>None</li> <li>Examination duration and 30 min</li> <li>Assignment for the Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory</li> </ul>					
• Students generalize developed results and present them to the participants         • Students practice to prepare and give a presentation         Social Competence         Social Competence         Autonomy         • Students are capable of developing solutions in interdisciplinary teams and present them         • They are able to provide appropriate feedback and handle constructive criticism of their own results         Autonomy         • Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the bissolution         • Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other student sheal a scientific discussion develops         Workload in Hours       Independent Study Time 32, Study Time in Lecture 28         Course achievement       None         Examination       Presentation         Resentation       Presentation         Staignment for the       Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory         Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory         Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory         Biomedical Engineering: Specialisation Maagement and Business Administration: Elective Compulsory         Biomedical Engineering: Specialisation Maagement and Business Administration: Elective Compulsory <td>Skills</td> <td><ul> <li>Students acquire knowledge about sel</li> </ul></td> <td>ected aspects of humanoid robotics, base</td> <td>ed on specified literature</td> <td></td>	Skills	<ul> <li>Students acquire knowledge about sel</li> </ul>	ected aspects of humanoid robotics, base	ed on specified literature	
Personal Competence       Social Competence         Social Competence       • Students are capable of developing solutions in interdisciplinary teams and present them         Autonomy       • They are able to provide appropriate feedback and handle constructive criticism of their own results         Autonomy       • Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the bisolution         • Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studer such that a scientific discussion develops         Workload in Hours       Independent Study Time 32, Study Time in Lecture 28         Credit points       2         Course achievement       None         Examination       Presentation         Scale       Presentation         Assignment for the scale       Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory         Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory         Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory         Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory					
Social Competence <ul> <li>Students are capable of developing solutions in interdisciplinary teams and present them</li> <li>They are able to provide appropriate feedback and handle constructive criticism of their own results</li> <li>Autonomy</li> <li>Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the bisolution</li> <li>Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studer such that a scientific discussion develops</li> </ul> <li>Workload in Hours         <ul> <li>Independent Study Time 32, Study Time in Lecture 28</li> <li>Ceredit points</li> <li>Presentation</li> <li>Presentation</li> <li>Presentation</li> <li>Micharonics: Specialisation Intelligent Systems and Robotics: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory</li> </ul> </li>		<ul> <li>Students practice to prepare and give</li> </ul>	a presentation		
Social Competence <ul> <li>Students are capable of developing solutions in interdisciplinary teams and present them</li> <li>They are able to provide appropriate feedback and handle constructive criticism of their own results</li> </ul> Autonomy <ul> <li>Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the bisolution</li> <li>Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other student such that a scientific discussion develops</li> </ul> Workload in Hours       Independent Study Time 32, Study Time in Lecture 28         Credit points       2         Course achievement       None         Examination duration and scelet       30 min         Scelet       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 Management and Business Administration: Elective Compulsory	Demonstration of the second				
<ul> <li>Students are capable of developing solutions in interdisciplinary teams and present them</li> <li>They are able to provide appropriate feedback and handle constructive criticism of their own results</li> <li>Autonomy</li> <li>Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the be solution</li> <li>Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other student such that a scientific discussion develops</li> <li>Workload in Hours</li> <li>Independent Study Time 32, Study Time in Lecture 28</li> <li>Credit points</li> <li>Course achievement</li> <li>None</li> <li>Examination</li> <li>Presentation</li> <li>Presentation</li> <li>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Matigen Artificial Organs and Regenerative Medicine: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory</li> </ul>	-				
Autonomy <ul> <li>Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the bisolution             <li>Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studen such that a scientific discussion develops</li> </li></ul> <li>Workload in Hours         <ul> <li>Independent Study Time 32, Study Time in Lecture 28</li> <li>Credit points</li> <li>None</li> </ul> </li> <li>Examination Presentation</li> <li>Presentation</li> <li>Assignment for the Following Curricula</li> <li>Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory</li>	Social Competence	Students are capable of developing sc	lutions in interdisciplinary teams and pre	sent them	
<ul> <li>Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the basolution</li> <li>Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studen such that a scientific discussion develops</li> <li>Workload in Hours</li> <li>Independent Study Time 32, Study Time in Lecture 28</li> <li>Credit points</li> <li>2</li> <li>Course achievement</li> <li>None</li> <li>Examination Presentation</li> <li>Scale</li> <li>Assignment for the Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory</li> </ul>		<ul> <li>They are able to provide appropriate f</li> </ul>	eedback and handle constructive criticisr	n of their own results	
<ul> <li>Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the basolution</li> <li>Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studen such that a scientific discussion develops</li> <li>Workload in Hours</li> <li>Independent Study Time 32, Study Time in Lecture 28</li> <li>Credit points</li> <li>2</li> <li>Course achievement</li> <li>None</li> <li>Examination Presentation</li> <li>Stadents for the Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory</li> <li>Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory</li> </ul>	Autonomi				
• Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other studen such that a scientific discussion develops         • Workload in Hours       Independent Study Time 32, Study Time in Lecture 28         • Credit points       2         • Course achievement       None         • Examination       Presentation         • Presentation duration and scale       30 min         • Course achievement       Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory         • Following Curricul       Mechatronics: 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       Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory	Autonomy	<ul> <li>Students evaluate advantages and of</li> </ul>	drawbacks of different forms of present	ation for specific tasks	and select the be
such that a scientific discussion develops         Workload in Hours       Independent Study Time 32, Study Time in Lecture 28         Credit points       2         Course achievement       None         Examination       Presentation         Presentation duration and scale       30 min         Following Curricul       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		solution			
Workload in Hours       Independent Study Time 32, Study Time in Lecture 28         Credit points       2         Course achievement       None         Examination       Presentation         Scale       30 min         Assignment for the Following Curricula       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		<ul> <li>Students familiarize themselves with</li> </ul>	a scientific field, are able of introduce i	t and follow presentatio	ns of other studen
Credit points       2         Course achievement       None         Examination       Presentation         Examination duration and scale       30 min         Assignment for the Following Curricula       Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory         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		such that a scientific discussion devel	ops		
Course achievement         None           Examination         Presentation           Examination duration and scale         30 min           Assignment for the Following Curricula         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	Workload in Hours	Independent Study Time 32, Study Time in L	ecture 28		
Examination       Presentation         Examination duration and scale       30 min         Assignment for the Following Curricula       Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory         Mechatronics: Specialisation System Design: Elective Compulsory       Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory         Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory       Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory         Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory       Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory	Credit points	2			
Examination duration and scale       30 min         scale       Assignment for the         Assignment for the       Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory         Following Curricula       Mechatronics: Specialisation System Design: Elective Compulsory         Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory         Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory         Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory         Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory	Course achievement	None			
scale         Assignment for the       Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory         Following Curricula       Mechatronics: Specialisation System Design: Elective Compulsory         Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory         Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory         Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory         Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory	Examination	Presentation			
Assignment for the       Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory         Following Curricula       Mechatronics: Specialisation System Design: Elective Compulsory         Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory         Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory         Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory         Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory	Examination duration and	30 min			
Following CurriculaMechatronics: Specialisation System Design: Elective CompulsoryBiomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective CompulsoryBiomedical Engineering: Specialisation Implants and Endoprostheses: Elective CompulsoryBiomedical Engineering: Specialisation Medical Technology and Control Theory: Elective CompulsoryBiomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory	scale				
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	Assignment for the	Mechatronics: Specialisation Intelligent Syste	ems and Robotics: 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	Following Curricula				
Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory					
Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory					
			-		

Course L0663: Humanoid Ro	botics
Тур	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Patrick Göttsch
Language	DE
Cycle	SoSe
Content	<ul> <li>Grundlagen der Regelungstechnik</li> <li>Control systems theory and design</li> </ul>
Literature	- B. Siciliano, O. Khatib. "Handbook of Robotics. Part A: Robotics Foundations", Springer (2008).

Title         Linear and Nonlinear System Identification (L0660)         Module Responsible       Prof. Herbert Werner         Admission Requirements       None	<b>Typ</b> Lecture	Hrs/wk 2	СР
Module Responsible Prof. Herbert Werner	Lecture	2	
			3
Admission Requirements None			
Recommended Previous			
Classical control (frequency response, root locus)			
State space methods     Discrete time systems			
Discrete-time systems			
<ul> <li>Linear algebra, singular value decomposition</li> <li>Basic knowledge about stochastic processes</li> </ul>			
Basic knowledge about stochastic processes			
Educational Objectives After taking part successfully, students have reached the	following learning results		
Professional Competence			
Knowledge     Students can explain the general framework of the ge	a prodiction arrar mathad	and its application to a	variaty of linear
nonlinear model structures		and its application to a	variety of fifiear a
They can explain how multilayer perceptron network	rks are used to model popli	near dynamics	
<ul> <li>They can explain now mutually perception network</li> <li>They can explain how an approximate predictive co</li> </ul>		-	ls
<ul> <li>They can explain now an approximate predictive co-</li> <li>They can explain the idea of subspace identification</li> </ul>			15
• Students are capable of applying the predicition	orror mothod to the experi	rimontal identification of	linear and poplin
models for dynamic systems	error method to the exper		
<ul> <li>They are capable of implementing a nonlinear pred</li> </ul>	lictive control scheme base	d on a neural network mo	del
<ul> <li>They are capable of applying subspace algorithms</li> </ul>			
<ul> <li>They can do the above using standard software too</li> </ul>			
	sis (meraanig the matab by:		
Personal Competence			
Social Competence Students can work in mixed groups on specific problems t	to arrive at joint solutions.		
Autonomy Students are able to find required information in sources	provided (lecture notes, lite	erature, software docume	ntation) and use it
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 30 min			
scale			
Assignment for the Electrical Engineering: Specialisation Control and Power S		e Compulsory	
Following Curricula Mechatronics: Specialisation Intelligent Systems and Robo			
Mechatronics: Specialisation System Design: Elective Com			
Biomedical Engineering: Specialisation Artificial Organs ar	-		
Biomedical Engineering: Specialisation Implants and Endo			
Biomedical Engineering: Specialisation Medical Technolog			
Biomedical Engineering: Specialisation Management and I Theoretical Mechanical Engineering: Core Qualification: El		ective Compulsory	

Course L0660: Linear and Nonlinear System Identification		
Тур	Lecture	
Hrs/wk	2	
CP	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Lecturer	Prof. Herbert Werner	
Language	EN	
Cycle	SoSe	
Content	<ul> <li>Prediction error method</li> <li>Linear and nonlinear model structures</li> <li>Nonlinear model structure based on multilayer perceptron network</li> <li>Approximate predictive control based on multilayer perceptron network model</li> <li>Subspace identification</li> </ul>	
Literature	<ul> <li>Lennart Ljung, System Identification - Theory for the User, Prentice Hall 1999</li> <li>M. Norgaard, O. Ravn, N.K. Poulsen and L.K. Hansen, Neural Networks for Modeling and Control of Dynamic Systems, Springer Verlag, London 2003</li> <li>T. Kailath, A.H. Sayed and B. Hassibi, Linear Estimation, Prentice Hall 2000</li> </ul>	

Module M0939: Contr	ol Lab A			
Courses				
Title		Тур	Hrs/wk	СР
Control Lab I (L1093)		Practical Course	1	1
Control Lab II (L1291)		Practical Course	1	1
Control Lab III (L1665)		Practical Course	1	1
Control Lab IV (L1666)		Practical Course	1	1
Module Responsible	Prof. Herbert Werner			
Admission Requirements				
<b>Recommended Previous</b>				
Knowledge	<ul> <li>State space methods</li> </ul>			
	LQG control			
	<ul> <li>H2 and H-infinity optimal control</li> </ul>			
	<ul> <li>uncertain plant models and robust con</li> </ul>	trol		
	LPV control			
Educational Objectives	After taking part successfully, students have	reached the following learning results		
Professional Competence	· · · · · · · · · · · · · · · · · · ·	· · · · · · · · · · · · · · · · · · ·		
Knowledge				
Knowledge	Students can explain the difference be	tween validation of a control lop in simulatio	n and experimental v	alidation
Skills	<ul> <li>Students are canable of applying ba</li> </ul>	sic system identification tools (Matlab Syst	em Identification To	olbox) to identify
	dynamic model that can be used for co			onbox, to racinity
			the design and imp	loncentation of LC
		software tools (Matlab Control Toolbox) for	the design and imp	nementation of LQ
	controllers			
		ftware tools (Matlab Robust Control Toolbox)	for the mixed-sensit	ivity design and th
	implementation of H-infinity optimal co			
	<ul> <li>They are capable of representing mode</li> </ul>	el uncertainty, and of designing and impleme	enting a robust contro	oller
	<ul> <li>They are capable of using standard so</li> </ul>	ftware tools (Matlab Robust Control Toolbox)	for the design and th	e implementation
	LPV gain-scheduled controllers			
Devenuel Commetence				
Personal Competence				
Social Competence	<ul> <li>Students can work in teams to conduct</li> </ul>	t experiments and document the results		
Autonomy	<ul> <li>Students can independently carry out.</li> </ul>	simulation studies to design and validate con	trol loops	
	• Students can independently carry out	simulation staties to design and validate con	100000	
Workload in Hours	Independent Study Time 64, Study Time in Le	ecture 56		
Credit points				
Course achievement				
Examination	Written elaboration			
Examination duration and	1			
scale				
	Electrical Engineering: Specialisation Control		mpulsory	
Following Curricula				
	Mechatronics: Specialisation Intelligent Syste	ms and Robotics: Elective Compulsory		
	Theoretical Mechanical Engineering: Specialis	sation Robotics and Computer Science: Electi	ve Compulsory	
	1			

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

## Module Manual M.Sc. "Mechatronics"

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

urse L1665: Control Lab III	
Practical Course	
1	
1	
Independent Study Time 16, Study Time in Lecture 14	
Prof. Herbert Werner, Adwait Datar, Patrick Göttsch	
EN	
WiSe/SoSe	
One of the offered experiments in control theory.	
Experiment Guides	

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

Module M0924: Softw	vare for Embedded Systen	26			
Module M0924. Soltw	are for Embedded System	15			
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. Bernd-Christian Renner				
Admission Requirements	None				
<b>Recommended Previous</b>	<ul> <li>Very Good knowledge and practice</li> </ul>	stical experience in progra	mming in the Clanguage		
Knowledge	Basic knowledge in software en		nming in the Clanguage		
	Basic understanding of assemble	5 5			
	<ul> <li>Basic understanding of assertion</li> </ul>	Jiy laliguage			
<b>Educational Objectives</b>	After taking part successfully, studen	ts have reached the follow	ng learning results		
Professional Competence					
Knowledge	Students know the basic principles a	nd procedures of software	engineering for embedded sy	ystems. They are	able to describe th
	usage and pros of event based p	rogramming using interru	pts. They know the compo	onents and func	tions of a concret
	microcontroller. The participants exp	lain requirements of real	ime systems. They know at	least three sched	duling algorithms fo
	real time operating systems including	their pros and cons.			
Skills	s Students build interrupt-based programs for a concrete microcontroller. They build and use a preemptive scheduler. They			scheduler. They us	
	peripheral components (timer, ADC, EEPROM) to realize complex tasks for embedded systems. To interface with exter				erface with externa
	components they utilize serial protoco	ols.			
Personal Competence					
Social Competence					
Autonomy					
Workload in Hours	Independent Study Time 110, Study	Time in Lecture 70			
Credit points	6				
Course achievement	Compulsory Bonus Form	Description			
	No 10 % Attestation				
	Written exam				
Examination duration and	90 min				
scale					
Assignment for the	Computer Science: Specialisation I. C	omputer and Software Eng	ineering: Elective Compulsory	/	
Following Curricula	Electrical Engineering: Specialisation	Information and Communi	cation Systems: Elective Com	pulsory	
	Information and Communication Syst	ems: Specialisation Comm	unication Systems, Focus Soft	ware: Elective Co	mpulsory
	Mechatronics: Technical Complement	ary Course: Elective Comp	ulsory		
	Mechatronics: Specialisation Intellige	nt Systems and Robotics: E	lective Compulsory		
	Mechatronics: Specialisation System		-		
	Microelectronics and Microsystems: S	pecialisation Embedded Sy	stems: Elective Compulsory		

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

Course L1070: Software for I	irse L1070: Software for Embdedded Systems		
Тур	Recitation Section (small)		
Hrs/wk	3		
CP	3		
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42		
Lecturer	Prof. Bernd-Christian Renner		
Language	DE/EN		
Cycle	SoSe		
Content	See interlocking course		
Literature	See interlocking course		

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			
<b>Recommended Previous</b>	Module "Embedded Systems"			
Knowledge	C/C++ Programming skills			
Educational Objectives	After taking part successfully, students have r	eached the following learning results		
Professional Competence				
, nonege	embedded processors grows continuously du of embedded systems, highly optimized and impose high demands on compilers which have the students are able • to illustrate the structure and organizat • to distinguish and explain intermediate • to assess optimizations and their under The high demands on compilers for embed particular, • which kinds of optimizations are applic • how the translation from source code t • which kinds of optimizations are applic • how register allocation is performed, ar • how memory hierarchies can be exploit	representations of various abstraction levels, and lying problems in all compiler phases. ded systems make effective code optimizations able at the source code level, o assembly code is performed, able at the assembly code level, able at the assembly code level, ded effectively.	of the particu uch highly sp ccessful attend mandatory. Th	lar application are: ecialized processo dance of this cours ne students learn
		have to optimize for multiple objectives (e.g., aver arn to evaluate the influence of optimizations on t		
Skills	be enabled to assess which kind of code optir assembly code) within a compiler.	dents shall be able to translate high-level program nization should be applied most effectively at whi rn to implement a fully functional compiler includir	ch abstraction	level (e.g., source
Personal Competence				
-	Students are able to solve similar problems al	one or in a group and to present the results accord	lingly.	
		rom specific literature and to associate this knowle		r classes.
Workload in Hours	Independent Study Time 124, Study Time in L	ecture 56		
Credit points				
Course achievement				
Examination				
Examination duration and				
scale				
Assignment for the	Computer Science: Specialisation I. Computer	and Software Engineering: Elective Compulsory		
Following Curricula	Electrical Engineering: Specialisation Informat	ion and Communication Systems: Elective Compul	sory	
	Aircraft Systems Engineering: Core Qualificati	on: Elective Compulsory		
	Mechatronics: Specialisation Intelligent System	ns and Robotics: Elective Compulsory		
	Mechatronics: Specialisation System Design: I	Elective Compulsory		
	Mechatronics: Technical Complementary Cour			
	Theoretical Mechanical Engineering: Specialis	ation Robotics and Computer Science: Elective Cor	npulsory	

Тур	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	Introduction and Motivation
	Compilers for Embedded Systems - Requirements and Dependencies
	Internal Structure of Compilers
	Pre-Pass Optimizations
	HIR Optimizations and Transformations
	Code Generation
	LIR Optimizations and Transformations
	Register Allocation
	WCET-Aware Compilation
	Outlook
Literature	• Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2 <sup>nd</sup> Editic
	Springer, 2012.
	<ul> <li>Steven S. Muchnick. Advanced Compiler Design and Implementation. Morgan Kaufmann, 1997.</li> </ul>
	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

Courses				
Courses				
Title		<b>Typ</b> Lecture	Hrs/wk 2	<b>CP</b> 3
Optimal and Robust Control (L0658 Optimal and Robust Control (L0659		Recitation Section (small)	2	3
Module Responsible				-
Admission Requirements				
Recommended Previous	None			
Knowledge	Classical control (frequency response, root locus)			
Kilomeuge	State space methods			
	Linear algebra, singular value decomposition			
Educational Objectives	After taking part successfully, students have reached the	following learning results		
Professional Competence	Price taking pare successiony, staticities have reached the			
Knowledge				
nnomeage	<ul> <li>Students can explain the significance of the matri</li> </ul>	x Riccati equation for the solution of I	LQ problems.	
	<ul> <li>They can explain the duality between optimal stat</li> </ul>	e feedback and optimal state estima	tion.	
	<ul> <li>They can explain how the H2 and H-infinity norms</li> </ul>			
	They can explain how an LQG design problem can			
	They can explain how model uncertainty can be r			
	They can explain how - based on the small gain	neorem - a robust controller can gu	arantee stability	and performance
	<ul><li>an uncertain plant.</li><li>They understand how analysis and synthesis cond</li></ul>	itions on feedback loops can be rent	sontod as linoar	matrix inequalitie
	• They understand now analysis and synthesis cone	nions on recuback loops can be repre	esented as intear	matrix mequance
Skills	<ul> <li>Students are capable of decigning and tuning LOC</li> </ul>	controllors for multivariable plant m	adala	
	<ul> <li>Students are capable of designing and tuning LQC</li> <li>They are capable of representing a H2 or H-infinit</li> </ul>			nd of using stand
	software tools for solving it.	y design problem in the form of a ger	neralizeu plant, a	ind of using stand
	<ul> <li>They are capable of translating time and frequer</li> </ul>	cy domain specifications for control	loops into const	raints on closed-lo
	sensitivity functions, and of carrying out a mixed-			
	<ul> <li>They are capable of constructing an LFT uncertainty</li> </ul>		, and of designir	ng a mixed-object
	robust controller.			5
	<ul> <li>They are capable of formulating analysis and syn</li> </ul>	thesis conditions as linear matrix ine	qualities (LMI), a	nd of using stand
	LMI-solvers for solving them.			
	<ul> <li>They can carry out all of the above using standard</li> </ul>	software tools (Matlab robust contro	l toolbox).	
Barcanal Compotence				
Personal Competence	Students can work in small groups on specific problems	a arrive at joint colutions		
	Students are able to find required information in sources	-	oftware decume	ntation) and use it
Autonomy	solve given problems.	provided (lecture notes, interature, s		ntation) and use n
	solve given problems.			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points				
Course achievement				
Examination				
Examination duration and				
scale	50 mm			
56416				
Assignment for the	Electrical Engineering: Specialisation Control and Power	Systems Engineering: Elective Compu	ulsory	
Following Curricula	Energy Systems: Core Qualification: Elective Compulsory			
	Aircraft Systems Engineering: Core Qualification: Elective			
	Mechatronics: Specialisation Intelligent Systems and Rob			
	Mechatronics: Specialisation System Design: Elective Co		Compulsor	
	Biomedical Engineering: Specialisation Artificial Organs a	-	Lompulsory	
	Biomedical Engineering: Specialisation Implants and Eng		oulsony	
	Biomedical Engineering: Specialisation Medical Technolo Biomedical Engineering: Specialisation Management and		-	
	Product Development, Materials and Production: Special			
	Product Development, Materials and Production: Special Product Development, Materials and Production: Special	•		
	Product Development, Materials and Production: Special		-	
	Theoretical Mechanical Engineering: Core Qualification: I			

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

Course L0659: Optimal and F	ourse 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: Desig		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,				
Courses						
Title			1	Гур	Hrs/wk	СР
Designing Dependable Systems (L	2000)			ecture	2	3
Designing Dependable Systems (L	2001)		F	Recitation Section (small)	2	3
Module Responsible	Prof. Görschwin Fey					
Admission Requirements	None					
<b>Recommended Previous</b>	Basic knowledge about dat	ta structures and alo	gorithms			
Knowledge						
Educational Objectives	After taking part successfu	ully, students have re	eached the following	learning results		
Professional Competence						
Knowledge	In the following "dependat	ole" summarizes the	concepts Reliability	, Availability, Maintainabilit	y, Safety and Sec	urity.
	Knowledge about approact	has for designing do	popdable systems			
	Knowledge about approach	nes for designing de	pendable systems, e	z.y.,		
	Structural solutions	like modular redund	lancy			
	Algorithmic solution	ıs like handling byza	ntine faults or check	pointing		
	Knowledge about methods	for the analysis of (	denendable systems			
	Knowledge about methods	s for the analysis of t	dependable systems			
Skills	Ability to implement deper	ndable systems usin	a the above approac	hes		
Skiis	Ability to implement deper	lucible bysterns using	g the above approac			
	Ability to analyzs the depe	endability of systems	using the above me	ethods for analysis.		
Personal Competence						
Social Competence	Students					
booldi competence	bradento					
	<ul> <li>discuss relevant top</li> </ul>					
	<ul> <li>present their solution</li> </ul>	ons orally.				
Autonomy	Using accompanying mate	erial students inder	oendently learn in-d	epth relations between co	oncepts explaine	d in the lecture a
	additional solution strategi					
Workload in Hours	Independent Study Time 1	24, Study Time in Le	ecture 56			
Credit points	6					
Course achievement	Compulsory Bonus For	m	Description			
	Yes None Sub	bject theoretical	andDie Lösung eir	ner Aufgabe ist Zuslassung	gsvoraussetzung	für die Prüfung. D
	pra	actical work	Aufgabe wird ir	n Vorlesung und Übung def	iniert.	
Examination	Oral exam					
Examination duration and	30 min					
scale						
Assignment for the	Computer Science: Special	lisation I. Computer	and Software Engine	eering: Elective Compulsory	4	
Following Curricula	Computer Science in Engir	neering: Specialisatio	on I. Computer Scien	nce: Elective Compulsory		
	Information and Communi	cation Systems: Spe	cialisation Secure ar	nd Dependable IT Systems:	Elective Compuls	sory
	Mechatronics: Specialisatio	on System Design: E	lective Compulsory			
	Microelectronics and Micro	systems: Specialisat	tion Embedded Syste	ems: Elective Compulsory		

Course L2000: Designing Dep	pendable Systems
Тур	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Görschwin Fey
Language	DE/EN
Cycle	SoSe
Content	Description
	The term dependability comprises various aspects of a system. These are typically:
	<ul> <li>Reliability</li> <li>Availability</li> <li>Maintainability</li> <li>Safety</li> <li>Security</li> <li>This makes dependability a core aspect that has to be considered early in system design, no matter whether software, embedded</li> </ul>
	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	

ourse 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	

Courses				
<b>Title</b> Applied Design Methodology in Me	hotropics (11533)	<b>Typ</b> Lecture	Hrs/wk	<b>CP</b> 2
Applied Design Methodology in Met		Project-/problem-based Learning	2	4
Module Responsible		Hojeet /problem based Learning	5	7
Admission Requirements				
	Basics of mechanical design, electrical design	an or computer-sciences		
Knowledge	basics of mechanical design, electrical desig	in or computer-sciences		
	After taking part successfully, students have	reached the following learning results		
Professional Competence	Arter taking part successivily, students nave	reaction the following learning results		
•	Science-based working on interdisciplinary r	product design considering targeted application of sp	pecific product	desian techniques
landineage		and a second considering targeted application of sp		
Skills	Creative handling of processes used for scie	entific preparation and formulation of complex produ	ict design prot	olems / Application
	various product design techniques following theoretical aspects.			
Personal Competence				
•	Students will solve and execute technical	scientific tasks from an industrial context in small	l design-team	s with application
Social competence	Students will solve and execute technical-scientific tasks from an industrial context in small design-teams with application common, creative methodologies.			
Autonomy	Students are enabled to optimize the design and development process according to the target and topic of the design			
Autonomy	y students are enabled to optimize the design and development process according to the target and topic of the design			
	Students are educated to operate in a devel	opment team		
	Students learn about the right application of	creative methods in engineering.		
Workload in Hours	Independent Study Time 110, Study Time in	Lecture 70		
Credit points	6			
Course achievement	None			
Examination	Subject theoretical and practical work			
Examination duration and	30 min Presentation for a group design-work	<		
scale				
Assignment for the	International Management and Engineering:	Specialisation II. Product Development and Production	ion: Elective C	ompulsory
Following Curricula	International Management and Engineering:	Specialisation II. Mechatronics: Elective Compulsory	r	
	Mechanical Engineering and Management: S	Specialisation Product Development and Production:	Elective Comp	oulsory
	Mechatronics: Specialisation System Design	: Elective Compulsory		
	Biomedical Engineering: Specialisation Artifi	cial Organs and Regenerative Medicine: Elective Cor	npulsory	
	Biomedical Engineering: Specialisation Impla	ants and Endoprostheses: Elective Compulsory		
	Biomedical Engineering: Specialisation Medi	cal Technology and Control Theory: Elective Compul	sory	
	Biomedical Engineering: Specialisation Mana	agement and Business Administration: Elective Comp	oulsory	
	Theoretical Mechanical Engineering: Special	isation Product Development and Production: Electiv	e Compulsory	

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

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

C						
Courses						
Title		Тур	Hrs/wk	СР		
=	nas, and Electromagnetic Compatibility (L1669)	Lecture	3	4		
Introduction to Waveguides, Anten	nas, and Electromagnetic Compatibility (L1877)	Recitation Section (small)	2	2		
Module Responsible	Prof. Christian Schuster					
Admission Requirements	None					
<b>Recommended Previous</b>	Basic principles of physics and electrical engineering					
Knowledge						
Educational Objectives	After taking part successfully, students have reached the	e following learning results				
Professional Competence						
Knowledge	Students can explain the basic principles, relationship	s, and methods for the design of wa	veguides and an	tennas as well as		
	Electromagnetic Compatibility. Specific topics are:					
	- Fundamental properties and phenomena of electrical	circuits				
	- Steady-state sinusoidal analysis of electrical circuits					
	- Fundamental properties and phenomena of electroma					
	- Steady-state sinusoidal description of electromagnetic	fields and waves				
	- Useful microwave network parameters					
	- Transmission lines and basic results from transmission line theory					
	- Plane wave propagation, superposition, reflection and refraction					
	- General theory of waveguides					
	- Most important types of waveguides and their properties Radiation and bacic antenna parameters					
	- Radiation and basic antenna parameters					
	- Most important types of antennas and their properties					
	- Numerical techniques and CAD tools for waveguide and antenna design					
	- Fundamentals of Electromagnetic Compatibility					
	- Coupling mechanisms and countermeasures					
	- Shielding, grounding, filtering					
	- Standards and regulations					
	- EMC measurement techniques					
Skills	Students know how to apply various methods and mod	lels for characterization and choice of	f waveguides and	l antennas. They a		
	able to assess and qualify their basic electromagnetic properties. They can apply results and strategies from the field of					
	Electromagnetic Compatibilty to the development of ele	ctrical components and systems.				
Personal Competence						
Social Competence	Students are able to work together on subject related	tasks in small groups. They are able	to present their	results effectively		
	English (e.g. during small group exercises).					
Autonomy	Students are capable to gather information from sub	iect related professional publication	s and relate tha	t information to t		
hatehenny	context of the lecture. They are able to make a conne					
	other lectures (e.g. theory of electromagnetic fields, fu					
	problems and physical effects in English.		physics, mey c			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70					
Credit points						
Course achievement						
Examination	Oral exam					
Examination duration and	45 min					
scale						
-	General Engineering Science (German program, 7 seme		ering: Elective Co	mpulsory		
Following Curricula	5 5 .	-				
	Engineering Science: Specialisation Electrical Engineeri					
	Aircraft Systems Engineering: Core Qualification: Elective					
	Mechatronics: Specialisation System Design: Elective Co	ompulsory				

	Course L1669: Introduction t	o Waveguides, Antennas, and Electromagnetic Compatibility
CP       4         Workload in Hours       Independent Study Time 78, Study Time in Lecture 42         Lecturer       Prof. Christian Schuster         Language       DE/EN         Cycte       555         Content       This course is intended as an introduction to the topics of wave propagation, guiding, sending, and receiving as well         Electromagnetic Compatibility (EMC). It will be useful for engineers that face the technical challenge of transmitting high freque         / high bandwidth data in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of wave propagat         and Electromagnetic Compatibility will be introduced and discussed.         Topics:       - Fundamental properties and phenomena of electrical circuits         - 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, syueproposition, reflection and refraction       - General theory of waveguides and their properties         - Most important types of antennas and their properties       - Numerical techniques and CAD tools for waveguide and antenna design         - Numerical techniques and CAD tools for waveguide and antenna design       - Numerical techniques         - Steady-state techniques       - Steady-state requilations         - Budatis and requaluations       - EMC measurement t	Тур	Lecture
Workload in Hours         Independent Study Time 78, Study Time in Lecture 42.           Lecture         Prof. Christian Schuster           Cycle         ScSe           Content         This course is intended as an introduction to the topics of wave propagation, guiding, sending, and receiving as well Electromagnetic Compatibility (EM). It will be useful for engineers that face the technical challenge of transmitting high frequence / high bandwidth data in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of wave propagat and Electromagnetic Compatibility will be introduced and discussed.           Topics:         - Fundamental properties and phenomena of electrical circuits           - Steady-state sinusoidal analysis of electrical circuits         - Steady-state sinusoidal analysis of electromagnetic fields and waves           - Useful microwave network parameters         - Transmission line theory           - Plane wave propagation, superposition, reflection and refraction         - General theory of waveguides and their properties           - Most important types of macensa and their properties         - Radiation and basic antenna parameters           - Most important types of macensa and their properties         - Numerical techniques and CAD tools for waveguide and antenna design           - Fundamentals of Electromagnetic Compatibility         - Coupling mechanisms and countermeasures           - Shielding, grounding, fittering         - Standards and regulations           - ElkC measurement techniques         - Shielding, grou		3
Lecture       Prof. Christian Schuster         Language       DE/EN         Content       This course is intended as an introduction to the topics of wave propagation, guiding, sending, and receiving as well         Electromagnetic Compatibility (EMC). It will be useful for engineers that face the technical challenge of transmitting high frequee / high bandwitch data in e.g. medical, automotive, or avoine applications. Both circuit and field concepts of wave propagat and Electromagnetic Compatibility will be introduced and discussed.         Topics:       - Fundamental properties and phenomena of electrical circuits         - Steady-state sinusoidal description of electronagnetic fields and waves         - Steady-state sinusoidal description of electronagnetic fields and waves         - Useful microwave network parameters         - Transmission lines and basic results from transmission line theory         - Bane wave propagation, superposition, reflection and refraction         - General theory of waveguides         - Nost important types of antennas and their properties         - Numerical techniques and CAD tools for waveguide and antenna design         - Fundamental orgunations         - EMC measurement techniques         - Sheiding, grounding, filtering         - Stady-state sinusoidal angles between set in the properties         - Radiation and basic results from transmission line theory         - Bane wave propagation, Superposition, reflection and refraction <t< th=""><th>CP</th><th>4</th></t<>	CP	4
Language       DE/EN         Content       This course is intended as an introduction to the topics of wave propagation, guiding, sending, and receiving as well         Electromagnetic Compatibility (EMC). It will be useful for engineers that face the technical challenge of transmitting high freque         / high bandwidth data in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of wave propagat and Electromagnetic Compatibility will be introduced and discussed.         Topics:       -         - Fundamental properties and phenomena of electrical circuits         - Steady-state sinusoidal analysis of electrical circuits         - 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 anterna parameters         - Most important types of antennas and their properties         - Radiation and basic anterna parameters         - Steiding, motioning, filtering         - Gougning mechanisms and countermeasures         - Shielding, grounding, filtering         - Standards and toguidons         - EMC measurement techniques         - Standards and regulations         - EMC measurement techniques <th>Workload in Hours</th> <th>Independent Study Time 78, Study Time in Lecture 42</th>	Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Cycle         SoSe           Content         This course is intended as an introduction to the topics of wave propagation, guiding, sending, and receiving as well           Electromagnetic Compatibility (EMC). It will be useful for engineers that face the technical challenge of transmitting high freque           / high bandwidth data in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of wave propagat           and Electromagnetic Compatibility will be introduced and discussed.           Topics:           - Fundamental properties and phenomena of electrical circuits           - Steady-state sinusoidal analysis of electronagnetic fields and waves           - Steady-state sinusoidal description of electromagnetic fields and waves           - Useful microwave network parameters           - Transmission lines and basic results from transmission line theory           - Plane wave propagation. superposition, reflection and refraction           - General theory of waveguides           - Most important types of antennas and their properties           - Radiation and basic antenna parameters           - Most important types of antennas and countermeasures           - Numerical techniques and Color for waveguide and antenna design           - Fundamentals of Electromagnetic Compastibility           - Coupling mechanisms and countermeasures           - Shielding, grounding, filtering           - Standards and reguidations		
Content       This course is intended as an introduction to the topics of wave propagation, guiding, sending, and receiving as well         Electromagnetic Compatibility (EMC). It will be useful for engineers that face the technical challenge of transmitting high frequee         / high bandwidth data in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of wave propagat and Electromagnetic Compatibility will be introduced and discussed.         Topics:       - Fundamental properties and phenomena of electrical circuits         - Steady-state sinusoidal analysis of electrical circuits         - Steady-state sinusoidal description of electromagnetic fields and waves         - Useful microwave network parameters         - Transmission lines and basic results from transmission line theory         - Plane wave propagation, superposition, reflection and refraction         - General theory of waveguides         - Most important types of waveguides and their properties         - Radiation and basic antenna parameters         - Numerical techniques and CAD tools for waveguide and antenna design         - Fundamentals of Electromagnetic Compatibility         - Coupling mechanisms and neuromesures         - Shielding, grounding, filtering         - Standards and regulations         - EMC measurement techniques            - Literature            - Zinke, Brunswig, "Hochfrequenztechnik 1", Springer (1999)	Language	DE/EN
Electromagnetic Compatibility (EMC). It will be useful for engineers that face the technical challenge of transmitting high freques         / high bandwidth data in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of wave propagat         and Electromagnetic Compatibility will be introduced and discussed.         Topics:         - Fundamental properties and phenomena of electrical circuits         - Steady-state sinusoidal analysis of electrical circuits         - Steady-state sinusoidal description of electromagnetic fields and waves         - Steady-state sinusoidal description of electromagnetic fields and waves         - Steady-state sinusoidal description of electromagnetic fields and waves         - Useful microwave network parameters         - Transmission lines and basic results from transmission line theory         - Plane wave propagation, superposition, reflection and refraction         - General theory of waveguides         - Most important types of antennas and their properties         - Numerical techniques and CAD tools for waveguide and antenna design         - Fundamental of Electromagnetic Compatibility         - Coupling mechanisms and ountermeasures         - Standards and regulations         - Bude metal conding, filtering         - Standards and regulations         - Bude metal condingues         - Shedding, grounding, filtering         - Standards and regulations<	Cycle	SoSe
<ul> <li>J. Detlefsen, U. Siart, "Grundlagen der Hochfrequenztechnik", Oldenbourg (2012)</li> <li>D. M. Pozar, "Microwave Engineering", Wiley (2011)</li> <li>Y. Huang, K. Boyle, "Antenna: From Theory to Practice", Wiley (2008)</li> </ul>		This course is intended as an introduction to the topics of wave propagation, guiding, sending, and receiving as well as Electromagnetic Compatibility (EMC). It will be useful for engineers that face the technical challenge of transmitting high frequency / high bandwidth data in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of wave propagation and Electromagnetic Compatibility will be introduced and discussed. Topics: - Fundamental properties and phenomena of electrical circuits - Steady-state sinusoidal analysis of electrical circuits - Steady-state sinusoidal analysis of electromagnetic fields and waves - Steady-state sinusoidal description of electromagnetic fields and waves - Useful microwave network parameters - Transmission lines and basic results from transmission line theory - Plane wave propagation, superposition, reflection and refraction - General theory of waveguides - Most important types of averguides and their properties - Radiation and basic antenna parameters - Numerical techniques and CAD tools for waveguide and antenna design - Fundamentals of Electromagnetic Compatibility - Coupling mechanisms and countermeasures - Shielding, grounding, filtering - Standards and regulations
- D. M. Pozar, "Microwave Engineering", Wiley (2011) - Y. Huang, K. Boyle, "Antenna: From Theory to Practice", Wiley (2008)	Literature	- Zinke, Brunswig, "Hochfrequenztechnik 1", Springer (1999)
- Y. Huang, K. Boyle, "Antenna: From Theory to Practice", Wiley (2008)		- J. Detlefsen, U. Siart, "Grundlagen der Hochfrequenztechnik", Oldenbourg (2012)
		- D. M. Pozar, "Microwave Engineering", Wiley (2011)
- H. Ott, "Electromagnetic Compatibility Engineering", Wiley (2009)		- 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)		- A. Schwab, W. Kürner, "Elektromagnetische Verträglichkeit", Springer (2007)

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

Courses				
Title		Тур	Hrs/wk	СР
Machine Learning and Data Mining		Lecture	2	4
Machine Learning and Data Mining	(L0510)	Recitation Section (small)	2	2
Module Responsible	NN			
Admission Requirements	None			
Recommended Previous Knowledge	Calculus			
	<ul> <li>Stochastics</li> </ul>			
Educational Objectives	After taking part successfully, students h	ave reached the following learning results		
Professional Competence				
Skills	can be improved by ensemble learning, and they can summarize how this influences computational learning theory. Algorithms reinforcement learning can also be explained by students. Student derive decision trees and, in turn, propositional rule sets from simple and static data tables and are able to name explain basic optimization techniques. They present and apply the basic idea of first-order inductive leaning. Students apply BME, MAP, ML, and EM algorithms for learning parameters of Bayesian networks and compare the different algorithms. They a know how to carry out Gaussian mixture learning. They can contrast kNN classifiers, neural networks, and support ver machines, and name their basic application areas and algorithmic properties. Students can describe basic clustering techniques, e.g., k-me clustering and nearest neighbor classification. They can distinguish various ensemble learning techniques and compare different goals of those techniques.			
Personal Competence				
Social Competence				
Autonomy				
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	90 minutes			
scale				
Assignment for the	Computer Science: Specialisation II: Inte	ligence Engineering: Elective Compulsory		
Following Curricula		ng: Specialisation II. Information Technology: Elec	tive Compulsory	
	Mechatronics: Technical Complementary			
	Mechatronics: Specialisation System Des			
	Mechatronics: Specialisation Intelligent S Theoretical Mechanical Engineering: Spe	ystems and Robotics: Elective Compulsory		
	LIPOPROTICAL MOCHANICAL Engineering: Spo			

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

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

Courses						
Title				Turn	Hrs/wk	СР
Flight Control Law Design and Appl	ication (L2448)			Typ Lecture	2	4
Flight Control Law Design and Appl				Project-/problem-based Learning		2
Module Responsible	Prof. Frank Thielecke					
Admission Requirements	None					
<b>Recommended Previous</b>	Basic knowledge in:					
Knowledge	* mathematics (linear	algebra and ordinary	y differential equations	;)		
	* control systems (trai	nsfer functions and s	tate space representat	tion)		
	* mechanics (rigid-boo	dy kinetics)				
	* flight mechanics					
Educational Objectives	After taking part succe	essfully, students hav	ve reached the followin	ng learning results		
Professional Competence						
Knowledge	Students are able to:					
	* describe and unders	tand flight dynamics	models for control tas	ks		
	* assess handling qua	lities and understand	the need for augment	tation through control systems		
	* identify fundamenta	l performance limitat	tions of control laws			
Skills	Students are able to:					
	* design model-based	control laws for stab	ility augmentation			
	* design model-based	flight control laws				
	* assess robustness a	nd performance of co	ontrol laws			
Personal Competence						
Social Competence	Students are able to:					
	* design control laws i	n groups as well as d	discuss the requiremen	ts and results		
Autonomy	Students are able to:					
	* reflect on the contents of lectures and extend their knowledge through literature research					
	* solve control design tasks with software tools					
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56					
Credit points						
Course achievement	Compulsory Bonus Yes None	Form Attestation		r Vorlesung vermittelten H eitenden Projekt direkt auf das		
Examination	Written exam					
Examination duration and scale	60 min					
	Aircraft Systems Engir	neering: Core Qualific	cation: Elective Compu	lsory		
Following Curricula			n: Elective Compulsory			
	Mechatronics: Technical Complementary Course: Elective Compulsory					
		÷ • ·		ms Engineering: Elective Compu ms Engineering: Elective Compu	-	

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

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

Courses					
Title		т	ур	Hrs/wk	СР
Lab Applied Dynamics (L1631)		P	ractical Course	2	2
Applied Dynamics (L1630)		L	ecture	4	4
Module Responsible	Prof. Robert Seifried				
Admission Requirements	None				
Recommended Previous	Mathematics I, II, III, Mechanics I, II, II	I, IV			
Knowledge	Numerical Treatment of Ordinary Diff	erential Equations			
Educational Objectives	After taking part successfully, studen	ts have reached the following	learning results		
Professional Competence					
Knowledge	Students can represent the most imp and have a good understanding of the	-		pletion of the module	Technical dynami
Skills	Students are able				
	+ to think holistically				
	+ to independently, securly and critically analyze and optimize basic problems of the dynamics of rigid and flexible multibod systems				
	+ to describe dynamics problems ma	thematically			
	+ to investigate dynamics problems b	ooth experimentally and nume	erically		
Personal Competence					
Social Competence	Students are able to				
	+ solve problems in heterogeneous g	roups and to document the co	orresponding results.		
Autonomy	Students are able to				
	+ assess their knowledge by means of exercises and experiments.				
	+ acquaint themselves with the nece	ssary knowledge to solve rese	earch oriented tasks.		
Workload in Hours	Independent Study Time 96, Study Ti	me in Lecture 84			
Credit points	6				
Course achievement	Compulsory Bonus Form Yes None Subject the practical work	Description pretical and Versuche Fachle	abor		
Examination	Written exam				
Examination duration and	90 min				
scale					
Assignment for the	Mechatronics: Specialisation Intelliger	nt Systems and Robotics: Elec	tive Compulsory		
Following Curricula	Mechatronics: Specialisation System I	Design: Elective Compulsory			
	Theoretical Mechanical Engineering: (	Core Qualification: Compulsor	v		

Course L1631: Lab Applied D	ynamics
Тур	Practical Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Marc-André Pick
Language	DE
Cycle	SoSe
Content	Practical exercises are performed in groups. The examples are taken from different areas of applied dynamics, such as numerical simulation, experimental validation and experimental vibration analysis.
Literature	Schiehlen, W.; Eberhard, P.: Technische Dynamik, 4. Auflage, Vieweg+Teubner: Wiesbaden, 2014.

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

Module M1173: Appli	ed Statistics			
Courses				
Title	Тур		Hrs/wk	СР
Applied Statistics (L1584)	Lectu	re	2	3
Applied Statistics (L1586)	Project	ct-/problem-based Learning	2	2
Applied Statistics (L1585)	Recita	ation Section (small)	1	1
Module Responsible	Prof. Michael Morlock			
Admission Requirements	None			
<b>Recommended Previous</b>	Basic knowledge of statistical methods			
Knowledge				
Educational Objectives	After taking part successfully, students have reached the following lear	rning results		
Professional Competence				
Knowledge	Students can explain the statistical methods and the conditions of thei	r use.		
Skills	Students are able to use the statistics program to solve statistics problems and to interpret and depict the results			
Personal Competence				
Social Competence	Team Work, joined presentation of results			
Autonomy	To understand and interpret the question and solve			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and	90 minutes, 28 questions			
scale				
Assignment for the	Mechanical Engineering and Management: Specialisation Management	: Elective Compulsory		
Following Curricula	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective	Compulsory		
	Mechatronics: Specialisation System Design: Elective Compulsory			
	Mechatronics: Core Qualification: Elective Compulsory			
	Biomedical Engineering: Core Qualification: Compulsory			
	Product Development, Materials and Production: Core Qualification: Ele	ective Compulsory		
	Theoretical Mechanical Engineering: Specialisation Bio- and Medical Te	chnology: Elective Compul	sory	

Course L1584: Applied Statis	tics
Тур	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock
Language	DE/EN
Cycle	WiSe
Content	The goal is to introduce students to the basic statistical methods and their application to simple problems. The topics include:
	Chi square test
	Simple regression and correlation
	Multiple regression and correlation
	One way analysis of variance
	Two way analysis of variance
	Discriminant analysis
	Analysis of categorial data
	Chossing the appropriate statistical method
	Determining critical sample sizes
Literature	Applied Regression Analysis and Multivariable Methods, 3rd Edition, David G. Kleinbaum Emory University, Lawrence L. Kupper
	University of North Carolina at Chapel Hill, Keith E. Muller University of North Carolina at Chapel Hill, Azhar Nizam Emory University,
	Published by Duxbury Press, CB © 1998, ISBN/ISSN: 0-534-20910-6

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

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

Courses					
Title		Тур	Hrs/wk	СР	
Formulas and Vehicles - Dynamics	and Control of Autonomous Vehicles (L2869)	Integrated Lecture	1	1	
Formulas and Vehicles - Introduction	n into Mobile Underwater Robotics (L1981)	Project-/problem-based Learning	4	5	
Module Responsible	Prof. Robert Seifried				
Admission Requirements	None				
<b>Recommended Previous</b>	Mechanics IV, Applied Dynamics or Robotics				
Knowledge	Numerical Treatment of Ordinary Differential Equati	ons			
	Control Systems Theory and Design				
Educational Objectives	After taking part successfully, students have reache	d the following learning results			
Professional Competence					
Knowledge	After successful completion of the module studen areas of multibody dynamics and robotics	s demonstrate deeper knowledge and und	erstanding in	selected applicati	
Skills	Students are able				
	+ to think holistically				
	+ to independently, securly and critically analyze systems	and optimize basic problems of the dynam	ics of rigid a	nd flexible multibo	
	+ to describe dynamics problems mathematically				
	+ to implement dynamical problems on hardware				
Personal Competence					
Social Competence	Students are able to				
	+ solve problems in heterogeneous groups and to d	ocument the corresponding results and prese	ent them		
Autonomy	Students are able to				
	+ assess their knowledge by means of exercises and projects.				
	+ acquaint themselves with the necessary knowled	ge to solve research oriented tasks.			
Workload in Hours	Independent Study Time 110, Study Time in Lecture	70			
Credit points	6				
Course achievement	None				
Examination	Presentation				
Examination duration and	ТВА				
scale					
	Mechatronics: Specialisation Intelligent Systems and				
Following Curricula	Mechatronics: Specialisation System Design: Electiv				
	Mechatronics: Core Qualification: Elective Compulso Theoretical Mechanical Engineering: Core Qualificat	•			

Course L2869: Formulas and	urse L2869: Formulas and Vehicles - Dynamics and Control of Autonomous Vehicles		
Тур	Integrated Lecture		
Hrs/wk	1		
CP	1		
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14		
Lecturer	Prof. Robert Seifried, Daniel-André Dücker		
Language	DE		
Cycle	WiSe		
Content			
Literature			

Course L1981: Formulas and	Vehicles - Introduction into Mobile Underwater Robotics
Тур	Project-/problem-based Learning
Hrs/wk	4
CP	5
Workload in Hours	Independent Study Time 94, Study Time in Lecture 56
Lecturer	Prof. Robert Seifried, Daniel-André Dücker
Language	DE
Cycle	WiSe
Content	
Literature	Seifried, R.: Dynamics of underactuated multibody systems, Springer, 2014
	Popp, K.; Schiehlen, W.: Ground vehicle dynamics, Springer, 2010

Module M0832: Advar	nced Topics in Control			
Courses				
Title		Тур	Hrs/wk	СР
Advanced Topics in Control (L0661)	)	Lecture	2	3
Advanced Topics in Control (L0662)	)	Recitation Section (small)	2	3
Module Responsible	NN			
Admission Requirements	None			
<b>Recommended Previous</b>	H-infinity optimal control, mixed-sensitivity design, linear matrix	inequalities		
Knowledge				
Educational Objectives	After taking part successfully, students have reached the followi	ing learning results		
Professional Competence				
Knowledge Skills	<ul> <li>Students can explain the advantages and shortcomings o</li> <li>They can explain the representation of nonlinear systems</li> <li>They can explain how stability and performance condition</li> <li>They can explain how gridding techniques can be used to</li> <li>They are familiar with polytopic and LFT representatio associated with each of these model structures</li> <li>Students can explain how graph theoretic concepts ar systems</li> <li>They can explain the convergence properties of first orde</li> <li>They can explain analysis and synthesis conditions for for</li> <li>Students can construct LPV models of nonlinear plan controllers; they can do this using polytopic, LFT or gener</li> <li>They can use standard software tools (Matlab robust cont</li> <li>Students can design distributed formation controllers fo tools provided</li> </ul>	in the form of quasi-LPV systems for LPV systems can be forn o solve analysis and synthesis ins of LPV systems and som re used to represent the co r consensus protocols rmation control loops involvin- odel Predictive Control (MPC) hts and carry out a mixed- ral LPV models rrol toolbox) for these tasks	sensitivity design	' systems synthesis techniqu oology of multiage V agent models n of gain-schedule
Personal Competence	Students can design MPC controllers for linear and non-lin	near systems using Matlab too	bls	
	Students can work in small groups and arrive at joint results.			
		ture notes, literature, softwa	re documentatior	n) and use it to sol
	given problems.			
	Independent Study Time 124, Study Time in Lecture 56			
Credit points				
Course achievement				
Examination	Oral exam			
Examination duration and scale	30 min			
Assignment for the	Electrical Engineering: Specialisation Control and Power Systems	s Engineering: Elective Comp	ulsory	
Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Comp	ulsory		
	Aeronautics: Core Qualification: Elective Compulsory			
	Mechatronics: Specialisation Intelligent Systems and Robotics: E	lective Compulsory		
	Mechatronics: Specialisation System Design: Elective Compulsor	ry		
	Mechatronics: Core Qualification: Elective Compulsory			
	Biomedical Engineering: Specialisation Implants and Endoprosth	eses: Elective Compulsory		
	Biomedical Engineering: Specialisation Medical Technology and	Control Theory: Elective Com	pulsory	
	Biomedical Engineering: Specialisation Management and Busine	ss Administration: Elective Co	ompulsory	
	Biomedical Engineering: Specialisation Artificial Organs and Reg	enerative Medicine: Elective	Compulsory	
	Theoretical Mechanical Engineering: Specialisation Robotics and	Computer Science: Elective	Compulsory	

Tvn	Lecture
Hrs/wk	
CP	
	Independent Study Time 62, Study Time in Lecture 28
Lecturer	
Language	
Cycle	WiSe
Content	Linear Parameter-Varying (LPV) Gain Scheduling
	- Linearizing gain scheduling, hidden coupling
	- Jacobian linearization vs. quasi-LPV models
	- Stability and induced L2 norm of LPV systems
	- Synthesis of LPV controllers based on the two-sided projection lemma
	- Simplifications: controller synthesis for polytopic and LFT models
	- Experimental identification of LPV models
	- Controller synthesis based on input/output models
	- Applications: LPV torque vectoring for electric vehicles, LPV control of a robotic manipulator
	Control of Multi-Agent Systems
	- Communication graphs
	- Spectral properties of the graph Laplacian
	- First and second order consensus protocols
	- Formation control, stability and performance
	- LPV models for agents subject to nonholonomic constraints
	- Application: formation control for a team of quadrotor helicopters
	Linear and Nonlinear Model Predictive Control based on LMIs
Literature	Werner, H., Lecture Notes "Advanced Topics in Control"
	<ul> <li>Selection of relevant research papers made available as pdf documents via StudIP</li> </ul>

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

Courses				
Title		Тур	Hrs/wk	СР
Image Processing (L2443)		Lecture	2	4
Image Processing (L2444)		Recitation Section (small)	2	2
Module Responsible	Prof. Tobias Knopp			
Admission Requirements	None			
<b>Recommended Previous</b>	Signal and Systems			
Knowledge				
Educational Objectives	After taking part successfully, students have i	eached the following learning results		
Professional Competence				
Knowledge	The students know about			
	<ul> <li>visual perception</li> </ul>			
	<ul> <li>multidimensional signal processing</li> </ul>			
	<ul> <li>sampling and sampling theorem</li> </ul>			
	filtering			
	<ul> <li>image enhancement</li> </ul>			
	edge detection			
	<ul> <li>multi-resolution procedures: Gauss and</li> </ul>	Laplace pyramid, wavelets		
	image compression			
	<ul> <li>image segmentation</li> </ul>			
	<ul> <li>morphological image processing</li> </ul>			
Skills	The students can			
	<ul> <li>analyze, process, and improve multidin</li> </ul>	ancional imago data		
	<ul> <li>implement simple compression algorith</li> </ul>			
	<ul> <li>design custom filters for specific applic</li> </ul>			
	g			
Personal Competence				
Social Competence		independently and in teams. They can exchar	ige ideas with eacl	n other and use th
	individual strengths to solve the problem.			
Autonomy	Students are able to independently investigat	e a complex problem and assess which compe	tencies are require	d to solve it.
Workload in Hours	Independent Study Time 124, Study Time in L	ecture 56		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and	90 min			
scale				
Assignment for the	Data Science: Core Qualification: Elective Con	npulsory		
Following Curricula	Data Science: Specialisation I. Mathematics/C	omputer Science: Elective Compulsory		
	Data Science: Specialisation II. Computer Scie	nce: Elective Compulsory		
	Data Science: Specialisation IV. Special Focus	Area: Elective Compulsory		
	Electrical Engineering: Specialisation Informat	ion and Communication Systems: Elective Con	npulsory	
	Electrical Engineering: Specialisation Medical	Technology: Elective Compulsory		
		Specialisation Secure and Dependable IT S	Systems, Focus S	oftware and Sig
	Processing: Elective Compulsory			
		ecialisation Communication Systems, Focus Sig		ective Compulsory
		pecialisation II. Information Technology: Election	ve Compulsory	
	Mechatronics: Specialisation Intelligent System			
	Mechatronics: Specialisation System Design: I			
	Mechatronics: Core Qualification: Elective Cor			
		ation Communication and Signal Processing: Ele		
	Theoretical Mechanical Engineering: Specialis	ation Robotics and Computer Science: Elective	compulsory	

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

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

Courses				
			there deale	<u></u>
Title Integrated Circuit Design (L0691)		<b>Typ</b> Lecture	Hrs/wk 3	<b>CP</b> 4
Integrated Circuit Design (L0998)		Recitation Section (small)	1	2
Module Responsible	NN			
Admission Requirements	None			
<b>Recommended Previous</b>	Basic knowledge of (solid-state) physics and math	nematics.		
Knowledge	Knowledge in fundamentals of electrical engineer	ing and electrical networks.		
Educational Objections				
Educational Objectives	After taking part successfully, students have reac	ned the following learning results		
Professional Competence Knowledge				
Knowledge	<ul> <li>Students can explain basic concep</li> </ul>	ts of electron transport in semico	nductor devices	(energy ban
	generation/recombination, carrier concentr	rations, drift and diffusion current densities,	semiconductor de	vice equations).
	<ul> <li>Students are able to explain functional print</li> </ul>	nciples of pn-diodes, MOS capacitors, and MO	OSFETs using ener	gy band diagram
	<ul> <li>Students can present and discuss current-ways</li> </ul>	voltage relationships and small-signal equiva	alent circuits of th	ese devices.
	<ul> <li>Students can explain the physics and current</li> </ul>	ent-voltage behavior transistors based on ch	arged carrier flow	
	<ul> <li>Students are able to explain the basic cond</li> </ul>	epts for static and dynamic logic gates for i	ntegrated circuits	
	<ul> <li>Students can exemplify approaches for low</li> </ul>	power consumption on the device and circu	uit level	
	<ul> <li>Students can describe the potential and lin</li> </ul>	nitations of analytical expression for device	and circuit analys	s.
	<ul> <li>Students can explain characterization tech</li> </ul>	niques for MOS devices.		
Skills				
	Students can qualitatively construct energy	, , , , ,		<i>.</i>
	<ul> <li>Students are able to qualitatively deterr</li> </ul>	nine electric field, carrier concentrations,	and charge flow	from energy ba
	diagrams.			
	Students can understand scientific publicat			
	• Students can calculate the dimensions of N		operties	
	Students can design complex electronic cir			
	<ul> <li>Students know procedure for optimization</li> </ul>	regarding high performance and low power	consumption	
Personal Competence				
Social Competence				
	Students can team up with other experts in			
	<ul> <li>Students are able to work by their own or i</li> </ul>			stions.
	<ul> <li>Students have the ability to critically quest</li> </ul>	ion the value of their contributions to workir	ng groups.	
Autonomy				
Autonomy	<ul> <li>Students are able to assess their knowledg</li> </ul>	e in a realistic manner.		
	<ul> <li>Students are able to define their personal a</li> </ul>	approaches to solve challenging problems		
Workload in U.	Indonondont Study Time 124, Study Time in Least	170 56		
Credit points	Independent Study Time 124, Study Time in Lecto			
Course achievement	None			
Examination	Written exam			
Examination duration and	90 min			
scale				
Assignment for the	Electrical Engineering: Specialisation Nanoelectro	nics and Microsystems Technology: Elective	Compulsory	
Following Curricula	International Management and Engineering: Spec			
-	Mechanical Engineering and Management: Specia		-	
	Mechatronics: Specialisation System Design: Elec	tive Compulsory		
	Mechatronics: Core Qualification: Elective Compu	lsory		
	Microelectronics and Microsystems: Core Qualifica	ation: Elective Compulsory		

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

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

Module M1596: Engin	eering Haptic S	ystems			
Courses					
Title			Тур	Hrs/wk	СР
Haptic Technology for Human-Machine-Interfaces (HMI) (L2439)		Lecture	4	3	
Haptic Technology for Human-Mach	hine-Interfaces (HMI) (L28	59)	Project-/problem-bas	ed Learning 2	3
Module Responsible	Prof. Thorsten Kern				
Admission Requirements	None				
<b>Recommended Previous</b>	We recommend knowl	edge in the areas of	general engineering sciences, mechatro	nics and/or control-engi	neering. However a
Knowledge	neighbouring technica	l areas like mechanic	al-engineering or even process-engineers	s can join the course and	will be introduced i
	the content properly.				
Educational Objectives	After taking part succe	essfully, students hav	e reached the following learning results		
Professional Competence					
Knowledge	scratch. It covers a ph with consideration on	nysiological part, an a control theory for n	in methods and design-requirements to actuator development part, and goes up nore complex projects. Beside design-re in that field with many examples. This	to fundamentals of hig elated topics, it gives a	her system integrat valuable overview
	Motivation and application of haptic systems				
	Haptic perception				
	The role of the user in direct system interaction				
	Development of haptic systems				
	Identification of requirements				
	System-structure and control				
	Kinematic fundamentals				
	Actuation & Sensors technology for haptic applications				
	Control and system-design aspects				
	Fundamental co	onsiderations in simul	ating haptics		
Skills	towards the design a	nd application of ac	be developed to apply the general end tive haptic systems. The resulting comp dustry and consumer-device-developmer	petencies will open an	
Personal Competence					
Social Competence	application of "haptics	s". It teaches method	cs of a general design for human-mach Is to execute user-studies, judge on use ling with subjective perception.		
Autonomy	Independent design-ca	apability of haptic sys	tems, general competency in engineering	g from a design-perspect	tive
Workload in Hours	Independent Study Tin	ne 96, Study Time in	Lecture 84		
Credit points	6				
Course achievement	CompulsoryBonusYes20 %	Form Subject theoretica practical work	Description andDurchführung von Laborversuche	en	
Examination	Subject theoretical and	d practical work			
Examination duration and	30 min				
scale					
Assignment for the	Mechatronics: Speciali	sation Intelligent Syst	tems and Robotics: Elective Compulsory		
÷	Mechatronics: Speciali				
-	Mechatronics: Core Qu				
	Theoretical Mechanica	l Enginopring: Spocia	lisation Product Development and Produc	tion: Elective Compulso	rv.

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

· · · ·		
Тур	ject-/problem-based Learning	
Hrs/wk	2	
CP	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Lecturer	Prof. Thorsten Kern	
Language	EN	
Cycle	WiSe	
Content	See interlocking course	
Literature	See interlocking course	

Module M1552: Adva	nced Machine Learning			
	·······			
Courses				
Title		Тур	Hrs/wk	СР
Advanced Machine Learning (L2322		Lecture	2	3
Advanced Machine Learning (L2323	3)	Recitation Section (small)	2	3
Module Responsible	Dr. Jens-Peter Zemke			
Admission Requirements	None			
<b>Recommended Previous</b>	1. Mathematics I-III			
Knowledge	2. Numerical Mathematics 1/ Numerics			
	3. Programming skills, preferably in Python			
-	After taking part successfully, students have read	ched the following learning results		
Professional Competence	Chudanta and able to anno atom and the Maria			
Knowledge	Students are able to name, state and classify sta can assess the difficulties of different neural netw		esponding mathe	matical basics. They
Skille	Students are able to implement, understand, and		ural notworks	
Personal Competence	Students are able to implement, understand, and	, tailored to the field of application, apply he	urai networks.	
Social Competence	Students can			
Social competence				
	<ul> <li>develop and document joint solutions in sr</li> </ul>	nall teams;		
	<ul> <li>form groups to further develop the ideas and transfer them to other areas of applicability;</li> </ul>			
	<ul> <li>form a team to develop, build, and advance</li> </ul>	e a software library.		
Autonomy	Students are able to			
	<ul> <li>correctly assess the time and effort of self-</li> </ul>	-defined work;		
	<ul> <li>assess whether the supporting theoretical</li> </ul>		dividually or in a	team;
	<ul> <li>define test problems for testing and expan</li> </ul>	ding the methods;		
	<ul> <li>assess their individual progess and, if nece</li> </ul>	essary, to ask questions and seek help.		
Workload in Hours	Independent Study Time 124, Study Time in Lect	ure 56		
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and	25 min			
scale				
Assignment for the	Computer Science: Specialisation III. Mathematics	s: Elective Compulsory		
Following Curricula	Data Science: Core Qualification: Compulsory			
	Computer Science in Engineering: Specialisation			
	Mechatronics: Specialisation Intelligent Systems			
	Mechatronics: Specialisation System Design: Elec			
	Mechatronics: Core Qualification: Elective Compu	•		
	Technomathematics: Specialisation I. Mathematic			
	Theoretical Mechanical Engineering: Specialisation	in Robotics and Computer Science: Elective C	ompulsory	

Course L2322: Advanced Ma	chine Learning	
Тур	Lecture	
Hrs/wk		
CP	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Lecturer	Dr. Jens-Peter Zemke	
Language	DE/EN	
Cycle	WiSe	
Content	<ol> <li>Basics: analogy; layout of neural nets, universal approximation, NP-completeness</li> <li>Feedforward nets: backpropagation, variants of Stochastistic Gradients</li> <li>Deep Learning: problems and solution strategies</li> <li>Deep Belief Networks: energy based models, Contrastive Divergence</li> <li>CNN: idea, layout, FFT and Winograds algorithms, implementation details</li> <li>RNN: idea, relation to neural ODEs</li> <li>Standard libraries: Tensorflow, Keras, PyTorch</li> <li>Recent trends</li> </ol>	
Literature	<ol> <li>Skript</li> <li>Online-Werke:         <ul> <li>http://neuralnetworksanddeeplearning.com/</li> <li>https://www.deeplearningbook.org/</li> </ul> </li> </ol>	

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

Module M1268: Linea	r and Nonlinear Waves			
Courses				
Title		Тур	Hrs/wk	СР
Linear and Nonlinear Waves (L173	7)	Project-/problem-based Learning	4	6
Module Responsible	Prof. Norbert Hoffmann			
Admission Requirements	None			
<b>Recommended Previous</b>	Calculus, Algebra, Engineering Mechanics, Vibration	5.		
Knowledge				
Educational Objectives	After taking part successfully, students have reache	d the following learning results		
Professional Competence				
Knowledge	Chudents are able to reflect evicting terms and co	aconta in Mayo Machanisa		
	<ul> <li>Students are able to reflect existing terms and co</li> <li>Students are able to identify and express the need</li> </ul>		to	
	• Students are able to identify and express the neer			
Skills	<ul> <li>Chudents are able to apply sylisting research math</li> </ul>	ads and procedures of wave mashanics		
	<ul> <li>Students are able to apply existing research meth</li> <li>Students are able to develop novel research meth</li> </ul>			
	<ul> <li>Students are able to develop hovel research metric</li> </ul>	ous and procedures in wave mechanics.		
Personal Competence				
Social Competence	• Chudanta and an alian analytic data in any			
	Students can reach working results also in groups     Students can present and communicate working			
	<ul> <li>Students can present and communicate work</li> </ul>	ng results also in groups.		
Autonomy				
	Students are able to approach given research task			
	<ul> <li>Studetns are able to identify and follow up novel r</li> </ul>	esearch 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	2 Hours			
scale				
Assignment for the	Mechatronics: Specialisation System Design: Elective	e Compulsory		
Following Curricula	Mechatronics: Core Qualification: Elective Compulso	ГУ		
	Naval Architecture and Ocean Engineering: Core Qua	alification: Elective Compulsory		
	Theoretical Mechanical Engineering: Specialisation N	laritime Technology: Elective Compulsory		
	Theoretical Mechanical Engineering: Specialisation S	imulation Technology: Elective Compulsory		

Course L1737: Linear and Nonlinear Waves		
Тур	Project-/problem-based Learning	
Hrs/wk	4	
CP	6	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56	
Lecturer	Prof. Norbert Hoffmann	
Language	DE/EN	
Cycle	WiSe	
Content	Introduction into the Dynamics of Linear and Nonlinear Waves	
	<ul> <li>Linear Waves <ul> <li>Dispersion</li> <li>Phase and Group Velocity</li> <li>Envelopes</li> <li>Discrete Systems</li> </ul> </li> <li>Nonlinear Waves <ul> <li>Model Equations</li> <li>Solitons, Breathers, Extreme Waves</li> </ul> </li> <li>Water Waves, Ocean Waves <ul> <li>Airy and Stokes</li> <li>Natural Sea State</li> <li>Kinetic Modelling</li> </ul> </li> <li>Other topics</li> </ul>	
Literature	<ul> <li>F.K. Kneubühl: Oscillations and Waves. Springer.</li> <li>G.B. Witham, Linear and Nonlinear Waves. Wiley.</li> <li>C.C. Mei, Theory and Applications of Ocean Surface Waves. World Scientific.</li> <li>L.H. Holthuijsen, Waves in Oceanic and Coastal Waters. Cambridge.</li> <li>And others.</li> </ul>	

Courses				
Title		Тур	Hrs/wk	СР
Mathematical Image Processing (L	.0991)	Lecture	3	4
Mathematical Image Processing (L	.0992)	Recitation Section (small)	1	2
Module Responsible	Prof. Marko Lindner			
Admission Requirements	None			
<b>Recommended Previous</b>				
Knowledge				
	Linear Algebra: eigenvalues, least	squares solution of a linear system		
Educational Objectives	After taking part successfully, students h	ave reached the following learning results		
Professional Competence	1			
Knowledge	Students are able to			
	characterize and compare diffusion			
	explain elementary methods of im			
	<ul> <li>explain methods of image segment</li> <li>sketch and interrelate basic concet</li> </ul>			
	• sketch and interrelate basic conce			
Skills	Students are able to			
	<ul> <li>implement and apply elementary in</li> </ul>	methods of image processing		
	<ul> <li>explain and apply modern method</li> </ul>			
		s or image processing		
Personal Competence				
Social Competence	Students are able to work together i	in heterogeneously composed teams (i.e., team	ns from different	study programs a
	background knowledge) and to explain the	neoretical foundations.		
Autonomy	,			
,		their understanding of complex concepts on their	ir own. They can s	pecify open questio
	precisely and know where to get h			
		nt persistence to be able to work for longer per	iods in a goal-orier	nted manner on ha
	problems.			
Workload in Hours	Independent Study Time 124, Study Time	e in Lecture 56		
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and	20 min			
scale	1			
Assignment for the	Bioprocess Engineering: Specialisation A	- General Bioprocess Engineering: Elective Compu	llsory	
Following Curricula	Computer Science: Specialisation III. Mat	hematics: Elective Compulsory		
	Computer Science in Engineering: Specia	lisation III. Mathematics: Elective Compulsory		
	Interdisciplinary Mathematics: Specialisa	tion Computational Methods in Biomedical Imagin	g: Compulsory	
		ystems and Robotics: Elective Compulsory		
	Mechatronics: Specialisation System Des	5 1 5		
	Mechatronics: Core Qualification: Elective			
	Technomathematics: Specialisation I, Ma	thematics: Elective Compulsory		
		cialisation Robotics and Computer Science: Electiv	e Compulsory	

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

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

Module M0720: Matri	x Algorithms			
Courses				
Title		Тур	Hrs/wk	СР
Matrix Algorithms (L0984)		Lecture	2	3
Matrix Algorithms (L0985)		Recitation Section (small)	2	3
Module Responsible	Dr. Jens-Peter Zemke			
Admission Requirements	None			
Recommended Previous	Mathematics I - III			
Knowledge	Numerical Mathematics 1/ Numerics			
	Basic knowledge of the programming langua	ges Matlab and C		
Educational Objectives	After taking part successfully, students have reach	nd the following learning results		
Professional Competence	After taking part successfully, students have reache	ed the following learning results		
-	Students are able to			
	1. name, state and classify state-of-the-art Kryl		-	ns of the engineerir
	sciences, namely, eigenvalue problems, solu		on;	
	2. state approaches for the solution of matrix e	quations (Sylvester, Lyapunov, Riccati).		
Skills	Students are capable to			
	1. implement and assess basic Krylov subspace	e methods for the solution of eigenvalue	problems linear	systems and mod
	reduction;	e methods for the solution of eigenvalue	problems, intear	Systems, and mot
	<ol> <li>assess methods used in modern software with</li> </ol>	h respect to computing time, stability, an	d domain of appli	icability;
	3. adapt the approaches learned to new, unknow	wn types of problem.		
Barranal Commetance				
Personal Competence Social Competence				
Social Competence				
	develop and document joint solutions in smaller	ll teams;		
	<ul> <li>form groups to further develop the ideas and</li> </ul>		lity;	
	<ul> <li>form a team to develop, build, and advance a</li> </ul>	a software library.		
Autonomy	Students are able to			
	<ul> <li>correctly assess the time and effort of self-dependence</li> </ul>	efined work:		
	<ul> <li>assess whether the supporting theoretical ar</li> </ul>		ndividually or in a	team;
	define test problems for testing and expandi			
	assess their individual progess and, if necess	ary, to ask questions and seek help.		
Workload in Hours	Independent Study Time 124, Study Time in Lecture	e 56		
Credit points				
Course achievement	None			
Examination	Oral exam			
Examination duration and	25 min			
scale				
Assignment for the	Computer Science: Specialisation III. Mathematics:	Elective Compulsory		
Following Curricula	Data Science: Specialisation IV. Special Focus Area:	Elective Compulsory		
	Data Science: Specialisation I. Mathematics: Electiv			
	Mechatronics: Specialisation Intelligent Systems an			
	Mechatronics: Specialisation System Design: Electiv			
	Mechatronics: Core Qualification: Elective Compulse			
	Technomathematics: Specialisation I. Mathematics: Theoretical Mechanical Engineering: Specialisation		201	
	meorecical Mechanical Engineering: Specialisation	Simulation rechnology: Elective Compulso	лу	

Course L0984: Matrix Algorit	hms
Тур	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jens-Peter Zemke
Language	DE/EN
Cycle	WiSe
Content	<ul> <li>Part A: Krylov Subspace Methods:         <ul> <li>Basics (derivation, basis, Ritz, OR, MR)</li> <li>Arnoldi-based methods (Arnoldi, GMRes)</li> <li>Lanczos-based methods (Lanczos, CG, BiCG, QMR, SymmLQ, PvL)</li> <li>Sonneveld-based methods (IDR, BiCGStab, TFQMR, IDR(s))</li> </ul> </li> <li>Part B: Matrix Equations:         <ul> <li>Sylvester Equation</li> <li>Lyapunov Equation</li> <li>Algebraic Riccati Equation</li> </ul> </li> </ul>
Literature	<ol> <li>Skript (224 Seiten)</li> <li>Ergänzend können die folgenden Lehrbücher herangezogen werden:         <ol> <li>Saad, Yousef. Numerical methods for large eigenvalue problems: revised edition. Society for Industrial and Applied Mathematics, 2011.</li> <li>Saad, Yousef. Iterative methods for sparse linear systems. Society for Industrial and Applied Mathematics, 2003.</li> <li>Van der Vorst, Henk A. Iterative Krylov methods for large linear systems. No. 13. Cambridge University Press, 2003.</li> <li>Liesen, Jörg, and Zdenek Strakos. Krylov subspace methods: principles and analysis. Oxford University Press, 2013.</li> </ol> </li> </ol>

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

Courses						
Title		Тур	Hrs/wk	СР		
Methods of Product Development (	_1254)	Lecture	3	3		
Methods of Product Development (		Project-/problem-based Learning	2	3		
Module Responsible	Prof. Dieter Krause					
Admission Requirements	None					
Recommended Previous	Basic knowledge of Integrated product developmen	t and applying CAE systems				
Knowledge						
Educational Objectives	After taking part successfully, students have reache	d the following learning results				
Professional Competence						
Knowledge	After passing the module students are able to:					
	<ul> <li>explain technical terms of design methodology</li> </ul>	IV.				
	<ul> <li>describe essential elements of construction r</li> </ul>					
	describe current problems and the current st		ment.			
Skills	After passing the module students are able to:					
	<ul> <li>select and apply proper construction metho</li> </ul>	ds for non-standardized solutions of problem	ns as well as	adapt new bounda		
	conditions,					
	<ul> <li>solve product development problems with the assistance of a workshop based approach,</li> </ul>					
	<ul> <li>choose and execute appropriate moderation techniques.</li> </ul>					
Personal Competence						
Social Competence	After passing the module students are able to:					
	<ul> <li>prepare and lead team meetings and modera</li> </ul>	ition processes,				
	<ul> <li>work in teams on complex tasks,</li> </ul>					
	<ul> <li>represent problems and solutions and advance</li> </ul>	ce ideas.				
Autonomy	After passing the module students are able to:					
	<ul> <li>give a structured feedback and accept a criti</li> </ul>	cal feedback,				
	• implement the accepted feedback autonomo	us.				
Workload in Hours	Independent Study Time 110, Study Time in Lecture	≥ 70				
Credit points	6					
Course achievement	None					
Examination	Oral exam					
Examination duration and	30 Minuten					
scale						
Assignment for the	Aircraft Systems Engineering: Core Qualification: Ele	ective Compulsory				
Following Curricula	International Management and Engineering: Special		on: Elective C	ompulsory		
	Aeronautics: Core Qualification: Elective Compulsor					
	Mechatronics: Specialisation System Design: Electiv					
	Mechatronics: Core Qualification: Elective Compulso	•				
	Product Development, Materials and Production: Sp		У			
	Product Development, Materials and Production: Sp					
	Product Development, Materials and Production: Sp		_ ·			
	Theoretical Mechanical Engineering: Specialisation	Product Development and Production: Elective	e Compulsory			

Course L1254: Methods of Pr	oduct Development
Тур	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
	Prof. Dieter Krause
Language	
Cycle	
Content	Lecture
	The lecture extends and enhances the learned content of the module "Integrated Product Development and lightweight design
	and is based on the knowledge and skills acquired there.
	Topics of the course include in particular:
	Methods of product development,
	Presentation techniques,
	Industrial Design,
	Design for variety
	Modularization methods,
	Design catalogs,
	Adapted QFD matrix,
	Systematic material selection,
	Assembly oriented design,
	Construction management
	CE mark, declaration of conformity including risk assessment,
	Patents, patent rights, patent monitoring
	<ul> <li>Project management (cost, time, quality) and escalation principles,</li> </ul>
	Development management for mechatronics,
	Technical Supply Chain Management.
	Exercise (PBL)
	In the exercise the content presented in the lecture "Integrated Product Development II" and methods of product development and
	design management will be enhanced.
	Students learn an independently moderated and workshop based approach through industry related practice examples to solvi
	complex and currently existing issues in product development. They will learn the ability to apply important methods of produc
	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 um
	Trainer, Weinheim, Beltz 2007.
	Pahl, G., Beitz, W.: Konstruktionslehre, Berlin, Springer 2006.
	Roth, K.H.: Konstruieren mit Konstruktionskatalogen, Band 1-3, Berlin, Springer 2000.
	• Simpson, T.W., Siddique, Z., Jiao, R.J.: Product Platform and Product Family Design. Methods and Applications, New York,
	Springer 2013.

Course L1255: Methods of Pr	irse L1255: Methods of Product Development				
Тур	oject-/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 M0746: Micro	system	Engine	ering				
Courses							
Title					Түр	Hrs/wk	СР
Microsystem Engineering (L0680)					Lecture	2	4
Microsystem Engineering (L0682)					Project-/problem-based Learning	2	2
Module Responsible	Dr. Timo Li	ipka					
Admission Requirements	None						
<b>Recommended Previous</b>	Basic cours	ses in phys	ics, mathematic	s and electric engineering			
Knowledge							
Educational Objectives	After takin	g part succ	essfully, student	s have reached the followi	ng learning results		
Professional Competence							
Knowledge	The studer	nts know a	bout the most i	important technologies and	d materials of MEMS as well a	s their applica	tions in sensors ar
	actuators.						
Chille	Chudanta a	ava abla ta	analyza and a	lessibe the functional he	haviour of MEMC components	ممط المم من ما ا	ata tha natantial
SKIIIS	Students are able to analyze and describe the functional behaviour of MEMS components and to evaluate the potential or microsystems.						
	microsyste	:115.					
Personal Competence							
Social Competence	Students are able to solve specific problems alone or in a group and to present the results accordingly.						
Autonomy	Studonte a	ro ablo to	acquiro particul:	ar knowlodgo using sposial	ized literature and to integrate	and accoriate	this knowledge wi
Autonomy	Students are able to acquire particular knowledge using specialized literature and to integrate and associate this knowledge with other fields.						
Workload in Hours	Independe	nt Study Ti	me 124, Study 1	ime in Lecture 56			
Credit points							
Course achievement	Compulsory		Form	Description			
	No	10 %	Presentation				
Examination		am					
Examination duration and	2h						
scale							
-	Electrical Engineering: Core Qualification: Compulsory						
Following Curricula	International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory						
		-	-		chatronics: Elective Compulsory	1	
		-			tronics: Elective Compulsory		
			-	Design: Elective Compulsor	У		
				tive Compulsory	Compulsory		
			-	ore Qualification: Elective (		llconv	
	rileorerica	i mechanici	ai Engineering: S	ppecialisation bio- and Med	ical Technology: Elective Comp	lisoly	

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

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

Courses				
Title		Tun	Hrs/wk	СР
Flexible Multibody Systems (L1632)		<b>Typ</b> Lecture	2	3
Optimization of dynamical systems		Lecture	2	3
Module Responsible	Prof. Robert Seifried			
Admission Requirements	None			
Recommended Previous				
Knowledge	Mathematics I, II, III			
	Mechanics I, II, III, IV			
	<ul> <li>Simulation of dynamical Systems</li> </ul>			
Educational Objectives	After taking part successfully, students have reach	ed the following learning results		
Professional Competence		5 5		
	Students demonstrate basic knowledge and under	erstanding of modeling, simulation	n and analysis of comp	lex rigid and flexil
	multibody systems and methods for optimizing dyr			
CL ///				
Skills	Students are able			
	+ to think holistically			
	the independently converse extractly applying	and antimize basis problems of	the dynamics of visid a	nd flavible poultibe
	+ to independently, securly and critically analyze	and optimize basic problems of	the dynamics of rigid a	na fiexible multipo
	systems			
	+ to describe dynamics problems mathematically			
	+ to optimize dynamics problems			
Personal Competence				
Social Competence	Students are able to			
	+ solve problems in heterogeneous groups and to	document the corresponding result	ts	
	i solve problems in neterogeneous groups and to	document the corresponding result		
Διιτοποπγ	Students are able to			
Autonomy				
	+ assess their knowledge by means of exercises.			
	+ acquaint themselves with the necessary knowled	dge to solve research oriented task	s.	
	··· <b>·</b> ··· <b>·</b> ··························			
Workload in Hours	Independent Study Time 124, Study Time in Lectur	re 56		
Credit points				
Course achievement	None			
Examination	Oral exam			
Examination duration and				
scale				
Assignment for the	Aircraft Systems Engineering: Core Qualification: E	lective Compulsory		
Following Curricula	Aeronautics: Core Qualification: Elective Compulso			
-	Mechatronics: Specialisation Intelligent Systems ar			
	Mechatronics: Specialisation System Design: Electi	ve Compulsory		
	Mechatronics: Core Qualification: Elective Compuls	ory		
	Product Development, Materials and Production: Co		ory	
	Theoretical Mechanical Engineering: Core Qualifica	tion: Elective Compulsory		

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

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

ourses							
itle			-	Тур	Hrs/wk	СР	
ptics for Engineers (L2437)				Lecture	3	3	
ptics for Engineers (L2438)			F	Project-/problem-based Learning	3	3	
Module Responsible	Prof. Thorsten Kern						
Admission Requirements	None						
<b>Recommended Previous</b>	- Basics of physics						
Knowledge							
Educational Objectives	After taking part succ	essfully, students have	reached the following	g learning results			
Professional Competence							
Knowledge	Teaching subject ist t	he design of simple opti	cal systems for illum	ination and imaging optics			
	De sie verlage fe		ulation of the share of the second				
		or optical systems and lig					
		ck-bodies, color-perception und their characterizatio					
	<ul> <li>Eight-Sources</li> <li>Photometrics</li> </ul>		11				
	3 1	Ray-Optics					
	Matrix-Optics						
	Stops, Pupils and Windows     Light field Technology						
	Light-field Technology						
	Introduction to Wave-Optics     Introduction to Holography						
	<ul> <li>Introduction to</li> </ul>	поюдгарну					
Skills	Understandings of op	tics as part of light and e	electromagnetic spec	ctrum. Design rules, approach t	o designing o	ptics	
Personal Competence							
Social Competence							
Autonomy							
Workload in Hours	Independent Study Ti	ime 96, Study Time in Le	ecture 84				
Credit points	6						
Course achievement	Compulsory Bonus	Form	Description				
	Yes None	Subject theoretical	andTeilnahme an I	Laborübungen und Simulation			
		practical work					
Examination	Oral exam						
Examination duration and	30 min						
scale							
Assignment for the	Electrical Engineering	g: Specialisation Microwa	ave Engineering, Opti	cs, and Electromagnetic Comp	atibility: Electi	ve Compulsory	
Following Curricula	Mechatronics: Specia	lisation Intelligent System	ms and Robotics: Ele	ctive Compulsory			
	Mechatronics: Specia	lisation System Design:	Elective Compulsory				
	Mechatronics: Core Q	ualification: Elective Cor	mpulsory				

Course L2437: Optics for Eng	jineers			
Тур	Lecture			
Hrs/wk	3			
CP	3			
Workload in Hours	dependent Study Time 48, Study Time in Lecture 42			
Lecturer	Prof. Thorsten Kern			
Language	EN			
Cycle	WiSe			
Content	<ul> <li>Basic values for optical systems and lighting technology</li> <li>Spectrum, black-bodies, color-perception</li> <li>Light-Sources und their characterization</li> <li>Photometrics</li> <li>Ray-Optics</li> <li>Matrix-Optics</li> <li>Stops, Pupils and Windows</li> <li>Light-field Technology</li> <li>Introduction to Wave-Optics</li> <li>Introduction to Holography</li> </ul>			
Literature				

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

Courses						
Title		Тур	Hrs/wk	СР		
Nonlinear Structural Analysis (L027	7)	Lecture	3	4		
Nonlinear Structural Analysis (L027	9)	Recitation Section (small)	1	2		
Module Responsible	Prof. Alexander Düster					
Admission Requirements	None					
<b>Recommended Previous</b>	Knowledge of partial differential equations	is recommended.				
Knowledge						
Educational Objectives	After taking part successfully, students have	ve reached the following learning results				
Professional Competence						
Knowledge	Students are able to					
	+ give an overview of the different nonline	ar phenomena in structural mechanics.				
	+ explain the mechanical background of ne	onlinear phenomena in structural mechanics.				
	+ to specify problems of nonlinear structu	ral analysis, to identify them in a given situation a	and to explain th	eir mathematical a		
	mechanical background.					
Skille	Students are able to					
JKIIIS	+ model nonlinear structural problems.					
	+ select for a given nonlinear structural pro-	oblem a suitable computational procedure				
	+ apply finite element procedures for nonli					
	+ critically verify and judge results of nonli					
	+ to transfer their knowledge of nonlinear					
	· · · · · · · · · · · · · · · · · · ·					
Personal Competence						
Social Competence	Students are able to					
	+ solve problems in heterogeneous groups					
	+ present and discuss their results in front	of others.				
	+ give and accept professional constructiv	e criticism.				
Autonomy	Students are able to					
	+ assess their knowledge by means of exe	rcises and E-Learning.				
	+ acquaint themselves with the necessary knowledge to solve research oriented tasks.					
	+ to transform the acquired knowledge to					
Workload in Hours	Independent Study Time 124, Study Time i	n Lecture 56				
Credit points	6					
Course achievement	None					
Examination	Written exam					
Examination duration and	120 min					
scale						
Assignment for the	Civil Engineering: Specialisation Structural	Engineering: Elective Compulsory				
Following Curricula	Civil Engineering: Specialisation Computation	onal Engineering: Compulsory				
	International Management and Engineering	: Specialisation II. Civil Engineering: Elective Com	pulsory			
	Materials Science: Specialisation Modeling:	Elective Compulsory				
	Mechatronics: Technical Complementary C	ourse: Elective Compulsory				
	Mechatronics: Specialisation System Desig	n: Elective Compulsory				
	Mechatronics: Core Qualification: Elective 0	Compulsory				
	Product Development, Materials and Produ	ction: Core Qualification: Elective Compulsory				
	Naval Architecture and Ocean Engineering					
	Ship and Offshore Technology: Core Qualifi	cation: Elective Compulsory				
	Theoretical Mechanical Engineering: Specia	alisation Simulation Technology: Elective Compulse	arv.			

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

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

Courses						
Title		Тур	Hrs/wk	СР		
Control Lab V (L1667)		Practical Course	1	1		
Control Lab VI (L1668)		Practical Course	1	1		
Module Responsible	NN					
Admission Requirements	None					
<b>Recommended Previous</b>						
Knowledge	State space methods					
	LQG control					
	H2 and H-infinity optimal control					
	<ul> <li>uncertain plant models and robust</li> </ul>	control				
	LPV control					
Educational Objectives	After taking part successfully, students h	ave reached the following learning results				
Professional Competence						
Knowledge						
	<ul> <li>Students can explain the difference</li> </ul>	e between validation of a control lop in simulation	on and experimental	alidation		
Skills						
	Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify					
	<ul><li>dynamic model that can be used for controller synthesis</li><li>They are capable of using standard software tools (Matlab Control Toolbox) for the design and imple controllers</li></ul>					
	<ul> <li>They are capable of using standar</li> </ul>	d software tools (Matlab Robust Control Toolbox	) for the mixed-sensi	tivity design and t		
	implementation of H-infinity optim	al controllers				
	<ul> <li>They are capable of representing r</li> </ul>	model uncertainty, and of designing and implem	enting a robust contr	oller		
	<ul> <li>They are capable of using standard</li> </ul>	d software tools (Matlab Robust Control Toolbox)	for the design and th	e implementatior		
	LPV gain-scheduled controllers					
Personal Competence						
Social Competence	<ul> <li>Students can work in teams to con</li> </ul>	duct experiments and document the results				
Autonomy	<ul> <li>Students can independently carry</li> </ul>	out simulation studies to design and validate co	ntrol loops			
		-	•			
	Independent Study Time 32, Study Time	in Lecture 28				
Credit points	2					
Course achievement						
Examination	Written elaboration					
Examination duration and	1					
scale						
		trol and Power Systems Engineering: Elective C	ompulsory			
Following Curricula	Mechatronics: Core Qualification: Elective					
	Mechatronics: Specialisation Intelligent S	ystems and Robotics: Elective Compulsory				
	Mechatronics: Specialisation System Des	ign: Elective Compulsory				

Course L1667: Control Lab V	
Тур	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1668: Control Lab V	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, Adwait Datar, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Courses							
Title				Тур		Hrs/wk	СР
Advanced Topics in Control (L1803)				Semina	ar	2	2
Module Responsible	NN						
Admission Requirements							
Recommended Previous Knowledge	•	Introduction to contr Control theory and d optimal and robust c	esign				
Educational Objectives	After t	aking part successfu	lly, students have reac	hed the following lear	ning results		
Professional Competence Knowledge		Students can explair Students learn to ap	n modern control. ply basic control conce	epts for different tasks			
Skills	•	Students generalize	owledge about selected developed results and prepare and give a pre	present them to the p		n specified literature	
Personal Competence Social Competence			e of developing solution vide appropriate feedb		uctive criticism	of their own results	
Autonomy	•	solution Students familiarize				tion for specific tasks and follow presentatior	
Workload in Hours	Indepe	endent Study Time 32	2, Study Time in Lectur	re 28			
Credit points	2						
Course achievement	None						
Examination	Preser	ntation					
Examination duration and scale	90 mir	۱ 					
Assignment for the	Mecha	tronics: Specialisatio	n Intelligent Systems a	and Robotics: Elective	Compulsory		
Following Curricula			n System Design: Elect ation: Elective Compul				

Course L1803: Advanced Top	Dics in Control
Тур	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	NN
Language	EN
Cycle	WiSe/SoSe
Content	Seminar on selected topics in modern control
Literature	To be specified

Courses						
Title		Тур	Hrs/wk	СР		
Technical Acoustics II (Room Acous	tics, Computational Methods) (L0519)	Lecture	2	3		
Technical Acoustics II (Room Acous	tics, Computational Methods) (L0521)	Recitation Section (large)	2	3		
Module Responsible	Prof. Benedikt Kriegesmann					
Admission Requirements	None					
<b>Recommended Previous</b>	Technical Acoustics I (Acoustic Waves, Noise Prote	ction, Psycho Acoustics)				
Knowledge	Machanica I (Chatica Machanica of Matariala) and N	Asshanias II (I) destation Kinematica Dun				
	Mechanics I (Statics, Mechanics of Materials) and N	iechanics II (Hydrostatics, Kinematics, Dyn	amics)			
	Mathematics I, II, III (in particular differential equations)					
Educational Objectives	After taking part successfully, students have reach	ed the following learning results				
Professional Competence	Filter taking part succession, stadents have reach					
•	The students possess an in-depth knowledge in acoustics regarding room acoustics and computational methods and are a					
	give an overview of the corresponding theoretical and methodical basis.					
	g					
Skills	The students are capable to handle engineering problems in acoustics by theory-based application of					
	computational methods and procedures treated within the module.					
Personal Competence						
Social Competence	Students can work in small groups on specific prob	lems to arrive at joint solutions.				
Autonomy	Y The students are able to independently solve challenging acoustical problems in the areas treated within the module. Possi					
	conflicting issues and limitations can be identified	and the results are critically scrutinized.				
Workload in Hours	Independent Study Time 124, Study Time in Lectur	re 56				
Credit points	6					
Course achievement	None					
Examination	Oral exam					
Examination duration and	20 min					
scale						
Assignment for the	Aircraft Systems Engineering: Core Qualification: E	lective Compulsory				
Following Curricula	Aeronautics: Core Qualification: Elective Compulso	ry				
	Mechatronics: Specialisation System Design: Electi	ve Compulsory				
	Mechatronics: Core Qualification: Elective Compuls	ory				
	Product Development, Materials and Production: Co	ore Qualification: Elective Compulsory				
	Theoretical Mechanical Engineering: Specialisation	Product Development and Production: Elec	ctive Compulsory			
	Theoretical Mechanical Engineering: Specialisation	Simulation Technology: Elective Compulso	rv			

Course L0519: Technical Aco	ustics II (Room Acoustics, Computational Methods)
Тур	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	DrIng. Sören Keuchel
Language	EN
Cycle	WiSe
Content	- Room acoustics
	- Sound absorber
	- Standard computations
	- Statistical Energy Approaches
	- Finite Element Methods
	- Boundary Element Methods
	- Geometrical acoustics
	- Special formulations
	- Practical applications
	- Hands-on Sessions: Programming of elements (Matlab)
Literature	Cremer, L.; Heckl, M. (1996): Körperschall. Springer Verlag, Berlin
	Veit, I. (1988): Technische Akustik. Vogel-Buchverlag, Würzburg
	Veit, I. (1988): Flüssigkeitsschall. Vogel-Buchverlag, Würzburg
	Gaul, L.; Fiedler, Ch. (1997): Methode der Randelemente in Statik und Dynamik. Vieweg, Braunschweig, Wiesbaden
	Bathe, KJ. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin

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

Courses						
Title		Тур	Hrs/wk	СР		
Fundamentals of Maintenance, Rep	pair and Overhaul (MRO) (L3160)	Lecture	3	4		
Fundamentals of Maintenance, Rep	pair and Overhaul (MRO) (L3161)	Recitation Section (large)	1	2		
Module Responsible	Prof. Gerko Wende					
Admission Requirements	None					
<b>Recommended Previous</b>	We recommend knowledge in the areas of general	engineering sciences, aeronautics and ai	rcraft systems er	ngineering. Technie		
Knowledge	fields like mechanical engineering, mechatronics and production engineering will be introduced into the relevant aeronautic					
	content.					
Educational Objectives	After taking part successfully, students have reache	ed the following learning results				
Professional Competence						
Knowledge	The students are able to describe fundamental corr	elations for the sustainable operation of te	chnical assets ar	nd to identify solut		
	approaches for complex optimization problems.					
Skills						
SKIIIS	s The students are enabled to apply the general engineering capabilities of the individual course towards the optimization of the sustainability in operation of technical assets. The resulting competencies will open an entry into positions in the developmen					
	production and technical operation of sustainable products in the mobility and engineering industries.					
	production and technical operation of sustainable p	roducts in the mobility and engineering in	uusuites.			
Personal Competence						
Social Competence	The students are able to work in mixed groups with a clear focus on the approached solutions by respecting the comp					
	environment of multiple stakeholders.					
Autonomy	The students are enabled to find solutions for o	ontimization problems and to take requ	ired decision for	the accessment		
Autonomy	determining factors independently.	problems and to take requ	lifed decision for	the assessment		
	determining ractors independently.					
Workload in Hours	Independent Study Time 124, Study Time in Lecture	e 56				
Credit points	6					
Course achievement	None					
Examination	Oral exam					
Examination duration and	30 min					
scale						
Assignment for the	Aircraft Systems Engineering: Core Qualification: El	ective Compulsory				
Following Curricula	Aeronautics: Core Qualification: Elective Compulsor	У				
	Mechatronics: Specialisation Intelligent Systems and	d Robotics: Elective Compulsory				
	Mechatronics: Specialisation System Design: Elective					
	Mechatronics: Core Qualification: Elective Compulso					
	Product Development, Materials and Production: Sp					
	Product Development, Materials and Production: Sp		-			
	Product Development, Materials and Production: Sp					
	Theoretical Mechanical Engineering: Specialisation					
	Theoretical Mechanical Engineering: Specialisation	Aircraft Systems Engineering: Elective Cor	npulsory			

Course L3160: Fundamentals	s of Maintenance, Repair and Overhaul (MRO)
Тур	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Gerko Wende
Language	DE
Cycle	WiSe
Content	Fundamentals for the sustainable operation of technical assets by means of maintenance, repair and overhaul (MRO):
	<ul> <li>Life cycle analytics</li> <li>Material circularity and service products</li> <li>Rules and regulations</li> <li>Processes and production methods</li> <li>Tools and technologies</li> <li>Data handling and usage</li> <li>Design for maintenance</li> <li>Self-healing technical systems</li> </ul>
Literature	-

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

	Thesis
Module M1801: Maste	er thesis (dual study program)
Courses	
Title	Typ Hrs/wk CP
Module Responsible	
Admission Requirements	
Recommended Previous	
Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students
	<ul> <li> use the specialised knowledge (facts, theories and methods) from their field of study and the acquired profession knowledge confidently to deal with technical and practical professional issues.</li> <li> can explain the relevant approaches and terminologies in depth in one or more of their subject's specialist area describe current developments and take a critical stance.</li> <li> formulate their own research assignment to tackle a professional problem and contextualise it within their subject area They ascertain the current state of research and critically assess it.</li> </ul>
Skills	Dual students
	<ul> <li> can select suitable methods for the respective subject-related professional problem, apply them and develop them furth as required.</li> <li> assess knowledge and methods acquired during their studies (including practical phases) and apply their expertise complex and/or incompletely defined problems in a solution- and application-oriented manner.</li> </ul>
	<ul> <li> acquire new academic knowledge in their subject area and critically evaluate it.</li> </ul>
Personal Competence	
Social Competence	Dual students
	<ul> <li> can present a professional problem in the form of an academic question in a structured, comprehensible and factua correct manner, both in writing and orally, for a specialist audience and for professional stakeholders.</li> <li> answer questions as part of a professional discussion in an expert, appropriate manner. They represent their own poin</li> </ul>
	of view and assessments convincingly.
Autonomy	Dual students
	<ul> <li>regard to feasible courses of action for professional practice.</li> <li> work in-depth in a partially unknown area within the discipline and acquire the information required to do so.</li> <li> apply the techniques of academic work comprehensively in their own research work when dealing with an operation problem and question.</li> </ul>
Workload in Hours	Independent Study Time 900, Study Time in Lecture 0
	independent study nine 900, study nine in Lecture 0
Credit points	
	30
Credit points	30 None
Credit points Course achievement Examination	30 None
Credit points Course achievement Examination Examination duration and scale	30 None Thesis According to General Regulations
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Aeronautics: Thesis: Compulsory Materials Science and Engineering: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Aeronautics: Thesis: Compulsory Materials Science and Engineering: Thesis: Compulsory Materials Science: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30         None         Thesis         According to General Regulations         Civil Engineering: Thesis: Compulsory         Bioprocess Engineering: Thesis: Compulsory         Chemical and Bioprocess Engineering: Thesis: Compulsory         Computer Science: Thesis: Compulsory         Data Science: Thesis: Compulsory         Electrical Engineering: Thesis: Compulsory         Energy Systems: Thesis: Compulsory         Environmental Engineering: Thesis: Compulsory         Aircraft Systems Engineering: Thesis: Compulsory         Computer Science in Engineering: Thesis: Compulsory         Information and Communication Systems: Thesis: Compulsory         International Management and Engineering: Thesis: Compulsory         Logistics, Infrastructure and Mobility: Thesis: Compulsory         Aeronautics: Thesis: Compulsory         Materials Science and Engineering: Thesis: Compulsory         Materials Science and Engineering: Thesis: Compulsory         Materials Science: Thesis: Compulsory         Materials Science Thesis: Compulsory         Materials Science Thesis: Compulsory         Materials Science Thesis: Compulsory
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Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Materials Science and Engineering: Thesis: Compulsory Materials Science: Thesis: Compulsory Materials Science: Thesis: Compulsory Materials Science: Thesis: Compulsory Mechanical Engineering and Management: Thesis: Compulsory Mechatronics: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Aeronautics: Thesis: Compulsory Materials Science and Engineering: Thesis: Compulsory Materials Science: Thesis: Compulsory Mechanical Engineering: Thesis: Compulsory Mechanical Engineering: Thesis: Compulsory Biomedical Engineering and Management: Thesis: Compulsory Biomedical Engineering: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Materials Science: Thesis: Compulsory Materials Science: Thesis: Compulsory Materials Science: Thesis: Compulsory Mechanical Engineering: Thesis: Compulsory Biomedical Engineering: Thesis: Compulsory Biomedical Engineering: Thesis: Compulsory Product Development, Materials and Production: Thesis: Compulsory Renewable Energies: Thesis: Compulsory
Credit points Course achievement Examination Examination duration and scale Assignment for the	30 None Thesis According to General Regulations Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Materials Science: Thesis: Compulsory Materials Compulsory Microelectronics and Microsystems: Thesis: Compulsory Product Development, Materials and Production: Thesis: Compulsory

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