Module Manual

Master of Science (M.Sc.)

Information and Communication Systems

Cohort: Winter Term 2021

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Program description

Content

Among the industries with the greatest growth rates is the communications industry which, over the years, has achieved in its products the synergy of the classical disciplines of computer science and networking. The International Master Program Information and Communication Systems addresses this rapidly evolving area by laying in-depth foundations for the design and implementation of networking infrastructures, networked Cyber Physical Systems and the applications and services running on them.

The program is organized as a two-year course (four semesters) which starts on 1st of October each year. It includes around two semesters of lectures and practical courses and almost two semesters devoted to work in a research team (project work) and to the preparation of a master's thesis. The "Master of Science" degree will be awarded. Language of the program is English.

Graduates of the program are provided with the basics and knowledge that are required for a successful engineering activity in the information and communication technology in an international environment. They acquire extensive knowledge in the mathematical, engineering and scientific basic principles of this discipline based on a solid theoretical foundation including all the essential application-oriented aspects. Graduates are qualified to independently resolve problems in the information and communications technology and related disciplines.

The graduates are able to apply methods and procedures required to work on technical issues, as well as critically examine new insights to further develop and incorporate in their work. In this way, they are qualified to carry out their duties for society responsibly.

Career prospects

The study of Information and Communication Systems provides the in-depth training in the areas of Information and Communication Technology, Software Systems, IT Security and Signal Processing. This enables excellent career prospects both in the industrial as well as on the academic job market. The Master's degree qualifies graduates for doctoral studies.

Learning target

Knowledge

The students gain common knowledge from the core qualification and more specific knowledge depending on the selected specialisation. All students are able to describe information theory and coding basics.

Specialisation Communication Systems

Students can

- show their profound knowledge in digital communications,
- · describe their specialized knowledge in communication networks,
- explain software development principles,
- explain signal processing fundamentals.

Specialisation Secure and Dependable IT Systems:

Students can

- give an overview of software verification,
- describe security principles for information and communication systems,
- explain their specialized knowledge in communication networks,
- · describe software development and signal processing principles.

Skills

The ability to apply knowledge in order to perform tasks and solve problems will be supported in this course. Information and Communication Systems graduates are capable to

- solve problems in information and communication systems by applying and adapting techniques, procedures and methods that are required for a successful professional activity and by using engineering systematics,
- organize the planning of theoretical and experimental studies in order to develop optimal solutions for complex applications in information and
 communication technology and evaluate the solutions analyse problems using scientific systematics and solve them most effectively to develop
 economically viable approaches for products and systematically reflect non-technical implications of engineering activity to responsibly involve
 them in their actions.
- evaluate reliability of developed systems, prepare and review results of practical applications so that they can be used for systems optimization
- Investigate, evaluate and integrate new technologies, systems, architecture, services and applications for information and communication systems.

Social skills

The ability of target-oriented work in collaboration with others, communication, and understanding their interests and social situations are goals of this course. The students can

- present and argue the results of their work in written and oral form in an comprehensible way,
- communicate and collaborate with international professionals, also of other disciplines,
- collaborate in challenging projects of information and communications technology in a responsible position,
- develop ideas and solutions in team work.

Autonomy

The course helps to improve ability and readiness to act independently and responsibly, reflect own actions and the actions of others, and to develop the own functioning. Information and Communication Systems students are capable to

- identify knowledge gaps and propose solutions to overcome these gaps,
- expand and deepen their knowledge and skills independently, taking into account ecological and economic demands responsibly,
- familiarize themselves with complex tasks, define new tasks and develop the necessary knowledge for solving it and to systematically apply appropriate means.

Program structure

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

Core qualification: 48 CP Specialization: 42 CP Master thesis: 30 CP

Total: 120 CP

The core qualification consists of the module Information Theory and Coding (6 CP), technical complementary courses (12 CP), Business & Management (6 CP), nontechnical complementary courses (6 CP) and research project with seminar (18 CP). The research project with seminar consists of a scientific thesis with documentation and accompanying presentations in a seminar among fellow students.

The students choose between two specialisations (42 CP each):

• Communication Systems

Containing: Communications, software, and signal processing

• Secure and Dependable IT Systems

Containing: IT security, networks, software and signal processing

Students write a master thesis (30 CP).

Core qualification

Module M0523: Busin	ess & Management
Module Responsible	Prof. Matthias Meyer
Admission Requirements	None
Recommended Previous	None
Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge Skills	 Students are able to find their way around selected special areas of management within the scope of business management Students are able to explain basic theories, categories, and models in selected special areas of business management. Students are able to interrelate technical and management knowledge. Students are able to apply basic methods in selected areas of business management. Students are able to explain and give reasons for decision proposals on practical issues in areas of business management.
Personal Competence Social Competence Autonomy	Students are able to communicate in small interdisciplinary groups and to jointly develop solutions for complex problems
Workload in Hours Credit points	Students are capable of acquiring necessary knowledge independently by means of research and preparation of material. Depends on choice of courses 6

Courses

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

Module M0524: Non-technical Courses for Master		
Module Responsible	Dagmar Richter	
Admission Requirements	None	
Recommended Previous	None	
Knowledge		
Educational Objectives	After taking part successfully, students have reached the following learning results	
Duefe selevel Commetence		

Professional Competence

Knowledae

The Nontechnical Academic Programms (NTA)

imparts skills that, in view of the TUHH's training profile, professional engineering studies require but are not able to cover fully. Self-reliance, self-management, collaboration and professional and personnel management competences. The department implements these training objectives in its **teaching architecture**, in its **teaching and learning arrangements**, in **teaching areas** and by means of teaching offerings in which students can qualify by opting for **specific competences** and a **competence level** at the Bachelor's or Master's level. The teaching offerings are pooled in two different catalogues for nontechnical complementary courses.

The Learning Architecture

consists of a cross-disciplinarily study offering. The centrally designed teaching offering ensures that courses in the nontechnical academic programms follow the specific profiling of TUHH degree courses.

The learning architecture demands and trains independent educational planning as regards the individual development of competences. It also provides orientation knowledge in the form of "profiles".

The subjects that can be studied in parallel throughout the student's entire study program - if need be, it can be studied in one to two semesters. In view of the adaptation problems that individuals commonly face in their first semesters after making the transition from school to university and in order to encourage individually planned semesters abroad, there is no obligation to study these subjects in one or two specific semesters during the course of studies.

Teaching and Learning Arrangements

provide for students, separated into B.Sc. and M.Sc., to learn with and from each other across semesters. The challenge of dealing with interdisciplinarity and a variety of stages of learning in courses are part of the learning architecture and are deliberately encouraged in specific courses.

Fields of Teaching

are based on research findings from the academic disciplines cultural studies, social studies, arts, historical studies, communication studies, migration studies and sustainability research, and from engineering didactics. In addition, from the winter semester 2014/15 students on all Bachelor's courses will have the opportunity to learn about business management and start-ups in a goal-oriented way.

The fields of teaching are augmented by soft skills offers and a foreign language offer. Here, the focus is on encouraging goaloriented communication skills, e.g. the skills required by outgoing engineers in international and intercultural situations.

The Competence Level

of the courses offered in this area is different as regards the basic training objective in the Bachelor's and Master's fields. These differences are reflected in the practical examples used, in content topics that refer to different professional application contexts, and in the higher scientific and theoretical level of abstraction in the B.Sc.

This is also reflected in the different quality of soft skills, which relate to the different team positions and different group leadership functions of Bachelor's and Master's graduates in their future working life.

Specialized Competence (Knowledge)

Students can

- explain specialized areas in context of the relevant non-technical disciplines,
- outline basic theories, categories, terminology, models, concepts or artistic techniques in the disciplines represented in the learning area.
- different specialist disciplines relate to their own discipline and differentiate it as well as make connections,
- sketch the basic outlines of how scientific disciplines, paradigms, models, instruments, methods and forms of representation in the specialized sciences are subject to individual and socio-cultural interpretation and historicity,
- Can communicate in a foreign language in a manner appropriate to the subject.

Skills Professional Competence (Skills)

In selected sub-areas students can

- apply basic and specific methods of the said scientific disciplines,
- aquestion a specific technical phenomena, models, theories from the viewpoint of another, aforementioned specialist discipline.
- to handle simple and advanced questions in aforementioned scientific disciplines in a sucsessful manner,
- justify their decisions on forms of organization and application in practical questions in contexts that go beyond the technical relationship to the subject.

Personal Competence

Social Competence | Personal Competences (Social Skills)

Systems	
	 Students will be able to learn to collaborate in different manner, to present and analyze problems in the abovementioned fields in a partner or group situation in a manner appropriate to the addressees, to express themselves competently, in a culturally appropriate and gender-sensitive manner in the language of the country (as far as this study-focus would be chosen), to explain nontechnical items to auditorium with technical background knowledge.
	Personal Competences (Self-reliance) Students are able in selected areas • to reflect on their own profession and professionalism in the context of real-life fields of application • to organize themselves and their own learning processes • to reflect and decide questions in front of a broad education background • to communicate a nontechnical item in a competent way in writen form or verbaly • to organize themselves as an entrepreneurial subject country (as far as this study-focus would be chosen)
	Depends on choice of courses
Credit points	b

Courses

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

Module M1246: Technical Complementary Course for IMPICS (according to Subject Specific Regulations)				
Courses				
itle	Typ Hrs/wk	СР		
Module Responsible	Prof. Andreas Timm-Giel			
Admission Requirements	None			
Recommended Previous				
Knowledge				
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence				
Knowledge				
Skills				
Personal Competence				
Social Competence				
Autonomy				
Workload in Hours	Depends on choice of courses			
Credit points	12			
Assignment for the	Information and Communication Systems: Core qualification: Compulsory			
Following Curricula				

Module M0673: Inforr	nation Theory and Coding			
Courses				
Title Information Theory and Coding (L0436)		Typ Lecture Recitation Section (large)	Hrs/wk 3 2	CP 4 2
Information Theory and Coding (LO- Module Responsible		Recitation Section (large)	2	2
Admission Requirements				
Recommended Previous Knowledge	Mathematics 1-3 Probability theory and random processes Basic knowledge of communications engineering (e.g. Processes")	j. from lecture "Fundamentals	of Communica	ations and Random
Educational Objectives	After taking part successfully, students have reached the follow	ring learning results		
Skills Personal Competence Social Competence	The students know the basic definitions for quantification of in source coding theorem and channel coding theorem and are a free data transmission over noisy channels. They understand to correcting channel coding. They are familiar with the princi decoding. They know fundamental coding schemes, their proper the students are able to determine the limits of data compressated on those limits to design basic parameters of a transference of the properties of basic channel coding scheme for achist properties of basic channel coding and decoding schemes complexity and to decide for a suitable method. They are software. The students can jointly solve specific problems. The students are able to acquire relevant information from knowledge during the lecture period by solving tutorial problems.	able to determine theoretical line, the principles of source coding a ples of decoding, in particular erties and decoding algorithms. The session as well as of data transmersision scheme. They can estieving certain performance targer regarding error correction capacapable of implementing basic appropriate literature sources.	nits of data cons well as error- with modern of mission through imate the para ets. They are a abilities, decoding and dec	npression and error- detecting and error- nethods of iterative noisy channels and meters of an error- ble to compare the ing delay, decoding ecoding schemes in
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points				
Course achievement	None			
Examination	Written exam			
Examination duration and scale				
Assignment for the Following Curricula		neering Science: Elective Compul compulsory ectrical Engineering: Elective Co	sory	

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

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

Module M0804: Resea	arch Project and Seminar			
Courses				
Title		Тур	Hrs/wk	СР
Project Work (L1761)		Projection Course	10	15
Seminar (L0817)		Seminar	2	3
Module Responsible	Prof. Karl-Heinz Zimmermann			
Admission Requirements	None			
Recommended Previous	Basic knowledge and techniques in the chose	n field of specialization.		
Knowledge				
Educational Objectives	After taking part successfully, students have i	reached the following learning results		
Professional Competence				
Knowledge	Students are able to acquire advanced knowle	edge in a specific field of Computer Science o	or a closely related s	ubject.
Skills	Students are able to work self-dependent in a field of Computer Science or a closely related field.			
Personal Competence				
Social Competence				
Autonomy				
Workload in Hours	Independent Study Time 372, Study Time in L	ecture 168		
Credit points	18			
Course achievement	None			
Examination	Study work			
Examination duration and	Presentation of a current research topic (25-3	0 min and 5 min discussion).		
scale				
Assignment for the	Information and Communication Systems: Co	re qualification: Compulsory		
Following Curricula				

Course L1761: Project Work	
Тур	Projection Course
Hrs/wk	10
СР	15
Workload in Hours	Independent Study Time 310, Study Time in Lecture 140
Lecturer	Dozenten des SD E
Language	DE/EN
Cycle	WiSe
Content	Current research topics of the chosen specialization.
Literature	Aktuelle Literatur zu Forschungsthemen aus der gewählten Vertiefungsrichtung. / Current literature on research topics of the chosen specialization.

Course L0817: Seminar	
Тур	Seminar
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dozenten des SD E
Language	DE/EN
Cycle	WiSe
Content	 Seminar presentations by enrolled students about the research work carried out by the students Active participation in discussions
Literature	Wird vom Veranstalter bekanntgegeben.

Specialization Communication Systems

Graduates of the Communication Systems specialisation are qualified to independently resolve problems in communication networks and digital communications. They also have profound knowledge in software development principles and signal processing. Graduates are qualified to independently resolve problems in communication systems technology and related disciplines.

The Communication Systems specialisation is recommended for students who already bring along a good mathematical foundation, basic knowledge in computer science and/or electrical engineering with focus on information and communication technology.

Module M0676: Digita	al Communications			
Courses				
Title		Тур	Hrs/wk	СР
Digital Communications (L0444)		Lecture	2	3
Digital Communications (L0445)		Recitation Section (large)	2	2
Laboratory Digital Communications	T	Practical Course	1	1
Module Responsible				
Admission Requirements	None			
Recommended Previous	Mathematics 1-3			
Knowledge	Signals and Systems			
	Fundamentals of Communications and R	landom Processes		
Educational Objectives	After taking part successfully, students have re	eached the following learning results		
Professional Competence				
Knowledge	The students are able to understand, compare	and design modern digital information tran	smission schemes.	They are familiar with
	the properties of linear and non-linear digital r	•	•	
	and design and evaluate detectors including	·		ples of single carrier
	transmission and multi-carrier transmission as	·		
Skills	The students are able to design and analyse a	-	- '	•
	choose a digital modulation scheme taking into	·		
	properties. They can design an appropriate			-
	performance and complexity properties of sub-		ameters of a single	carrier or multi carrier
Barranal Carranatanas	transmission scheme and trade the properties	or both approaches against each other.		
Personal Competence	The students can is just usely a specific much lone			
Social Competence	The students can jointly solve specific problem	5.		
Autonomy	The students are able to acquire relevant	information from appropriate literature s	ources. They can	control their level of
	knowledge during the lecture period by solving tutorial problems, software tools, clicker system.			
Workload in Hours	Indonesia de Chiele Tinos 110 Chiele Tinos in La	seture 70		
Credit points	Independent Study Time 110, Study Time in Le	ecture 70		
Course achievement		Description		
Course achievement	Yes None Written elaboration			
Examination	Written exam			
Examination duration and	90 min			
scale				
Assignment for the	Electrical Engineering: Core qualification: Com	oulsory		
Following Curricula		•	ompulsory	
	Information and Communication Systems: Spec	cialisation Communication Systems: Compu	lsory	
	Information and Communication Systems: Spec	cialisation Secure and Dependable IT Syste	ms, Focus Networks	: Elective Compulsory
	International Management and Engineering: Sp	pecialisation II. Information Technology: Ele	ctive Compulsory	
	International Management and Engineering: Sp	pecialisation II. Electrical Engineering: Elect	ve Compulsory	
	Microelectronics and Microsystems: Core qualit	ication: Elective Compulsory		

Course L0444: Digital Comm	unications
Тур	Lecture
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	WiSe
Content	 Digital modulation methods Coherent and non-coherent detection Channel estimation and equalization Single-Carrier- and multi carrier transmission schemes, multiple access schemes (TDMA, FDMA, CDMA, OFDM)
Literature	K. Kammeyer: Nachrichtenübertragung, Teubner P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner. J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill. S. Haykin: Communication Systems. Wiley R.G. Gallager: Principles of Digital Communication. Cambridge A. Goldsmith: Wireless Communication. Cambridge. D. Tse, P. Viswanath: Fundamentals of Wireless Communication. Cambridge.

Course L0445: Digital Comm	ourse L0445: Digital Communications				
Тур	Recitation Section (large)				
Hrs/wk	2				
СР	2				
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28				
Lecturer	Prof. Gerhard Bauch				
Language	DE/EN				
Cycle	WiSe				
Content	See interlocking course				
Literature	See interlocking course				

Course L0646: Laboratory Di	gital Communications
Тур	Practical Course
Hrs/wk	1
СР	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	WiSe
Content	- DSL transmission
	- Random processes - Digital data transmission
Literature	K. Kammeyer: Nachrichtenübertragung, Teubner P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner. J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill. S. Haykin: Communication Systems. Wiley R.G. Gallager: Principles of Digital Communication. Cambridge A. Goldsmith: Wireless Communication. Cambridge. D. Tse, P. Viswanath: Fundamentals of Wireless Communication. Cambridge.

Module M0710: Micro	wave Engineeri	ng					
Courses							
Title Microwave Engineering (L0573) Microwave Engineering (L0574) Microwave Engineering (L0575)					Typ Lecture Recitation Section (large) Practical Course	Hrs/wk 2 2 1	CP 3 2
Module Responsible	Prof. Alexander Kölpin						-
Admission Requirements	None						
Recommended Previous Knowledge		-	-		evices and circuits. Basics	of Wave propagatio	on from transmission
Educational Objectives	After taking part succ	essfully, students I	nave re	ached the follow	ng learning results		
Professional Competence Knowledge	and components. The	Students can explain the propagation of electromagnetic waves and related phenomena. They can describe transmission systems and components. They can name different types of antennas and describe the main characteristics of antennas. They can explain noise in linear circuits, compare different circuits using characteristic numbers and select the best one for specific scenarios.					
Skills	Students are able to calculate the propagation of electromagnetic waves. They can analyze complete transmission systems und configure simple receiver circuits. They can calculate the characteristic of simple antennas and arrays based on the geometry. They can calculate the noise of receivers and the signal-to-noise-ratio of transmission systems. They can apply their theoretical knowledge to the practical courses.						ed on the geometry.
Personal Competence Social Competence	Students work together in small groups during the practical courses. Together they document, evaluate and discuss their results.						iscuss their results.
Autonomy	Students are able to relate the knowledge gained in the course to contents of previous lectures. With given instructions they can extract data needed to solve specific problems from external sources. They are able to apply their knowledge to the laboratory courses using the given instructions.						
Workload in Hours	Independent Study Ti	ne 110, Study Tim	e in Le	cture 70			
Credit points	-	-					
Course achievement	Compulsory Bonus Yes None	Form Subject theore practical work	tical	Description and			
Examination	Written exam						
Examination duration and	90 min						
scale							
_	Electrical Engineering						
Following Curricula	International Manager	nent and Engineer	ing: Sp	ecialisation II. Ele	unication Systems: Elective ectrical Engineering: Electiv	re Compulsory	
	Microelectronics and I	Aicrosystems: Spe	cialisati	on Communicati	on and Signal Processing: E	lective Compulsory	'

Course L0573: Microwave En	gineering
Тур	Lecture
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Kölpin
Language	DE/EN
Cycle	WiSe
Content	- Antennas: Analysis - Characteristics - Realizations
	- Radio Wave Propagation
	- Transmitter: Power Generation with Vacuum Tubes and Transistors
	- Receiver: Preamplifier - Heterodyning - Noise
	- Selected System Applications
Literature	HG. Unger, "Elektromagnetische Theorie für die Hochfrequenztechnik, Teil I", Hüthig, Heidelberg, 1988
	HG. Unger, "Hochfrequenztechnik in Funk und Radar", Teubner, Stuttgart, 1994
	E. Voges, "Hochfrequenztechnik - Teil II: Leistungsröhren, Antennen und Funkübertragung, Funk- und Radartechnik", Hüthig, Heidelberg, 1991
	E. Voges, "Hochfrequenztechnik", Hüthig, Bonn, 2004
	C.A. Balanis, "Antenna Theory", John Wiley and Sons, 1982
	R. E. Collin, "Foundations for Microwave Engineering", McGraw-Hill, 1992
	D. M. Pozar, "Microwave and RF Design of Wireless Systems", John Wiley and Sons, 2001
	D. M. Pozar, "Microwave Engineerin", John Wiley and Sons, 2005

Course L0574: Microwave Engineering				
Тур	Recitation Section (large)			
Hrs/wk				
СР	2			
Workload in Hours	dependent Study Time 32, Study Time in Lecture 28			
Lecturer	of. Alexander Kölpin			
Language	DE/EN			
Cycle	WiSe			
Content	See interlocking course			
Literature	See interlocking course			

Course L0575: Microwave En	Course L0575: Microwave Engineering			
Тур	Practical Course			
Hrs/wk	1			
СР	1			
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14			
Lecturer	Prof. Alexander Kölpin			
Language	DE/EN			
Cycle	WiSe			
Content	See interlocking course			
Literature	See interlocking course			

Module M0836: Comn	nunication Networks			
Courses				
Title		Тур	Hrs/wk	СР
Selected Topics of Communication	Networks (L0899)	Project-/problem-based Learning	2	2
Communication Networks (L0897)		Lecture	2	2
Communication Networks Excercise	e (L0898)	Project-/problem-based Learning	1	2
Module Responsible	Prof. Andreas Timm-Giel			
Admission Requirements	None			
Recommended Previous	. From decreased the shooting			
Knowledge	Fundamental stochastics Paging understanding of computer networks and/our	ammunication to characteries is boundisi	al	
	Basic understanding of computer networks and/or of the state of t	ommunication technologies is benefici	dl	
Educational Objectives	After taking part successfully, students have reached the	following learning results		
Professional Competence				
Knowledge	Students are able to describe the principles and structu	res of communication networks in de	etail. They ca	an explain the formal
	description methods of communication networks and	their protocols. They are able to ex	xplain how	current and complex
	communication networks work and describe the current re	search in these examples.		
G1 ''11				
Skills	Students are able to evaluate the performance of commu	_	-	
	problems themselves and apply the learned methods. Th	ey can apply what they have learned	autonomousi	y on further and new
	communication networks.			
Personal Competence				
Social Competence	Students are able to define tasks themselves in small tea	ms and solve these problems together	r using the le	arned methods. They
	can present the obtained results. They are able to discuss	and critically analyse the solutions.		
4.4	Charles and the shade the same and the same	des for an almost discount of the first of the		
Autonomy	Students are able to obtain the necessary expert knowled	age for understanding the functionalit	ty and perfor	mance capabilities of
	new communication networks independently.			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	None			
Examination	Presentation			
Examination duration and	1.5 hours colloquium with three students, therefore about	t 30 min per student. Topics of the co	lloquium are	the posters from the
scale	previous poster session and the topics of the module.			
Assignment for the	Electrical Engineering: Specialisation Information and Con	munication Systems: Elective Compuls	sory	
Following Curricula	Electrical Engineering: Specialisation Control and Power S	stems Engineering: Elective Compulso	ory	
	Aircraft Systems Engineering: Core qualification: Elective	Compulsory		
	Computational Science and Engineering: Specialisation I.	Computer Science: Elective Compulsory	/	
	Information and Communication Systems: Specialisation S	ecure and Dependable IT Systems, Foo	cus Networks	: Elective Compulsory
	Information and Communication Systems: Specialisation 0	communication Systems: Elective Comp	oulsory	
	International Management and Engineering: Specialisation	II. Information Technology: Elective Co	ompulsory	
	Mechatronics: Technical Complementary Course: Elective	Compulsory		
	Microelectronics and Microsystems: Specialisation Commu	nication and Signal Processing: Electiv	e Compulsor	/

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

Course L0897: Communication	Course L0897: Communication Networks				
Тур	Lecture				
Hrs/wk	2				
СР	2				
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28				
Lecturer	Prof. Andreas Timm-Giel, DrIng. Koojana Kuladinithi				
Language	EN				
Cycle	WiSe				
Content					
Literature	Skript des Instituts für Kommunikationsnetze Tannenbaum, Computernetzwerke, Pearson-Studium Further literature is announced at the beginning of the lecture.				

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

Module M0638: Mode	rn Wireless Sys	tems					
Courses							
Title	Title			Тур	Hrs/wk	СР	
Selected Topics of Modern Wireless	S Systems (L1982)			Project-/problem-based Learning	2	3	
Modern Wireless Systems (L0296)	ı			Lecture	3	3	
Module Responsible	Dr. Rainer Grünheid						
Admission Requirements	None						
Recommended Previous	Lecture "Digital	Communications"					
Knowledge	_	ced Concepts of Wirele	see Communications	п			
	• Lecture Advant	ed Concepts of Wirele	ss communications				
Educational Objectives	After taking part succe	ssfully, students have	reached the followi	ng learning results			
Professional Competence							
Knowledge	Students have an ove	rview of a variety of o	ontemporary wirele	ss systems of different size and	complexity. Th	ney understand the	
	technical solutions from	n the perspective of t	he physical and dat	a link layer. They have develope	d a system vie	w and are aware of	
	the technical argume	nts, considering the r	espective application	ons and associated constraints.	For several ex	camples (e.g., Long	
	Term Evolution, LTE),	students are able to ex	plain different conc	epts in a very deep technical det	ail.		
Skills	Students have develo	ped a system view.	hey can transfer t	heir knowledge to evaluate oth	er systems, no	ot discussed in the	
	lecture, and to unders	and the respective te	chnical solutions. Gi	ven specific contraints and techr	nical requireme	ents, students are in	
	a position to make pro	a position to make proposals for certain design aspects by an appropriate assessment and the consideration of alternatives.					
Personal Competence							
Social Competence	Students can jointly el	aborate tasks in small	groups and present	their results in an adequate fash	nion.		
Autonomy	Students are able to e	ktract necessary inform	nation from given li	terature sources and put it into t	he perspective	of the lecture. They	
	can continuously chec	k their level of expert	ise with the help of	f accompanying measures (such	as online tests	s, clicker questions,	
	exercise tasks) and, ba	sed on that, to steer	their learning proce	ss accordingly. They can relate t	heir acquired l	knowledge to topics	
	of other lectures, e.g.,	"Digital Communication	ons" and "Advanced	Topics of Wireless Communicati	ons".		
	Independent Study Tin	ne 110, Study Time in	Lecture 70				
Credit points		_					
Course achievement	Compulsory Bonus Yes None	Form Subject theoretical	Description	Posterpräsentation			
	res None	practical work	dilurbt-kurs iilit	Posterprasentation			
Examination	Oral exam	practical Work					
Examination duration and							
scale	70 111111						
	Electrical Engineering	Specialisation Informa	ation and Communic	ration Systems: Flective Compuls	sorv		
_	Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory						
i onowing culticula	mioralation and comm	iameation bysteins. s	ccianoution commit	anication systems. Elective Comp	741301 y		

Course L1982: Selected Topics	s of Modern Wireless Systems
	3 of Piodelli Wileless Systems
Тур	Project-/problem-based Learning
Hrs/wk	2
CP 3	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Rainer Grünheid
Language	EN
Cycle	WiSe
•	In this course, selected "hot" topics of modern wireless systems will be covererd. For that purpose, students work in groups to elaborate a given subject. The results will be presented in a poster session towards the end of the semester. Possible topics can include various system concepts and related technical principles, such as: • 5G systems • Millimeter wave communication • Visible light communication • Cooperative Multipoint • Massive MIMO • Massive machine-type communication • Interference cancellation • Non-orthogonal multiple access • Heterogeneous networks •
Literature	will be provided, depending on the given topics

Course L0296: Modern Wirel	ess Systems
Тур	Lecture
Hrs/wk	3
СР	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Rainer Grünheid
Language	EN
Cycle	WiSe
Content	The lecture gives an overview of contemporary wireless communication concepts and related techniques from a system point of
	view. For that purpose, different systems, ranging from Wireless Personal to Wide Area Networks, are covered, mainly discussing
	the physical and data link layer.
	Systems under consideration include:
	- ZigBee / IEEE 802.15.4 - Bluetooth
	- IEEE 802.11 family
	- Long Term Evolution (LTE) and LTE Advanced
	- WIMAX
	A special focus is placed on 4th generation networks; in particular, an in-depth view into the technical principles of the Long Term
	Evolution (LTE / LTE Advanced) standard is given, with an emphasis on multiple antenna techniques.
Literature	John G. Proakis, Masoud Salehi: Digital Communications. 5th Edition, Irwin/McGraw Hill, 2007
	Stefani Sesia, Issam Toufik, Matthew Baker: LTE - The UMTS Long Term Evolution. Second Edition, Wiley, 2011
	Steram Sesia, issum Tourik, Matthew Baker. Ett The OMTS Long Term Evolution. Second Edition, Wiley, 2011
	Jeffrey G. Andrews, Arunabha Ghosh, Rias Muhamed: Fundamentals of WiMAX. Prentice Hall, 2007

Module M0837: Simulation of Communication Networks				
Courses				
Title		Тур	Hrs/wk	СР
Simulation of Communication Netw	orks (L0887)	Project-/problem-based Learning	5	6
-	Prof. Andreas Timm-Giel			
Admission Requirements	None			
Recommended Previous	Knowledge of computer and communication networks			
Knowledge	Basic programming skills			
	After taking part successfully, students have reached the follow	ving learning results		
Professional Competence				
Knowledge	Students are able to explain the necessary stochastics, the d	iscrete event simulation technolo	gy and modellir	ng of networks for
	performance evaluation.			
Skills	Students are able to apply the method of simulation for per	formance evaluation to different	, also not pract	iced, problems of
	communication networks. The students can analyse the obtained	ed results and explain the effects	observed in the	network. They are
	able to question their own results.			
Personal Competence				
·	Students are able to acquire expert knowledge in groups, present the results, and discuss solution approaches and results. They			
Social competence	are able to work out solutions for new problems in small teams.		пол арргоастер	and results mey
	·			
Autonomy	Students are able to transfer independently and in discussion	·	od and expert k	nowledge to new
	problems. They can identify missing knowledge and acquire this	s knowledge independently.		
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 min	30 min		
scale				
_	Electrical Engineering: Specialisation Information and Communi		sory	
Following Curricula	Aircraft Systems Engineering: Core qualification: Elective Comp	•		
	Information and Communication Systems: Specialisation Comm	, ,	,	
	Information and Communication Systems: Specialisation Secure			ective Compulsory
	International Management and Engineering: Specialisation II. In	formation Technology: Elective Co	ompulsory	

Course L0887: Simulation of	Communication Networks
	Project-/problem-based Learning
Hrs/wk	5
СР	6
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	SoSe
Content	In the course necessary basic stochastics and the discrete event simulation are introduced. Also simulation models for communication networks, for example, traffic models, mobility models and radio channel models are presented in the lecture. Students work with a simulation tool, where they can directly try out the acquired skills, algorithms and models. At the end of the course increasingly complex networks and protocols are considered and their performance is determined by simulation.
Literature	Skript des Instituts für Kommunikationsnetze Further literature is announced at the beginning of the lecture.

Module M0637: Adva	nced Concepts of Wireless Communic	ations		
Courses				
Title Advanced Concepts of Wireless Communications (L0297)		Typ Lecture	Hrs/wk	CP 4
Advanced Concepts of Wireless Cor	mmunications (L0298)	Recitation Section (large)	2	2
Module Responsible	Dr. Rainer Grünheid			
Admission Requirements	None			
Recommended Previous Knowledge	Lecture "Signals and Systems" Lecture "Fundamentals of Telecommunications a Lecture "Digital Communications"	and Stochastic Processes"		
Educational Objectives	After taking part successfully, students have reached t	he following learning results		
Skills Personal Competence Social Competence	Students are able to explain the general as well as advanced principles and techniques that are applied to wireless communications. They understand the properties of wireless channels and the corresponding mathematical description. Furthermore, students are able to explain the physical layer of wireless transmission systems. In this context, they are proficient in the concepts of multicarrier transmission (OFDM), modulation, error control coding, channel estimation and multi-antenna techniques (MIMO). Students can also explain methods of multiple access. On the example of contemporary communication systems (UMTS, LTE) they can put the learnt content into a larger context. Using the acquired knowledge, students are able to understand the design of current and future wireless systems. Moreover, given certain constraints, they can choose appropriate parameter settings of communication systems. Students are also able to assess the suitability of technical concepts for a given application.			
	can continuously check their level of expertise with the exercise tasks) and, based on that, to steer their learn of other lectures, e.g., "Fundamentals of Communication of Com	ing process accordingly. They can rela	te their acquired	knowledge to topics
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70)		
Credit points	6			
Course achievement	None			
Examination	Written exam			
	90 minutes; scope: content of lecture and exercise			
scale	Flanksian Famina anima Constallantian Info	Communication Contains Els. 11 C		
Assignment for the Following Curricula	Electrical Engineering: Specialisation Information and C Information and Communication Systems: Specialisation Microelectronics and Microsystems: Specialisation Com	on Communication Systems: Elective C	ompulsory	

Course L0297: Advanced Cor	ncepts of Wireless Communications
Тур	Lecture
Hrs/wk	3
СР	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Dr. Rainer Grünheid
Language	EN
Cycle	SoSe
	The lecture deals with technical principles and related concepts of mobile communications. In this context, the main focus is put on the physical and data link layer of the ISO-OSI stack. In the lecture, the transmission medium, i.e., the mobile radio channel, serves as the starting point of all considerations. The characteristics and the mathematical descriptions of the radio channel are discussed in detail. Subsequently, various physical layer aspects of wireless transmission are covered, such as channel coding, modulation/demodulation, channel estimation, synchronization, and equalization. Moreover, the different uses of multiple antennas at the transmitter and receiver, known as MIMO techniques, are described. Besides these physical layer topics, concepts of multiple access schemes in a cellular network are outlined. In order to illustrate the above-mentioned technical solutions, the lecture will also provide a system view, highlighting the basics of some contemporary wireless systems, including UMTS/HSPA, LTE, LTE Advanced, and WiMAX.
Literature	John G. Proakis, Masoud Salehi: Digital Communications. 5th Edition, Irwin/McGraw Hill, 2007 David Tse, Pramod Viswanath: Fundamentals of Wireless Communication. Cambridge, 2005 Bernard Sklar: Digital Communications: Fundamentals and Applications. 2nd Edition, Pearson, 2013 Stefani Sesia, Issam Toufik, Matthew Baker: LTE - The UMTS Long Term Evolution. Second Edition, Wiley, 2011

Course L0298: Advanced Concepts of Wireless Communications	
Тур	Recitation Section (large)
Hrs/wk	2
СР	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Rainer Grünheid
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Focus Signal Processing

Module M0550: Digita	al Image Analysis
Courses	
Title	Typ Hrs/wk CP
Digital Image Analysis (L0126)	Lecture 4 6
Module Responsible	
Admission Requirements	
Recommended Previous Knowledge	
Kilowiedge	transform, linear time-invariant systems), linear algebra (Eigenvalue decomposition, SVD), basic stochastics and statistics (expectation values, influence of sample size, correlation and covariance, normal distribution and its parameters), basics of Matlab,
	basics in optics
	ousies in optics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can
	Describe imaging processes
	Depict the physics of sensorics
	Explain linear and non-linear filtering of signals Figure 1 in the problem of the problem
	Establish interdisciplinary connections in the subject area and arrange them in their context
	Interpret effects of the most important classes of imaging sensors and displays using mathematical methods and physical
	models.
Skills	Students are able to
	Use highly sophisticated methods and procedures of the subject area
	Identify problems and develop and implement creative solutions.
	Students can solve simple arithmetical problems relating to the specification and design of image processing and image analysis
	systems.
	Students are able to assess different solution approaches in multidimensional decision-making areas.
	Students can undertake a prototypical analysis of processes in Matlab.
Personal Competence	
Social Competence	k.A.
Autonomy	Students can solve image analysis tasks independently using the relevant literature.
Autonomy	Statemes can solve intage analysis tasks independently using the relevant interactine.
Worldood in House	Independent Study Time 124, Study Time in Lecture 56
	Independent Study Time 124, Study Time in Lecture 56
Credit points	
Course achievement	
Examination	
Examination duration and	
scale	
Assignment for the	
Following Curricula	
	Electrical Engineering: Specialisation Medical Technology: Elective Compulsory
	Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory
	Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal
	Processing: Elective Compulsory
	International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory
	Missaclastranias and Missacratores, Consisting Communication and Cignal Proposition, Flority Communication
	Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory

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

Module M0677: Digita	al Signal Processing and Digital Filters			
Courses				
Title		Тур	Hrs/wk	СР
Digital Signal Processing and Digital		Lecture	3	4
Digital Signal Processing and Digital		Recitation Section (large)	2	2
Module Responsible				
Admission Requirements	None			
Recommended Previous	Mathematics 1-3			
Knowledge	Signals and Systems			
	 Fundamentals of signal and system theory as we 	l as random processes.		
	Fundamentals of spectral transforms (Fourier ser	es, Fourier transform, Laplace transf	form)	
Educational Objectives	After taking part successfully, students have reached th	e following learning results		
Professional Competence				
Knowledge	The students know and understand basic algorithms of			
	discrete-time signals and are able to describe and are	, ,	3	,
	structures of digital filters and can identify and a effects caused by quantization of filter coefficients an			
	perform traditional and parametric methods of spectrum			-
Skills	The students are able to apply methods of digital signa			
	filter striuctures. In particular, the can design adaptive		•	
	develop an efficient implementation, e.g. based on t	ne LMS or RLS algorithm. Further	more, the student	s are able to apply
	methods of spectrum estimation and to take the effects of a limited observation window into account.			
Personal Competence				
Social Competence	The students can jointly solve specific problems.			
Autonomy	The students are able to acquire relevant information	on from appropriate literature sou	rces. They can co	ontrol their level of
	knowledge during the lecture period by solving tutorial problems, software tools, clicker system.			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and	90 min			
scale				
Assignment for the	Electrical Engineering: Specialisation Control and Power		•	
Following Curricula				ativa Camarulana
	Information and Communication Systems: Specialisation Mechanical Engineering and Management: Specialisatio	•	-	ective Compulsory
	Mechatronics: Specialisation Intelligent Systems and Ro			
	Microelectronics and Microsystems: Specialisation Commission Commi		ective Compulsory	
	Theoretical Mechanical Engineering: Technical Complen	-		
	Theoretical Mechanical Engineering: Specialisation Robo		Compulsory	
L	<u> </u>			i

Course L0446: Digital Signal	Processing and Digital Filters
Тур	Lecture
Hrs/wk	3
СР	
	Independent Study Time 78, Study Time in Lecture 42
Lecturer	
Language Cycle	
Content	Transforms of discrete-time signals:
	Discrete-time Fourier Transform (DTFT)
	Discrete Fourier-Transform (DFT), Fast Fourier Transform (FFT)
	Z-Transform
	Correspondence of continuous-time and discrete-time signals, sampling, sampling theorem
	Fast convolution, Overlap-Add-Method, Overlap-Save-Method
	Fundamental structures and basic types of digital filters
	Characterization of digital filters using pole-zero plots, important properties of digital filters
	Quantization effects
	Design of linear-phase filters
	Fundamentals of stochastic signal processing and adaptive filters
	MMSE criterion
	Wiener Filter
	LMS- and RLS-algorithm
	Traditional and parametric methods of spectrum estimation
Literature	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 M0738: Digita	al Audio Signal Processing			
Courses				
Title		Тур	Hrs/wk	СР
Digital Audio Signal Processing (L06		Lecture	3	4
Digital Audio Signal Processing (L06		Recitation Section (large)	1	2
Module Responsible				
Admission Requirements				
Recommended Previous	Signals and Systems			
Knowledge				
-	After taking part successfully, students have reached the fo	llowing learning results		
Professional Competence	Die Studierenden können die grundlegenden Verfahren und			
Skills	die wesentlichen physikalischen Effekte bei der Sprach- ur können einen Überblick der numerischen Methoden Audiosignalverarbeitung geben. Sie können die erart Informationstechnik und Informatik abstrahieren. The students will be able to apply methods and technique communication. They can rely on elementary algorithms of applets. They can study parameter modifications and evaluations.	und messtechnischen Chara beiteten Algorithmen auf weite ues from audio signal processing of audio signal processing in form	kterisierung vol ere Anwendunge in the fields of n of Matlab code	n Algorithmen zur en im Bereich der mobile and internet and interactive JAVA
Personal Competence Social Competence	variety of applications beyond audio signal processing. So order to give objective and subjective quality measures with the students can work in small groups to study special the adequate methods during the exercise.	tudents can perform measurement has been dependent to the methods and app	nts in time and the lications.	frequency domain in
Autonomy	The students will be able to retrieve information out of the lecture. They can relate their gathered knowledge and relative systems, image and video processing, and pattern recognicand effects in the field audio signal processing.	ate them to other lectures (signal	s and systems, d	igital communication
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and	60 min			
scale				
Assignment for the	Electrical Engineering: Specialisation Information and Comm	nunication Systems: Elective Com	pulsory	
Following Curricula	Information and Communication Systems: Specialisation	Secure and Dependable IT S	ystems, Focus S	Software and Signal
	Processing: Elective Compulsory			
	Information and Communication Systems: Specialisation Co		_	
	Microelectronics and Microsystems: Specialisation Commun	ication and Signal Processing: Ele-	ctive Compulsory	

Course L0650: Digital Audio	Signal Processing
Тур	Lecture
Hrs/wk	3
СР	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Udo Zölzer
Language	EN
Cycle	WiSe
Content	Introduction (Studio Technology, Digital Transmission Systems, Storage Media, Audio Components at Home)
	Quantization (Signal Quantization, Dither, Noise Shaping, Number Representation)
	AD/DA Conversion (Methods, AD Converters, DA Converters, Audio Processing Systems, Digital Signal Processors, Digital Audio Interfaces, Single-Processor Systems, Multiprocessor Systems)
	Equalizers (Recursive Audio Filters, Nonrecursive Audio Filters, Multi-Complementary Filter Bank)
	Room Simulation (Early Reflections, Subsequent Reverberation, Approximation of Room Impulse Responses)
	Dynamic Range Control (Static Curve, Dynamic Behavior, Implementation, Realization Aspects)
	Sampling Rate Conversion (Synchronous Conversion, Asynchronous Conversion, Interpolation Methods)
	Data Compression (Lossless Data Compression, Lossy Data Compression, Psychoacoustics, ISO-MPEG1 Audio Coding)
Literature	- U. Zölzer, Digitale Audiosignalverarbeitung, 3. Aufl., B.G. Teubner, 2005 .
	- U. Zölzer, Digitale Audio Signal Processing, 2nd Edition, J. Wiley & Sons, 2005.
	- U. Zölzer (Ed), Digital Audio Effects, 2nd Edition, J. Wiley & Sons, 2011.

Course L0651: Digital Audio Signal Processing	
Тур	Recitation Section (large)
Hrs/wk	1
СР	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Udo Zölzer
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0556: Comp	uter Graphics			
Courses				
Title		Тур	Hrs/wk	СР
Computer Graphics (L0145) Computer Graphics (L0768)		Lecture Recitation Section (small)	2	3
Module Responsible	Prof. Tobias Knopp			
Admission Requirements	None			
Recommended Previous	Linear Algebra (in particular matrix/vector computation)	on)		
Knowledge	Basic programming skills in C/C++	on		
	Busic programming skins in eye i			
Educational Objectives	After taking part successfully, students have reached the fol	lowing learning results		
Professional Competence				
Knowledge	Students can explain and describe basic algorithms in 3D co	mputer graphics.		
Skills	Students are capable of			
	implementing a basic 3D rendering pipeline. This cor	nsists of projecting simple 3D stru	ıctures (e.g. cube	, spheres) onto a 2D
	surface using a virtual camera.			
	 apply geometric transformations (e.g. rotation, scalin 	g) in 2D and 3D computer graphi	cs.	
	using well-known 2D/3D APIs (OpenGL, Cairo) for solv	ving a given problem statement.		
Personal Competence				
Social Competence	Students can collaborate in a small team on the realization a	and validation of a 3D computer g	raphics pipeline.	
Autonomy				
riaconomy	Students are able to solve simple tasks independent!	•		
	 Students are able to solve detailed problems indeper 	ndently with the aid of the tutorial	's programming t	ask.
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				
_	Computer Science: Specialisation I. Computer and Software			
Following Curricula	Information and Communication Systems: Specialisation Cor	•	_	
	Information and Communication Systems: Specialisation	Secure and Dependable IT Sy	stems, Focus S	oπware and Signal
	Processing: Elective Compulsory International Management and Engineering: Specialisation II	Information Technology: Floctive	- Compulsory	
	international Management and Engineering. Specialisation in	. Information reciliology. Elective	compulsory	

Course L0145: Computer Gra	phics
Тур	Lecture
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	EN
Cycle	SoSe
	Computer graphics and animation are leading to an unprecedented visual revolution. The course deals with its technological foundations: Object-oriented Computer Graphics Projections and Transformations Polygonal and Parametric Modelling Illuminating, Shading, Rendering Computer Animation Techniques Kinematics and Dynamics Effects Students will be be working on a series of mini-projects which will eventually evolve into a final project. Learning computer graphics and animation resembles learning a musical instrument. Therefore, doing your projects well and in time is essential for performing well on this course.
Literature	Alan H. Watt: 3D Computer Graphics. Harlow: Pearson (3rd ed., repr., 2009). Dariush Derakhshani: Introducing Autodesk Maya 2014. New York, NY: Wiley (2013).

Course L0768: Computer Gra	urse L0768: Computer Graphics		
Тур	Recitation Section (small)		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Lecturer	Prof. Tobias Knopp		
Language	EN		
Cycle	SoSe		
Content	See interlocking course		
Literature	See interlocking course		

Module M1700: Satell	lite Communications and N	avigation			
Courses					
Title		Тур		Hrs/wk	СР
Radio-Based Positioning and Naviga	ation (L2711)	Lectu	ıre	2	3
Satellite Communications (L2710)		Lectu	ıre	2	3
Module Responsible	Prof. Gerhard Bauch				
Admission Requirements	None				
Recommended Previous					
Knowledge					
Educational Objectives	After taking part successfully, students	have reached the following lea	rning results		
Professional Competence					
Knowledge					
Skills					
Personal Competence					
Social Competence					
Autonomy					
Workload in Hours	Independent Study Time 124, Study Tir	me in Lecture 56			
Credit points	6				
Course achievement	None				
Examination	Oral exam				
Examination duration and	30 min				
scale					
Assignment for the	Electrical Engineering: Specialisation In	formation and Communication	Systems: Elective Compuls	ory	
Following Curricula	Information and Communication System	ns: Specialisation Communicati	ion Systems, Focus Signal P	rocessing: Electi	ive Compulsory
	Information and Communication Syst	tems: Specialisation Secure a	and Dependable IT Syste	ms, Focus Soft	ware and Signal
	Processing: Elective Compulsory				
	Microelectronics and Microsystems: Spe	ecialisation Communication and	d Signal Processing: Elective	e Compulsory	

Course L2711: Radio-Based F	Course L2711: Radio-Based Positioning and Navigation		
Тур	Lecture		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Lecturer	Prof. Gerhard Bauch, Dr. Ing. Rico Mendrzik		
Language	EN		
Cycle	SoSe		
Content			
Literature			

Course L2710: Satellite Com	Course L2710: Satellite Communications	
Тур	Lecture	
Hrs/wk	2	
СР	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Lecturer	Prof. Gerhard Bauch	
Language	EN	
Cycle	SoSe	
Content		
Literature		

Эуэссті				
Module M1702: Proce	ss Imaging			
Courses				
Title		Тур	Hrs/wk	СР
Process Imaging (L2723)		Lecture	2	3
Process Imaging (L2724)	_	Project-/problem-based Learning	2	3
Module Responsible	Prof. Alexander Penn			
Admission Requirements	None			
Recommended Previous				
Knowledge				
Educational Objectives	After taking part successfully, students have reached the follow	ing learning results		
Professional Competence				
Knowledge				
Skills				
Personal Competence				
Social Competence				
Autonomy				
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and	120 min			
scale				
Assignment for the	Bioprocess Engineering: Specialisation A - General Bioprocess E	naineerina: Elective Compulsory		
	Bioprocess Engineering: Specialisation A - General Bioprocess E			
	Bioprocess Engineering: Specialisation B - Industrial Bioprocess		,	
	Bioprocess Engineering: Specialisation B - Industrial Bioprocess	Engineering: Elective Compulsory	1	
	Bioprocess Engineering: Specialisation C - Bioeconomic Proces	ss Engineering, Focus Energy and	d Bioprocess T	echnology: Elective
	Compulsory			
	Bioprocess Engineering: Specialisation C - Bioeconomic Proces	ss Engineering, Focus Energy and	d Bioprocess T	echnology: Elective
	Compulsory			
	Chemical and Bioprocess Engineering: Specialisation General Pr	rocess Engineering: Elective Comp	oulsory	
	Chemical and Bioprocess Engineering: Specialisation General Pr	rocess Engineering: Elective Comp	oulsory	
	Chemical and Bioprocess Engineering: Specialisation Bioprocess	s Engineering: Elective Compulsor	У	
	Chemical and Bioprocess Engineering: Specialisation Bioprocess	s Engineering: Elective Compulsor	У	
	Chemical and Bioprocess Engineering: Specialisation Chemical			
	Chemical and Bioprocess Engineering: Specialisation Chemical		npulsory	
	Computer Science: Specialisation II: Intelligence Engineering: El			
	Information and Communication Systems: Specialisation Comm			
	International Management and Engineering: Specialisation II. Pr			ompulsory
	Theoretical Mechanical Engineering: Specialisation Robotics and Theoretical Mechanical Engineering: Specialisation Robotics and	'	. ,	
	Process Engineering: Specialisation Process Engineering: Electiv	•	ipuisui y	
	Process Engineering: Specialisation Process Engineering: Elective Process Engineering: Specialisation Process Engineering: Elective Process Engineering: Ele			
	Process Engineering: Specialisation Chemical Process Engineering:			
	Process Engineering: Specialisation Chemical Process Engineeri			
	Process Engineering: Specialisation Environmental Process Engineering	, ,		
	Process Engineering: Specialisation Environmental Process Engi			
	Water and Environmental Engineering: Specialisation Environmental			
	Water and Environmental Engineering: Specialisation Environmental	' '		
	Water and Environmental Engineering: Specialisation Water: Ele	. ,		
j	Water and Environmental Engineering. Specialisation Water. En	ective compaisory		

Course L2723: Process Imagi	urse L2723: Process Imaging		
Тур	Lecture		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Lecturer	Prof. Alexander Penn		
Language	EN		
Cycle	SoSe		
Content			
Literature			

Course L2724: Process Imaging	
Тур	Project-/problem-based Learning
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Penn
Language	EN
Cycle	SoSe
Content	
Literature	

Module M1598: Image	e Processing				
Courses					
Title Image Processing (L2443)		Typ Lecture Recitation Section (small)	Hrs/wk 2 2	CP 4 2	
Image Processing (L2444) Module Responsible	Prof. Tobias Knopp	Recitation Section (small)	2	2	
Admission Requirements	None				
Recommended Previous					
Knowledge	orginal and officering				
Educational Objectives	After taking part successfully, students have reached the	following learning results			
Professional Competence					
Knowledge	The students know about				
	visual perception				
	multidimensional signal processing				
	sampling and sampling theorem				
	• filtering				
	image enhancement				
	edge detection				
	 multi-resolution procedures: Gauss and Laplace py 	ramid, wavelets			
	image compression				
	image segmentation				
	morphological image processing				
Skills	The students can				
	analyze, process, and improve multidimensional image data				
	implement simple compression algorithms				
	design custom filters for specific applications				
Personal Competence					
Social Competence	Students can work on complex problems both independe	ntly and in teams. They can exchang	e ideas with eacl	other and use their	
	individual strengths to solve the problem.				
Autonomy	Students are able to independently investigate a complex	x problem and assess which compete	encies are require	d 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	1				
Following Curricula	1	•	oulsory		
	Electrical Engineering: Specialisation Medical Technology				
	Information and Communication Systems: Specialisation	•	-		
	Information and Communication Systems: Specialisat	ion Secure and Dependable IT Sy	rstems, Focus S	oπware and Signa	
	Processing: Elective Compulsory International Management and Engineering: Specialisation	in II. Information Technology: Flective	Compulsory		
	Microelectronics and Microsystems: Specialisation Comm				
	selectionics and Pherosystems. Specialisation Commi	aeacion and orginal riocessing. Liet	c compuisory		

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

Course L2444: Image Processing		
Тур	Recitation Section (small)	
Hrs/wk	2	
СР	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	

Focus Software

Module M0753: Softw	vare verification			
Courses				
Title		Тур	Hrs/wk	СР
Software Verification (L0629)		Lecture	2	3
Software Verification (L0630)	1	Recitation Section (small)	2	3
Module Responsible	Prof. Sibylle Schupp			
Admission Requirements	None			
Recommended Previous	 Automata theory and formal language 			
Knowledge	Computational logic			
	Object-oriented programming, algorithms, and data structures			
	Functional programming or procedural programming			
	Concurrency	, , , , , , , , , , , , , , , , , , , ,		
	·			
Educational Objectives	After taking part successfully, students have	reached the following learning results		
Professional Competence				
Knowledge				
	* * *	ques in model checking and deductive verificati		-
		d assess the expressivity of different logics as		-
	formal properties of software systems. They	find flaws in formal arguments, arising from mo	odeling artifacts or	r underspecification.
Skills	Students formulate provable properties of a	software system in a formal language. They de	evelop logic-based	models that properl
	abstract from the software under verification and, where necessary, adapt model or property. They construct proofs and property			
	checks by hand or using tools for model checking or deductive verification, and reflect on the scope of the results. Presented with			
	verification problem in natural language, they select the appropriate verification technique and justify their choice.			
Personal Competence				
Social Competence		ey defend their solutions orally. They communic	ate in English	
30ciai competence	Students discuss relevant topics in class. The	ey defend their solutions orany. They communic	ate iii Liigiisii.	
Autonomy	Using accompanying on-line material for s	elf study, students can assess their level of	knowledge contir	nuously and adjust
	appropriately. Working on exercise problems, they receive additional feedback. Within limits, they can set their own learning			
	goals. Upon successful completion, students can identify and precisely formulate new problems in academic or applied research in			
	s field, they can conduct independent studies	to acquire the nec	cessary competencie	
	and compile their findings in academic repor	ts. They can devise plans to arrive at new solut	ions or assess exi	sting ones.
Workload in Hours	Independent Study Time 124, Study Time in	Lecture 56		
Credit points				
Course achievement		Description		
	Yes 15 % Excercises			
Examination	Written exam			
Examination duration and	90 min			
scale				
Assignment for the	Computer Science: Specialisation I. Computer	er and Software Engineering: Elective Compulso	ry	
Following Curricula	Computational Science and Engineering: Spe	ecialisation I. Computer Science: Elective Comp	ulsory	
	Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory			
	Information and Communication Systems: Specialisation Secure and Dependable IT Systems: Compulsory			
	International Management and Engineering	Specialisation II. Information Technology: Elect	ive Compulsory	

Course L0629: Software Veri	fication					
Тур	Lecture					
Hrs/wk	2					
СР						
Workload in Hours	pendent Study Time 62, Study Time in Lecture 28					
Lecturer	Prof. Sibylle Schupp					
Language	EN					
Cycle	WiSe					
Content	Syntax and semantics of logic-based systems Deductive verification Specification Proof obligations Program properties Automated vs. interactive theorem proving Model checking Foundations Property languages Tool support Timed automata Recent developments of verification techniques and applications					
Literature	 C. Baier and J-P. Katoen, Principles of Model Checking, MIT Press 2007. M. Huth and M. Bryan, Logic in Computer Science. Modelling and Reasoning about Systems, 2nd Edition, 2004. Selected Research Papers 					

Course L0630: Software Veri	ourse L0630: Software Verification			
Тур	Typ Recitation Section (small)			
Hrs/wk	2			
СР	P 3			
Workload in Hours	dependent Study Time 62, Study Time in Lecture 28			
Lecturer	Lecturer Prof. Sibylle Schupp			
Language	EN			
Cycle	Cycle WiSe			
Content	See interlocking course			
Literature	Literature See interlocking course			

,				
Module M0733: Softw	vare Analysis			
Courses				
Title		Тур	Hrs/wk	СР
Software Analysis (L0631)		Lecture	2	3
Software Analysis (L0632)		Recitation Section (small)	2	3
Module Responsible	Prof. Sibylle Schupp			
Admission Requirements	None			
Recommended Previous	Basic knowledge of software-engineering activities			
Knowledge	Discrete algebraic structures			
	Object-oriented programming, algorithms, and data	structures		
	Functional programming or Procedural programmin			
	, , , , , , , , , , , , , , , , , , , ,			
Educational Objectives	After taking part successfully, students have reached the	following learning results		
Professional Competence				
Knowledge	Students apply the major approaches to data-flow ana			
	classification schemes, and employ abstract interpretat			
	models, including their mathematical structure and prope	•		
	and categorize the major analysis algorithms. They dis	stinguish precise solutions from a	proximative ap	proacnes, and snow
	termination and soundness properties.			
Skills	Presented with an analytical task for a software artifact, s	tudents select appropriate approach	es from software	analysis, and justify
	their choice. They design suitable representations by mod	difying standard representations. Th	ey develop custo	omized analyses and
	devise them as safe overapproximations. They formulate	analyses in a formal way and const	ruct arguments	for their correctness,
	behavior, and precision.			
Personal Competence				
Social Competence	Students discuss relevant topics in class. They defend the	ir solutions orally. They communicat	e in English.	
,			-	
Autonomy	Using accompanying on-line material for self study, stu		_	* *
	appropriately. Working on exercise problems, they rece		-	-
	goals. Upon successful completion, students can identify a			
	the field of software analysis. Within this field, they can compile their findings in academic reports. They can devise			
	compile their findings in academic reports. They can devis	se plans to arrive at new solutions of	assess existing	ones.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Subject theoretical and practical work			
Examination duration and	software artifacts/mathematical write-ups; short presental	tion		
scale				
Assignment for the	Information and Communication Systems: Specialisation C	Communication Systems, Focus Soft	ware: Elective Co	mpulsory
Following Curricula	Information and Communication Systems: Specialisation	on Secure and Dependable IT Sy	stems, Focus S	Software and Signal
	Processing: Elective Compulsory			
	International Management and Engineering: Specialisation	n II. Information Technology: Elective	Compulsory	

Course L0631: Software Ana	lysis					
Тур	Lecture					
Hrs/wk						
СР						
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28					
Lecturer	Prof. Sibylle Schupp					
Language	EN					
Cycle	WiSe					
Content						
	 Modeling: Control-Flow Modeling, Data Dependences, Intermediate Languages) Classical Bit-Vector Analyses (Reaching Definition, Very Busy Expressions, Liveness, Available Expressions, May/Must, Forward/Backward) Monotone Frameworks (Lattices, Transfer Functions, Ascending Chain Condition, Distributivity, Constant Propagation) Theory of Data-Flow Analysis (Tarski's Fixed Point Theorem, Data-Flow Equations, MFP Solution, MOP Solution, Worklist Algorithm) Non-Classical Data-Flow Analyses Abstract Interpretation (Galois Connections, Approximating Fixed Points, Construction Techniques) Type Systems (Type Derivation, Inference Trees, Algorithm W, Unification) Recent Developments of Analysis Techniques and Applications 					
Literature	 Flemming Nielsen, Hanne Nielsen, and Chris Hankin. Principles of Program Analysis. Springer, 2nd. ed. 2005. Uday Khedker, Amitabha Sanyal, and Bageshri Karkara. Data Flow Analysis: Theory and Practice. CRC Press, 2009. Benjamin Pierce, Types and Programming Languages, MIT Press. Selected research papers 					

Course L0632: Software Analysis					
Тур	ecitation Section (small)				
Hrs/wk	2				
СР					
Workload in Hours	dependent Study Time 62, Study Time in Lecture 28				
Lecturer	Prof. Sibylle Schupp				
Language	EN				
Cycle	WiSe				
Content	ee interlocking course				
Literature	ature See interlocking course				

Systems"					
Module M13	301: Software Testing				
Courses					
Title Software Testing (I		Typ Lecture	Hrs/wk	CP 3	
Software Testing (I		Project-/problem-based Learning	2	3	
Module Responsible					
Admission					
Requirements					
Recommended					
Previous					
Knowledge	Higher Programming Languages Object Oriented Programming				
	Object-Oriented Programming Algorithms and Data Structures				
	Experience with (Small) Software Projects				
	Statistics				
Educational Objectives		rning results			
Professional					
Competence					
Knowledge					
_	Students explain the different phases of testing, describe				
	techniques of different types of testing, and paraphrase				
	principles of the corresponding test process. They give e	•			
	software development scenarios and the corresponding technique. They explain algorithms used for particular to	= -			
	techniques and describe possible advantages and limital	5			
Skills	Students identify the appropriate testing type and techn problem. They adapt and execute respective algorithms concrete test technique properly. They interpret testing execute corresponding steps for proper re-test scenarios analyze test specifications. They apply bug finding techr non-trivial problems.	to execute a results and s. They write and			
Personal					
Competence					
Social		orally.			
Competence	They communicate in English.				
Autonomy	v Students can assess their level of knowledge continuously and adjust own learning goals. Upon successful completion, students can identify testing. Within this field, they can conduct independent studies to addevise plans to arrive at new solutions or assess existing ones	and precisely formulate new problems in	n academic or	applied research in	the field o
Workload in Hours					
Credit points	6				
Course					
achievement					
Examination					
Examination					
duration and					
Scale		og. Elective Compulser:			
Assignment for the			nnulsory		
Following				essing: Elective Con	npulsory
Curricula			-	-	
	ı				

Course L1791: Software Testing					
Тур	cture				
Hrs/wk	2				
СР	3				
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28				
Lecturer	Prof. Sibylle Schupp				
Language	N				
Cycle	oSe				
Content	 Fundamentals of software testing Model-based testing Test automation Criteria-based testing 				
Literature	 M. Pezze and M. Young, Software Testing and Analysis, John Wiley 2008. P. Ammann and J. Offutt, "Introduction to Software Testing", 2nd edition 2016. A. Zeller: "Why Programs Fail: A Guide to Systematic Debugging", 2nd edition 2012. 				

Course L1792: Software Test	ourse L1792: Software Testing			
Тур	roject-/problem-based Learning			
Hrs/wk	2			
СР	3			
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28			
Lecturer	Prof. Sibylle Schupp			
Language	EN			
Cycle	oSe			
Content	Fundamentals of software testing Model-based testing Test automation Criteria-based testing			
Literature	 M. Pezze and M. Young, Software Testing and Analysis, John Wiley 2008. P. Ammann and J. Offutt, "Introduction to Software Testing", 2nd edition 2015. 			

Module M1682: Secur	e Software Engineering			
Courses				
Title	Тур	р	Hrs/wk	СР
Secure Software Engineering (L266	7) Lect	cture	2	3
Secure Software Engineering (L266	8) Proj	ject-/problem-based Learning	2	3
Module Responsible	Prof. Riccardo Scandariato			
Admission Requirements	None			
Recommended Previous				
Knowledge				
Educational Objectives	After taking part successfully, students have reached the following le	earning results		
Professional Competence				
Knowledge				
Skills				
Personal Competence				
Social Competence				
Autonomy				
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and	120 min			
scale				
Assignment for the	Computer Science: Specialisation I. Computer and Software Engineer	ring: Elective Compulsory		
Following Curricula	Information and Communication Systems: Specialisation Secure	and Dependable IT Syste	ms, Focus So	oftware and Signal
	Processing: Elective Compulsory			
	Information and Communication Systems: Specialisation Communica	ation Systems, Focus Softwar	e: Elective Cor	mpulsory

Course L2667: Secure Softwa	urse L2667: Secure Software Engineering				
Тур	cture				
Hrs/wk					
СР					
Workload in Hours	dependent Study Time 62, Study Time in Lecture 28				
Lecturer	of. Riccardo Scandariato				
Language	EN				
Cycle	SoSe				
Content					
Literature					

Course L2668: Secure Software Engineering				
Тур	Project-/problem-based Learning			
Hrs/wk	2			
СР	3			
Workload in Hours	endent Study Time 62, Study Time in Lecture 28			
Lecturer	f. Riccardo Scandariato			
Language	d .			
Cycle	SoSe			
Content				
Literature				

Module M1397: Mode	l Checking - Pro	oof Engines and	Algorithms				
Courses							
Title				Тур	Hrs/wk	СР	
Model Checking - Proof Engines and	d Algorithms (L1979)			Lecture	2	3	
Model Checking - Proof Engines and	d Algorithms (L1980)			Recitation Section (small)	2	3	
Module Responsible	Prof. Görschwin Fey						
Admission Requirements	None						
Recommended Previous	Basic knowledge abou	ut data structures and al	gorithms				
Knowledge							
Educational Objectives	After taking part succ	essfully, students have r	eached the following	g learning results			
Professional Competence							
Knowledge	Students know						
1	• algorithms and	data structures for mod	ol chocking				
	_	an reasoning engines an	_				
				ional effort for model check	ring		
	• the impact of a	pecinication and modelin	ng on the computat	ional enore for model eneer	ang.		
Skills	Students can						
	Avnlain and im	nlement algorithms and	data structures for	model checking			
	-	explain and implement algorithms and data structures for model checking, decide whether a given problem can be solved using Replace reasoning or model checking, and					
		 decide whether a given problem can be solved using Boolean reasoning or model checking, and implement the respective algorithms. 					
	prement the	respective digoritanis					
Personal Competence							
Social Competence	Students						
	discuss relevan	nt topics in class and					
	defend their so						
	- defend their se	nations orany.					
Autonomy	Using accompanying	material students indep	pendently learn in-	depth relations between of	concepts explained	I in the lecture and	
	additional solution str	ategies.					
Workload in Hours	Independent Study Ti	Independent Study Time 124, Study Time in Lecture 56					
Credit points	6						
Course achievement	Compulsory Bonus	Form	Description	<u> </u>			
	Yes None	Subject theoretical	_	wird im Rahmen von Volres	-	lefiniert. Die Lösung	
		practical work	der Aufgabe i	st Zulassungsvoraussetzun	g für die Prüfung.		
Examination	Oral exam						
Examination duration and	30 min						
scale							
Assignment for the	Computer Science: Sp	pecialisation I. Computer	and Software Engir	neering: Elective Compulsor	ry		
Following Curricula	Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory						
	Information and Com	munication Systems: Spe	ecialisation Secure a	and Dependable IT Systems	: Elective Compuls	ory	

Course L1979: Model Checkin	ng - Proof Engines and Algorithms
Тур	Lecture
Hrs/wk	2
CP Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Görschwin Fey
Language	
Cycle	
Content	Correctness is a major concern in embedded systems. Model checking can fully automatically proof formal properties about digital hardware or software. Such properties are given in temporal logic, e.g., to prove "No two orthogonal traffic lights will ever be green." And how do the underlying reasoning algorithms work so effectively in practice despite a computational complexity of NP hardness
	and beyond?
	But what are the limitations of model checking?
	How are the models generated from a given design? The lecture will answer these questions. Open source tools will be used to gather a practical experience.
	Among other topics, the lecture will consider the following topics:
	Modelling digital Hardware, Software, and Cyber Physical Systems
	Data structures, decision procedures and proof engines
	Binary Decision Diagrams
	And-Inverter-Graphs
	Boolean Satisfiability
	Satisfiability Modulo Theories
	Specification Languages
	• CTL
	∘ LTL
	System Verilog Assertions
	Algorithms for
	Reachability Analysis
	Symbolic CTL Checking
	Bounded LTL-Model Checking
	Optimizations, e.g., induction, abstraction
	Quality assurance
Literature	Edmund M. Clarke, Jr., Orna Grumberg, and Doron A. Peled. 1999. <i>Model Checking</i> . MIT Press, Cambridge, MA, USA.
	A. Biere, A. Biere, M. Heule, H. van Maaren, and T. Walsh. 2009. <i>Handbook of Satisfiability: Volume 185 Frontiers in Artificial Intelligence and Applications.</i> IOS Press, Amsterdam, The Netherlands, The Netherlands.
	Selected research papers

Course L1980: Model Checkin	ourse L1980: Model Checking - Proof Engines and Algorithms			
Тур	Recitation Section (small)			
Hrs/wk	2			
СР	3			
Workload in Hours	lependent Study Time 62, Study Time in Lecture 28			
Lecturer	of. Görschwin Fey			
Language	E/EN			
Cycle	SoSe			
Content	e interlocking course			
Literature	See interlocking course			

Specialization Secure and Dependable IT Systems

Graduates of the Secure and Dependable IT Systems specialisation acquire extensive knowledge in software verification and IT security. They also have knowledge in communication networks and signal processing. They are able to apply methods and procedures required to work on secure and dependable IT systems, as well as critically examine new insights to further develop and incorporate in their work.

The Secure and Dependable IT Systems specialisation is recommended for students who already have a good mathematical foundation and basic knowledge in computer science and software development.

Module M0753: Softw	are Verification			
Courses				
Title Software Verification (L0629) Software Verification (L0630)		Typ Lecture Recitation Section (small)	Hrs/wk 2 2	CP 3 3
Module Responsible	Prof. Sibylle Schupp			
Admission Requirements	None			
Recommended Previous Knowledge	Automata theory and formal languages Computational logic Object-oriented programming, algorithms, and data Functional programming or procedural programmin Concurrency			
Educational Objectives	After taking part successfully, students have reached the	following learning results		
Professional Competence Knowledge				
Skills Personal Competence	Students apply the major verification techniques in mode and semantics of the underlying logics, and assess the formal properties of software systems. They find flaws in Students formulate provable properties of a software system abstract from the software under verification and, where checks by hand or using tools for model checking or deduverification problem in natural language, they select the assumption of the students discuss relevant topics in class. They defend the	expressivity of different logics as formal arguments, arising from mo tem in a formal language. They de necessary, adapt model or proper active verification, and reflect on the appropriate verification technique are resolutions or ally. They communicate the communication of the com	well as their limit deling artifacts or velop logic-based ity. They construct e scope of the resund justify their choose ate in English. knowledge continumits, they can setems in academic or	ations. They classify underspecification. models that properly proofs and property ults. Presented with a pice. uously and adjust it their own learning r applied research in
Workload in Hours	and compile their findings in academic reports. They can Independent Study Time 124, Study Time in Lecture 56	devise plans to arrive at new soluti	ons or assess exis	ting ones.
Credit points	, , , ,			
Course achievement		ption		
Examination	Written exam			
Examination duration and scale	90 min			
Assignment for the Following Curricula	Computer Science: Specialisation I. Computer and Softwa Computational Science and Engineering: Specialisation I. Information and Communication Systems: Specialisation of the Communication Systems: Specialisation Systems: S	Computer Science: Elective Compu	ilsory	mpulsory
	Information and Communication Systems: Specialisation Statement and Engineering: Specialisation	,	. ,	

Course L0629: Software Veri	fication				
Тур	Lecture				
Hrs/wk					
СР					
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28				
Lecturer	Prof. Sibylle Schupp				
Language	EN				
Cycle	WiSe				
Content	Syntax and semantics of logic-based systems Deductive verification Specification Proof obligations Program properties Automated vs. interactive theorem proving Model checking Foundations Property languages Tool support Timed automata Recent developments of verification techniques and applications				
Literature	 C. Baier and J-P. Katoen, Principles of Model Checking, MIT Press 2007. M. Huth and M. Bryan, Logic in Computer Science. Modelling and Reasoning about Systems, 2nd Edition, 2004. Selected Research Papers 				

Course L0630: Software Veri	urse L0630: Software Verification			
Тур	Recitation Section (small)			
Hrs/wk	2			
СР	3			
Workload in Hours	ependent Study Time 62, Study Time in Lecture 28			
Lecturer	. Sibylle Schupp			
Language	EN			
Cycle	WiSe			
Content	See interlocking course			
Literature	See interlocking course			

Module M0942: Softw	vare Security			
Courses				
Title		Тур	Hrs/wk	СР
Software Security (L1103)		Lecture	2	3
Software Security (L1104)		Recitation Section (small)	2	3
Module Responsible	Prof. Riccardo Scandariato			
Admission Requirements	None			
Recommended Previous	Familiarity with C/C++, web programming			
Knowledge				
Educational Objectives	After taking part successfully, students have reached the fo	llowing learning results		
Professional Competence				
Knowledge	Students can			
		6		
	 name the main causes for security vulnerabilities in s explain current methods for identifying and avoiding 			
	explain current methods for identifying and avoiding explain the fundamental concepts of code-based acc	•		
	explain the fundamental concepts of code-based acc	ess control		
Skills	Students are capable of			
	performing a software vulnerability analysis			
	developing secure code			
Personal Competence				
Social Competence	None			
Autonomy	Students are capable of acquiring knowledge independe	ntly from professional publicatio	ns, technical	standards, and other
	sources, and are capable of applying newly acquired knowle	edge to new problems.		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and	120 minutes			
scale				
Assignment for the	Computer Science: Specialisation I. Computer and Software	Engineering: Elective Compulsory		
Following Curricula	Computational Science and Engineering: Specialisation I. Co	omputer Science: Elective Compuls	sory	
	Information and Communication Systems: Specialisation Se	cure and Dependable IT Systems:	Elective Compu	ulsory

Course L1103: Software Seco	urity
Тур	Lecture
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Riccardo Scandariato
Language	EN
Cycle	WiSe
Content	 Reliability and Software Security Attacks exploiting character and integer representations Buffer overruns Vulnerabilities in memory managemet: double free attacks Race conditions SQL injection Cross-site scripting and cross-site request forgery Testing for security; taint analysis Type safe languages Development proceses for secure software Code-based access control
Literature	M. Howard, D. LeBlanc: Writing Secure Code, 2nd edition, Microsoft Press (2002) G. Hoglund, G. McGraw: Exploiting Software, Addison-Wesley (2004) L. Gong, G. Ellison, M. Dageforde: Inside Java 2 Platform Security, 2nd edition, Addison-Wesley (2003) B. LaMacchia, S. Lange, M. Lyons, R. Martin, K. T. Price: .NET Framework Security, Addison-Wesley Professional (2002) D. Gollmann: Computer Security, 3rd edition (2011)

ourse L1104: Software Security			
Тур	citation Section (small)		
Hrs/wk	2		
СР			
Workload in Hours	lependent Study Time 62, Study Time in Lecture 28		
Lecturer	of. Riccardo Scandariato		
Language	EN		
Cycle	WiSe		
Content	See interlocking course		
Literature	See interlocking course		

Module M1397: Mode	l Checking - Pro	oof Engines and	Algorithms			
Courses						
Title				Тур	Hrs/wk	СР
Model Checking - Proof Engines and	d Algorithms (L1979)			Lecture	2	3
Model Checking - Proof Engines and	d Algorithms (L1980)			Recitation Section (small)	2	3
Module Responsible	Prof. Görschwin Fey					
Admission Requirements	None					
Recommended Previous	Basic knowledge abou	ut data structures and alg	gorithms			
Knowledge						
Educational Objectives	After taking part succ	essfully, students have r	eached the following	ng learning results		
Professional Competence						
Knowledge	Students know					
	algorithms and	data structures for mod	el checking			
	_	an reasoning engines an	_			
				tional effort for model checki	na	
	and impact of s	premeasion and modelin	.g on the computation	cional chore for model check	9.	
Skills	Students can					
	explain and im	plement algorithms and	data structures for	model checking		
	7				king and	
		 decide whether a given problem can be solved using Boolean reasoning or model checking, and implement the respective algorithms. 				
	, , ,					
Personal Competence						
Social Competence	Students					
	discuss relevar	nt topics in class and				
	defend their so					
		,				
Autonomy	Using accompanying	material students indep	pendently learn in	-depth relations between co	oncepts explained	d in the lecture and
	additional solution str	ategies.				
Workload in Hours	Independent Study Ti	Independent Study Time 124, Study Time in Lecture 56				
Credit points						
Course achievement	Compulsory Bonus	Form	Description	united in Dalam		1-6-1-+ D:
	Yes None	Subject theoretical	-	wird im Rahmen von Volresu	-	geπniert. Die Losung
Programme 11	Oral avera	practical work	der Aufgabe i	st Zulassungsvoraussetzung	iui die Prutung.	
Examination						
Examination duration and	30 min					
scale			10.0 - :			
_				neering: Elective Compulsory		
Following Curricula	Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems: Elective Compulsory					
	Information and Comi	munication Systems: Spe	cialisation Secure	and Dependable IT Systems:	Elective Compuls	ory

Course L1979: Model Checki	ng - Proof Engines and Algorithms			
Тур				
Hrs/wk				
CP Workload in Hours				
Lecturer	Prof. Görschwin Fey			
Cycle				
Content	Correctness is a major concern in embedded systems. Model checking can fully automatically proof formal properties about digital hardware or software. Such properties are given in temporal logic, e.g., to prove "No two orthogonal traffic lights will ever be green."			
	And how do the underlying reasoning algorithms work so effectively in practice despite a computational complexity of NP hardness and beyond?			
	But what are the limitations of model checking?			
	How are the models generated from a given design?			
	The lecture will answer these questions. Open source tools will be used to gather a practical experience.			
	Among other topics, the lecture will consider the following topics:			
	Modelling digital Hardware, Software, and Cyber Physical Systems			
	Data structures, decision procedures and proof engines			
	Binary Decision Diagrams			
	And-Inverter-Graphs			
	Boolean Satisfiability			
	Satisfiability Modulo Theories			
	Specification Languages			
	• CTL			
	∘ LTL			
	System Verilog Assertions			
	Algorithms for			
	Reachability Analysis			
	Symbolic CTL Checking			
	Bounded LTL-Model Checking			
	Optimizations, e.g., induction, abstraction			
	Quality assurance			
Literature	Edmund M. Clarke, Jr., Orna Grumberg, and Doron A. Peled. 1999. <i>Model Checking</i> . MIT Press, Cambridge, MA, USA.			
	A. Biere, A. Biere, M. Heule, H. van Maaren, and T. Walsh. 2009. <i>Handbook of Satisfiability: Volume 185 Frontiers in Artificial Intelligence and Applications.</i> IOS Press, Amsterdam, The Netherlands, The Netherlands.			
	Selected research papers			

Course L1980: Model Checkin	ourse L1980: Model Checking - Proof Engines and Algorithms			
Тур	Recitation Section (small)			
Hrs/wk	2			
СР	3			
Workload in Hours	lependent Study Time 62, Study Time in Lecture 28			
Lecturer	of. Görschwin Fey			
Language	E/EN			
Cycle	SoSe			
Content	e interlocking course			
Literature	See interlocking course			

Module M1400: Desig	ın of Dependable	Systems					
Courses							
Title				Тур	Hrs/wk	СР	
Designing Dependable Systems (L2000)				Lecture	2	3	
Designing Dependable Systems (L2	2001)			Recitation Section (small)	2	3	
Module Responsible	Prof. Görschwin Fey						
Admission Requirements	None						
Recommended Previous	Basic knowledge about	data structures and alg	gorithms				
Knowledge							
Educational Objectives	After taking part succes	ssfully, students have r	eached the following	ng learning results			
Professional Competence							
Knowledge	In the following "depend	dable" summarizes the	concepts Reliabilit	ty, Availability, Maintainabili	ty, Safety and Secu	urity.	
	Knowledge about appro	oaches for designing de	pendable systems	, e.g.,			
	Structural solution	ons like modular redund	lancy				
	Algorithmic solut	ions like handling byza	ntine faults or che	ckpointing			
	Knowledge about math	ada far tha analysis of	dan an dahla ayatan				
	Knowledge about method	ous for the analysis of t	dependable system	15			
Skills	Ability to implement de	nendahle systems usin	a the above appro	aches			
Skins	Ability to implement de	pendable systems asm	g the above appro	acrics.			
	Ability to analyzs the de	Ability to analyzs the dependability of systems using the above methods for analysis.					
Personal Competence							
Social Competence	Students						
	discuss relevant	tonics in class and					
	present their solu	•					
	present their sen	acions orany.					
Autonomy			pendently learn in	-depth relations between c	oncepts explained	in the lecture and	
	additional solution strat						
Workload in Hours		e 124, Study Time in Lo	ecture 56				
Credit points		-	B				
Course achievement		Form Subject theoretical	Description	einer Aufgabe ist Zuslassun	asvoralissetziina t	iir die Priifung Die	
		practical work	_	in Vorlesung und Übung de	-	ar are fraiding. Die	
Examination		p		gg doi			
Examination duration and							
scale							
Assignment for the	Computer Science: Spe	cialisation I. Computer	and Software Engi	neering: Elective Compulsor	у		
Following Curricula	· ·	•	_	ter Science: Elective Compu	-		
	Information and Commi	unication Systems: Spe	cialisation Secure	and Dependable IT Systems	: Elective Compuls	ory	
	Mechatronics: Specialis	Mechatronics: Specialisation System Design: Elective Compulsory					
	Microelectronics and Mi	croelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory					

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

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

Focus Networks

Module M0676: Digita	al Communications			
Courses				
Title		Тур	Hrs/w	k CP
Digital Communications (L0444)		Lecture	2	3
Digital Communications (L0445)		Recitation Section	(large) 2	2
Laboratory Digital Communications	(L0646)	Practical Course	1	1
Module Responsible	Prof. Gerhard Bauch			
Admission Requirements	None			
Recommended Previous	Mathematics 1-3			
Knowledge	Signals and Systems			
	Fundamentals of Communications and	Random Processes		
	Fundamentals of Communications and	Random Frocesses		
Educational Objectives	After taking part successfully, students have r	eached the following learning results	5	
Professional Competence				
Knowledge	The students are able to understand, compare	e and design modern digital informat	ion transmission schen	nes. They are familiar with
	the properties of linear and non-linear digital	modulation methods. They can desc	ribe distortions caused	by transmission channels
	and design and evaluate detectors including	g channel estimation and equalizat	ion. They know the p	principles of single carrier
	transmission and multi-carrier transmission as	well as the fundamentals of basic m	nultiple access scheme	S.
Skills	The students are able to design and analyse a	a digital information transmission scl	neme including multiple	e access. They are able to
	choose a digital modulation scheme taking in	to account transmission rate, require	d bandwidth, error pro	bability, and further signal
	properties. They can design an appropria	te detector including channel est	imation and equalizat	tion taking into account
	performance and complexity properties of sub	ooptimum solutions. They are able to	set parameters of a si	ngle carrier or multi carrier
	transmission scheme and trade the properties	of both approaches against each ot	her.	
Personal Competence				
Social Competence	The students can jointly solve specific probler	ns.		
Autonomy	The students are able to acquire relevant	information from appropriate liter.	ature sources. They o	can control their level of
, iaconomy	knowledge during the lecture period by solvin		•	
		g,,,,,,,		
Workload in Hours	Independent Study Time 110, Study Time in L	ecture 70		
Credit points	6			
Course achievement	Compulsory Bonus Form	Description		
	Yes None Written elaboration			
Examination				
Examination duration and	90 min			
scale				
Assignment for the				
Following Curricula	Computational Science and Engineering: Spec			
	Information and Communication Systems: Spe	•		and a Clarking C
	Information and Communication Systems: Spe	·	-	
	International Management and Engineering: S	•	,	,
	International Management and Engineering: S		g: Elective Compulsory	
	Microelectronics and Microsystems: Core qual	ilication: Elective Compulsory		

Course L0444: Digital Comm	unications
Тур	Lecture
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	WiSe
Content	Digital modulation methods Coherent and non-coherent detection Channel estimation and equalization Single-Carrier- and multi carrier transmission schemes, multiple access schemes (TDMA, FDMA, CDMA, OFDM)
Literature	K. Kammeyer: Nachrichtenübertragung, Teubner P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner. J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill. S. Haykin: Communication Systems. Wiley R.G. Gallager: Principles of Digital Communication. Cambridge A. Goldsmith: Wireless Communication. Cambridge. D. Tse, P. Viswanath: Fundamentals of Wireless Communication. Cambridge.

ourse L0445: Digital Communications	
Тур	Recitation Section (large)
Hrs/wk	2
СР	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0646: Laboratory Di	Course L0646: Laboratory Digital Communications	
Тур	Practical Course	
Hrs/wk	1	
СР	1	
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14	
Lecturer	Prof. Gerhard Bauch	
Language	DE/EN	
Cycle	WiSe	
Content	- DSL transmission	
	- Random processes - Digital data transmission	
Literature	K. Kammeyer: Nachrichtenübertragung, Teubner	
	P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner.	
	J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill.	
	S. Haykin: Communication Systems. Wiley	
	R.G. Gallager: Principles of Digital Communication. Cambridge	
	A. Goldsmith: Wireless Communication. Cambridge.	
	D. Tse, P. Viswanath: Fundamentals of Wireless Communication. Cambridge.	

Courses				
Title		Тур	Hrs/wk	СР
Selected Topics of Communication Net	tworks (L0899)	Project-/problem-based Learning	2	2
Communication Networks (L0897)		Lecture	2	2
Communication Networks Excercise (L	· · · · · · · · · · · · · · · · · · ·	Project-/problem-based Learning	1	2
Module Responsible Pr				
	one			
Recommended Previous	Fundamental stochastics			
Knowledge	Basic understanding of computer networks and/or cor	mmunication technologies is beneficia	al	
Educational Objectives Af	Control in a control of the state of the sta	University of the second secon		
_	fter taking part successfully, students have reached the fol	llowing learning results		
Professional Competence	tudents are able to describe the principles and structure	os of communication notworks in de	stail Thou say	n avalain the formal
-	escription methods of communication networks and th		-	•
	ommunication networks work and describe the current rese		Apidiii iiow c	untene una complex
	tudents are able to evaluate the performance of communi		-	
	roblems themselves and apply the learned methods. They	can apply what they have learned	autonomously	on further and new
cc	ommunication networks.			
Personal Competence				
Social Competence St	Students are able to define tasks themselves in small teams and solve these problems together using the learned methods. They			
ca	can present the obtained results. They are able to discuss and critically analyse the solutions.			
Autonomy St	tudents are able to obtain the necessary expert knowledg	ge for understanding the functionalit	v and perform	nance canabilities of
•	ew communication networks independently.	ge for understanding the functionality	y una perion	nunce capabilities of
	dependent Study Time 110, Study Time in Lecture 70			
Credit points 6				
	one			
Examination Pr				
	1.5 hours colloquium with three students, therefore about 30 min per student. Topics of the colloquium are the posters from the			
·	revious poster session and the topics of the module.			
-	Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory			
-	lectrical Engineering: Specialisation Control and Power Systerist Systems Engineering: Core qualification: Elective Co	- ·	ory	
	omputational Science and Engineering: Specialisation I. Co		,	
	ornputational Science and Engineering. Specialisation is conformation and Communication Systems: Specialisation Sec			Elective Compulsory
	formation and Communication Systems: Specialisation Sec			
	sternational Management and Engineering: Specialisation II	•	-	
	echatronics: Technical Complementary Course: Elective Co	**		
	icroelectronics and Microsystems: Specialisation Communi	•	e Compulsory	

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

Course L0897: Communication	Course L0897: Communication Networks	
Тур	Lecture	
Hrs/wk	2	
СР	2	
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28	
Lecturer	Prof. Andreas Timm-Giel, DrIng. Koojana Kuladinithi	
Language	EN	
Cycle	WiSe	
Content		
Literature	Skript des Instituts für Kommunikationsnetze Tannenbaum, Computernetzwerke, Pearson-Studium Further literature is announced at the beginning of the lecture.	

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

Module M0837: Simul	ation of Communication Networks			
Courses				
Title		Тур	Hrs/wk	СР
Simulation of Communication Netw	· · ·	Project-/problem-based Learning	5	6
Module Responsible	Prof. Andreas Timm-Giel			
Admission Requirements	None			
Recommended Previous	Knowledge of computer and communication networks			
Knowledge	Basic programming skills			
	3			
	After taking part successfully, students have reached the follow	wing learning results		
Professional Competence				
Knowledge	Students are able to explain the necessary stochastics, the	discrete event simulation technolo	gy and modelli	ng of networks for
	performance evaluation.			
Skills	Students are able to apply the method of simulation for pe	erformance evaluation to different	, also not prac	ticed, problems of
	communication networks. The students can analyse the obtain	ned results and explain the effects	observed in the	network. They are
	able to question their own results.			
Personal Competence				
_	Students are able to acquire expert knowledge in groups, pre	esent the results, and discuss solu	tion approaches	and results. They
	are able to work out solutions for new problems in small teams			
Autonomy	Students are able to transfer independently and in discussion	•	od and expert	knowledge to new
	problems. They can identify missing knowledge and acquire th	ils knowledge independently.		
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 min			
scale				
Assignment for the	Electrical Engineering: Specialisation Information and Commun	nication Systems: Elective Compuls	sory	
Following Curricula	Aircraft Systems Engineering: Core qualification: Elective Com	•		
	Information and Communication Systems: Specialisation Comm	•	•	
	Information and Communication Systems: Specialisation Secur			ective Compulsory
	International Management and Engineering: Specialisation II. I	nformation Technology: Elective Co	ompulsory	

Course L0887: Simulation of	Communication Networks
Тур	Project-/problem-based Learning
Hrs/wk	5
СР	6
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	SoSe
Content	In the course necessary basic stochastics and the discrete event simulation are introduced. Also simulation models for communication networks, for example, traffic models, mobility models and radio channel models are presented in the lecture. Students work with a simulation tool, where they can directly try out the acquired skills, algorithms and models. At the end of the course increasingly complex networks and protocols are considered and their performance is determined by simulation.
Literature	Skript des Instituts für Kommunikationsnetze Further literature is announced at the beginning of the lecture.

- ,				
Module M0839: Traffi	c Engineering			
Courses				
Title		Тур	Hrs/wk	СР
Seminar Traffic Engineering (L0902	2)	Seminar	2	2
Traffic Engineering (L0900)		Lecture	2	2
Traffic Engineering Exercises (L090	21)	Recitation Section (small)	1	2
Module Responsible	Prof. Andreas Timm-Giel			
Admission Requirements	None			
Recommended Previous		a company the arm of the order		
Knowledge		r computer networks		
	Stochastics			
Educational Objectives	After taking part successfully, students ha	ave reached the following learning results		
Professional Competence				
Knowledge	Students are able to describe methods for	r planning, optimisation and performance evaluation	n of communication	on networks.
Skille	Students are able to solve typical plann	ing and optimisation tasks for communication net	tworks Furtherm	ore they are able to
Skills	evaluate the network performance using		.works. Turtiferin	ore triey are able to
	evaluate the network performance using t	queuing theory.		
	Students are able to apply independently	y what they have learned to other and new proble	ms. They can pro	esent their results in
	front of experts and discuss them.			
Personal Competence				
Social Competence				
Autonomy	Students are able to acquire the nece	essary expert knowledge to understand the fur	nctionality and p	performance of new
-	communication networks independently.			
Workload in Hours	Independent Study Time 110, Study Time	in Lecture 70		
Credit points				
Course achievement	None			
Examination				
Examination duration and	30 min			
scale				
_		uter and Software Engineering: Elective Compulsory		
Following Curricula	Electrical Engineering: Specialisation Infor	rmation and Communication Systems: Elective Com	pulsory	
	Information and Communication Systems:	: Specialisation Secure and Dependable IT Systems,	Focus Networks:	Elective Compulsory

Course L0902: Seminar Traff	ic Engineering
Тур	Seminar
Hrs/wk	2
СР	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Andreas Timm-Giel, Dr. Phuong Nga Tran
Language	EN
Cycle	WiSe
Content	Selected applications of methods for planning, optimization, and performance evaluation of communication networks, which have been introduced in the traffic engineering lecture are prepared by the students and presented in a seminar.
Literature	U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Vieweg + Teubner further literature announced in the lecture

Course L0900: Traffic Engineering		
Тур	Lecture	
Hrs/wk	2	
СР	2	
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28	
Lecturer	Prof. Andreas Timm-Giel, Dr. Phuong Nga Tran	
Language	EN	
Cycle	WiSe	
Content	Network Planning and Optimization	
	Linear Programming (LP)	
	Network planning with LP solvers	
	Planning of communication networks	
	Queueing Theory for Communication Networks	
	Stochastic processes	
	Queueing systems	
	Switches (circuit- and packet switching)	
	Network of queues	
Literature	Literatur:	
	U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer	
	Weitere Literatur wird in der Lehrveranstaltung bekanntgegeben	
	/	
	Literature:	
	U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer	
	further literature announced in the lecture	

Course L0901: Traffic Engineering Exercises		
Тур	Recitation Section (small)	
Hrs/wk	1	
СР	2	
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14	
Lecturer	Prof. Andreas Timm-Giel	
Language	EN	
Cycle	WiSe	
Content	Accompanying exercise for the traffic engineering course	
Literature	Literatur:	
	U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer	
	Weitere Literatur wird in der Lehrveranstaltung bekanntgegeben / Literature:	
	U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer	
	further literature announced in the lecture	

Focus Software and Signal Processing

Module M0738: Digita	I Audio Signal Processing			
Courses				
Title		Тур	Hrs/wk	СР
Digital Audio Signal Processing (L06	550)	Lecture	3	4
Digital Audio Signal Processing (L06	551)	Recitation Section (large)	1	2
Module Responsible	Prof. Udo Zölzer			
Admission Requirements	None			
Recommended Previous	Signals and Systems			
Knowledge				
Educational Objectives	After taking part successfully, students have reached t	he following learning results		
Professional Competence				
Knowledge	Die Studierenden können die grundlegenden Verfahre die wesentlichen physikalischen Effekte bei der Sprackönnen einen Überblick der numerischen Meth Audiosignalverarbeitung geben. Sie können die Informationstechnik und Informatik abstrahieren.	h- und Audiosignalverarbeitung erlä oden und messtechnischen Cha	utern und in Kate rakterisierung vo	gorien einordnen. Sie on Algorithmen zur
Skills	The students will be able to apply methods and techniques from audio signal processing in the fields of mobile and internet communication. They can rely on elementary algorithms of audio signal processing in form of Matlab code and interactive JAVA applets. They can study parameter modifications and evaluate the influence on human perception and technical applications in a variety of applications beyond audio signal processing. Students can perform measurements in time and frequency domain in order to give objective and subjective quality measures with respect to the methods and applications.			
Personal Competence Social Competence	The students can work in small groups to study speadequate methods during the exercise.	cial tasks and problems and will be	enforced to pres	ent their results with
Autonomy	The students will be able to retrieve information out of the relevant literature in the field and putt hem into the context of the lecture. They can relate their gathered knowledge and relate them to other lectures (signals and systems, digital communication systems, image and video processing, and pattern recognition). They will be prepared to understand and communicate problems and effects in the field audio signal processing.			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 50	5		
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and	60 min			
scale				
Assignment for the	Electrical Engineering: Specialisation Information and G	Communication Systems: Elective Co	mpulsory	
Following Curricula	Information and Communication Systems: Specialis	ation Secure and Dependable IT	Systems, Focus	Software and Signal
	Processing: Elective Compulsory			
	Information and Communication Systems: Specialisation	•	-	
	Microelectronics and Microsystems: Specialisation Com	munication and Signal Processing: E	lective Compulsor	У

Course L0650: Digital Audio	Signal Processing
Тур	Lecture
Hrs/wk	3
СР	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Udo Zölzer
Language	EN
Cycle	WiSe
Content	Introduction (Studio Technology, Digital Transmission Systems, Storage Media, Audio Components at Home)
	Quantization (Signal Quantization, Dither, Noise Shaping, Number Representation)
	 AD/DA Conversion (Methods, AD Converters, DA Converters, Audio Processing Systems, Digital Signal Processors, Digital Audio Interfaces, Single-Processor Systems, Multiprocessor Systems)
	Equalizers (Recursive Audio Filters, Nonrecursive Audio Filters, Multi-Complementary Filter Bank)
	Room Simulation (Early Reflections, Subsequent Reverberation, Approximation of Room Impulse Responses)
	Dynamic Range Control (Static Curve, Dynamic Behavior, Implementation, Realization Aspects)
	Sampling Rate Conversion (Synchronous Conversion, Asynchronous Conversion, Interpolation Methods)
	Data Compression (Lossless Data Compression, Lossy Data Compression, Psychoacoustics, ISO-MPEG1 Audio Coding)
Literature	- U. Zölzer, Digitale Audiosignalverarbeitung, 3. Aufl., B.G. Teubner, 2005 .
	- U. Zölzer, Digitale Audio Signal Processing, 2nd Edition, J. Wiley & Sons, 2005.
	- U. Zölzer (Ed), Digital Audio Effects, 2nd Edition, J. Wiley & Sons, 2011.

Course L0651: Digital Audio Signal Processing		
Тур	Recitation Section (large)	
Hrs/wk	1	
СР	2	
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14	
Lecturer	Prof. Udo Zölzer	
Language	EN	
Cycle	WiSe	
Content	See interlocking course	
Literature	See interlocking course	

Systems				
Module M0733: Softw	vare Analysis			
Courses				
Title		Тур	Hrs/wk	СР
Software Analysis (L0631)		Lecture	2	3
Software Analysis (L0632)		Recitation Section (small)	2	3
Module Responsible	Prof. Sibylle Schupp			
Admission Requirements	None			
Recommended Previous	Basic knowledge of software-engineering activities			
Knowledge	Discrete algebraic structures			
	Object-oriented programming, algorithms, and dat	a structures		
	Functional programming or Procedural programming	ng		
Educational Objectives	After taking part successfully, students have reached the	following loarning results		
Professional Competence	After taking part successiumy, students have reached the	Tollowing learning results		
•	Students apply the major approaches to data-flow an	alveis control flow analysis and to	ing based analyi	ris along with their
Knowieuge	classification schemes, and employ abstract interpreta			-
	models, including their mathematical structure and prop	* '		
	and categorize the major analysis algorithms. They d			
	termination and soundness properties.			
Skills	Presented with an analytical task for a software artifact, students select appropriate approaches from software analysis, and justify			
	their choice. They design suitable representations by mo		-	-
	devise them as safe overapproximations. They formulate behavior, and precision.	e analyses in a formal way and const	ruct arguments i	or their correctness,
	benavior, and precision.			
Personal Competence				
Social Competence	Students discuss relevant topics in class. They defend the	eir solutions orally. They communicat	e in English.	
Autonomy	Using accompanying on-line material for self study, st	udents can assess their level of k	nowledge continu	uously and adjust it
	appropriately. Working on exercise problems, they rec	eive additional feedback. Within lim	its, they can set	their own learning
	goals. Upon successful completion, students can identify	and precisely formulate new probler	ns in academic o	r applied research in
	the field of software analysis. Within this field, they can			
	compile their findings in academic reports. They can devi	ise plans to arrive at new solutions of	assess existing	ones.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None	<u> </u>		
Examination	Subject theoretical and practical work			
Examination duration and	software artifacts/mathematical write-ups; short presenta	ation		
scale				
Assignment for the	Information and Communication Systems: Specialisation	Communication Systems, Focus Soft	ware: Elective Co	mpulsory
Following Curricula	Information and Communication Systems: Specialisat	ion Secure and Dependable IT Sy	stems, Focus S	oftware and Signal
	Processing: Elective Compulsory			
	International Management and Engineering: Specialisation	n II. Information Technology: Elective	2 Compulsory	

Тур	Lecture
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	WiSe
Content	
	 Modeling: Control-Flow Modeling, Data Dependences, Intermediate Languages) Classical Bit-Vector Analyses (Reaching Definition, Very Busy Expressions, Liveness, Available Expressions, May/Mus Forward/Backward) Monotone Frameworks (Lattices, Transfer Functions, Ascending Chain Condition, Distributivity, Constant Propagation) Theory of Data-Flow Analysis (Tarski's Fixed Point Theorem, Data-Flow Equations, MFP Solution, MOP Solution, Workl Algorithm) Non-Classical Data-Flow Analyses Abstract Interpretation (Galois Connections, Approximating Fixed Points, Construction Techniques) Type Systems (Type Derivation, Inference Trees, Algorithm W, Unification) Recent Developments of Analysis Techniques and Applications
Literature	 Flemming Nielsen, Hanne Nielsen, and Chris Hankin. Principles of Program Analysis. Springer, 2nd. ed. 2005. Uday Khedker, Amitabha Sanyal, and Bageshri Karkara. Data Flow Analysis: Theory and Practice. CRC Press, 2009. Benjamin Pierce, Types and Programming Languages, MIT Press. Selected research papers

Course L0632: Software Analysis	
Тур	Recitation Section (small)
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0550: Digita	ii image Anaiysis		
Courses			
Title		rs/wk	CP
Digital Image Analysis (L0126)	Lecture 4		6
-	Prof. Rolf-Rainer Grigat		
Admission Requirements	None		
	System theory of one-dimensional signals (convolution and correlation, sampling theory, interpol		
Knowledge	transform, linear time-invariant systems), linear algebra (Eigenvalue decomposition, SVD), ba		
	(expectation values, influence of sample size, correlation and covariance, normal distribution and its	parameters	s), basics of Matia
	basics in optics		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence			
Knowledge	Students can		
	Describe imaging processes		
	Depict the physics of sensorics		
	Explain linear and non-linear filtering of signals		
	Establish interdisciplinary connections in the subject area and arrange them in their context		
	Interpret effects of the most important classes of imaging sensors and displays using mather	ematical me	thods and physic
	models.		
Skills	Students are able to		
	Use highly sophisticated methods and procedures of the subject area		
	Identify problems and develop and implement creative solutions.		
	deficitly problems and develop and implement electric solutions.		
	Students can solve simple arithmetical problems relating to the specification and design of image	processing	and image analy
	systems.		
	Students are able to assess different solution approaches in multidimensional decision-making areas	5.	
	Charles have a supplementary to the control of a supplementary to Makkets		
	Students can undertake a prototypical analysis of processes in Matlab.		
Porconal Compotonco			
Personal Competence Social Competence	L V		
30ciai Competence	N.M.		
Autonomy	Students can solve image analysis tasks independently using the relevant literature.		
	Independent Study Time 124, Study Time in Lecture 56		
Credit points			
Course achievement			
Examination	Written exam		
Examination duration and	60 Minutes, Content of Lecture and materials in StudIP		
scale			
Assignment for the	Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory		
Following Curricula		/	
-	Electrical Engineering: Specialisation Medical Technology: Elective Compulsory		
	Information and Communication Systems: Specialisation Communication Systems, Focus Signal Proc	essing: Elec	tive Compulsory
	Information and Communication Systems: Specialisation Secure and Dependable IT Systems	, Focus So	ftware and Sigr
	Processing: Elective Compulsory		
	International Management and Engineering: Specialisation II. Information Technology: Elective Comp	oulsory	
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory		
	Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Co		
	Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compul	Isory	

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

Title Typ Hrs/wk CP Software Testing (L1791) Software Testing (L1792) Project-/problem-based Learning 2 3 Module Responsible Admission Requirements	Systems"						
Trice Totaline 1 (1791)	Module M13	01: Software Testing					
Software Testing (1791) Lecture 2 3 Someware Testing (1792) Project-/groblem-based Learning 2 3 Someware Testing 2 3 Project-/groblem-based Learning 2	Courses						
Software Testing (1791) Lecture 2 3 Someware Testing (1792) Project-/groblem-based Learning 2 3 Someware Testing 2 3 Project-/groblem-based Learning 2	Title		Typ		Hrs/wk	СР	
Module Responsible Respo		1791)					
Recommended Provious None Software Engineering Software Engineering Higher Programming Languages Algorithms and Data Structures Experience with (Small) Software Projects Statistics Structures Experience with (Small) Software Projects Statistics Structures Software Engineering Software Projects Statistics Structures Software Engineering Software Projects Statistics Structures Software Engineering Structures Software Engineering Structures Software Engineering Software Projects Software Engineering Software Eng	Software Testing (L	1792)	Project-/problem-base	d Learning	2	3	
Admission Recommended Previous Recommended - Software Engineering - Higher Programming Languages - Object-Oriented Programming Languages - Object-Oriented Programming - Algorithms and Data Structures - Experience with (Small) Software Projects - Statistics - Experience with (Small) Software Projects - Statistics - Educational Objectives - Experience with (Small) Software Projects - Statistics - Experience Record Re	Module	Prof. Sibylle Schupp					
Recommented Previous Roomented Previous Substitute Substitute Programming Languages - Object-Oriented Programming Languages - Object-Oriented Programming Languages - Object-Oriented Programming Languages - Object-Oriented Programming Languages - Statistics Educational Objectives - Statistics Educational Objectives - Statistics Educational Competence Knowledge Students explain the different phases of testing, describe fundamental techniques of different types of testing, and paraphrase the basic principles of the corresponding test process. They give examples of software development scenarios and the corresponding test type and technique and describe possible advantages and limitations. Ställe Ställe Stüdents identify the appropriate testing type and technique for a given problem. They adapt and execute respective algorithms to execute a concrete test technique properly. They interpret testing results and execute corresponding steps for proper re-test scenarios. They write and analyze test specifications. They apply bug finding techniques for non-trivial problems. Personal Competence Social Students are sevent topics in class. They defend their solutions orally. They communicate in English. They communicate in English. Students an assess their level of knowledge continuously and adjust it appropriately, based on feedback and on self-guided studies. Within limits, they common learning agois. Upon successful completion, students can identify and precisely formulate new problems in academic or applied research in the field cheeping and process or assess existing ones achievement and pro	Responsible						
Software Engineering Higher Programming Languages Higher Programming Languages Object-Oriented Programming Languages Object-Oriented Programming Algorithms and Data Structures Experience with ISmall) Software Projects Statistics	Admission	None					
Previous Schware Engineering Schware E	Requirements						
Noveledge Algorithms and Data Structures Experience with (Small) Software Projects Statistics Stati	Recommended	Coffee on Familia and a					
Rowledge • Olgect-Oriented Programming - Algorithms and Data Structures • Experience with (Small) Software Projects • Statistics **Educational Objectives • Statistics **Professional Competence **Knowledge **Students explain the different phases of testing, describe fundamental techniques of different types of testing, and paraphrase the basic principles of the corresponding test process. They give examples of software development scenarios and the corresponding test type and technique. They explain algorithms used for particular testing techniques and describe possible advantages and limitations. **Skills Students identify the appropriate testing type and technique for a given problem. They adapt and execute respective algorithms to execute a concrete test technique properly. They interpret testing results and execute corresponding steps for proper re-test scenarios. They write and analyze test specifications. They apply bug finding techniques for non-trivial problems. **Personal** Competence** **Students discuss relevant topics in class. They defend their solutions orally.** They communicate in English. **Students can assess their level of knowledge continuously and adjust it appropriately, based on feedback and on self-guided studies. Within limits, they can will be a studies to acquire the necessary competencies and compile their findings in academic or applied research in the field of testing. Within this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports device plans to arrive at new solutions or assess soliting ones. **Workload in Moors** **	Previous						
Algorithms and Data Structures Experience with (Small) Software Projects Statistics After taking part successfully, students have reached the following learning results Objectives Profressional Competence Knowledge Students explain the different types of testing, describe fundamental techniques of different types of testing, and paraphrase the basic principles of the corresponding test process. They give examples of software development scenarios and the corresponding test type and technique, They explain algorithms used for particular testing techniques and describe possible advantages and limitations. Skills Students identify the appropriate testing type and technique for a given problem. They adapt and execute respective algorithms to execute a concrete test technique properly. They interpret testing results and execute corresponding steps for proper re-test scenarios. They write and analyze test specifications. They apply bug finding techniques for non-trivial problems. Personal Competence Social Competence Social Competence Students can assess their level of knowledge continuously and adjust it appropriately, based on feedback and on self-guided studies. Within limits, they can own learning goals. Upon successful completion, students can identify and precisely formulate new problems in academic or applied research in the field testing, within this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports, device plants to arrive at new solutions or assess existing ones Workload in Mours Credit point 6 Course None Schiewere Examination Subject theoretical and practical work Examination Subject theoretical and practical work Examination Subject theoretical and practical work	Knowledge						
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Hours Credit points 6 Course achievement Examination duration and scale		devise plans to arrive at new solutions or assess existing ones	5				
Hours Credit points 6 Course achievement Examination duration and scale	Workload in	Independent Study Time 124, Study Time in Lecture 56					
Course achievement Examination duration and scale		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,					
Course achievement Examination duration and scale		6					
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duration and scale							
scale							
Assignment Compact Science. Specialisation 1. Compact and Software Engineering. Elective Compaisory		Computer Science: Specialisation I. Computer and Software Er	ngineering: Flective Compulsory				
for the Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory				lective Com	nulsory		
Following Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory							
Curricula	_				. ,	5 222 00	, . ,

Course L1791: Software Testing		
Тур	Lecture	
Hrs/wk	2	
СР	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Lecturer	Prof. Sibylle Schupp	
Language	EN	
Cycle	SoSe	
Content	 Fundamentals of software testing Model-based testing Test automation Criteria-based testing 	
Literature	 M. Pezze and M. Young, Software Testing and Analysis, John Wiley 2008. P. Ammann and J. Offutt, "Introduction to Software Testing", 2nd edition 2016. A. Zeller: "Why Programs Fail: A Guide to Systematic Debugging", 2nd edition 2012. 	

Course L1792: Software Test	Course L1792: Software Testing			
Тур	Project-/problem-based Learning			
Hrs/wk	2			
СР	3			
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28			
Lecturer	Prof. Sibylle Schupp			
Language	EN			
Cycle	SoSe			
Content	 Fundamentals of software testing Model-based testing Test automation Criteria-based testing 			
Literature	 M. Pezze and M. Young, Software Testing and Analysis, John Wiley 2008. P. Ammann and J. Offutt, "Introduction to Software Testing", 2nd edition 2015. 			

Module M1682: Secur	e Software Engineering			
Courses				
Title		Тур	Hrs/wk	СР
Secure Software Engineering (L266	7)	Lecture	2	3
Secure Software Engineering (L266	8)	Project-/problem-based Learning	2	3
Module Responsible	Prof. Riccardo Scandariato			
Admission Requirements	None			
Recommended Previous				
Knowledge				
Educational Objectives	After taking part successfully, students have reached the follow	ving learning results		
Professional Competence				
Knowledge				
Skills				
Personal Competence				
Social Competence				
Autonomy				
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and	120 min			
scale				
Assignment for the	Computer Science: Specialisation I. Computer and Software En	gineering: Elective Compulsory		
Following Curricula	Information and Communication Systems: Specialisation Se	ecure and Dependable IT Syste	ems, Focus	Software and Signal
	Processing: Elective Compulsory			
	Information and Communication Systems: Specialisation Comm	nunication Systems, Focus Softwa	re: Elective C	ompulsory

Course L2667: Secure Softwa	ourse L2667: Secure Software Engineering		
Тур	Lecture		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Lecturer	Prof. Riccardo Scandariato		
Language	EN		
Cycle	SoSe		
Content			
Literature			

Course L2668: Secure Softwa	Course L2668: Secure Software Engineering		
Тур	Project-/problem-based Learning		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Lecturer	Prof. Riccardo Scandariato		
Language	EN		
Cycle	SoSe		
Content			
Literature			

Module M1700: Satell	lite Communications and	Navigation			
Courses					
Title		Ty	ур	Hrs/wk	СР
Radio-Based Positioning and Naviga	ation (L2711)	Le	ecture	2	3
Satellite Communications (L2710)		Le	ecture	2	3
Module Responsible	Prof. Gerhard Bauch				
Admission Requirements	None				
Recommended Previous					
Knowledge					
Educational Objectives	After taking part successfully, studen	nts have reached the following	learning results		
Professional Competence					
Knowledge					
Skills					
Personal Competence					
Social Competence					
Autonomy					
Workload in Hours	Independent Study Time 124, Study	Time in Lecture 56			
Credit points	6				
Course achievement	None				
Examination	Oral exam				
Examination duration and	30 min				
scale					
Assignment for the	Electrical Engineering: Specialisation	Information and Communication	on Systems: Elective Co	ompulsory	
Following Curricula	Information and Communication Syst	tems: Specialisation Communic	cation Systems, Focus S	ignal Processing: Ele	ective Compulsory
	Information and Communication S	systems: Specialisation Secure	e and Dependable IT	Systems, Focus S	oftware and Signal
	Processing: Elective Compulsory				
	Microelectronics and Microsystems: S	Specialisation Communication a	and Signal Processing: E	Elective Compulsory	

Course L2711: Radio-Based I	ourse L2711: Radio-Based Positioning and Navigation		
Тур	Lecture		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Lecturer	Prof. Gerhard Bauch, Dr. Ing. Rico Mendrzik		
Language	EN		
Cycle	SoSe		
Content			
Literature			

Course L2710: Satellite Com	Course L2710: Satellite Communications		
Тур	Lecture		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Lecturer	Prof. Gerhard Bauch		
Language	EN		
Cycle	SoSe		
Content			
Literature			

Module M0556: Comp	outer Graphics			
Courses				
Title		Тур	Hrs/wk	СР
Computer Graphics (L0145) Computer Graphics (L0768)		Lecture Recitation Section (small)	2	3
Module Responsible	Prof. Tobias Knopp			
Admission Requirements	None			
Recommended Previous	Linear Algebra (in particular matrix/vector computation))		
Knowledge	Basic programming skills in C/C++	,		
Educational Objectives	After taking part successfully, students have reached the follo	wing learning results		
Professional Competence				
Knowledge	Students can explain and describe basic algorithms in 3D com	puter graphics.		
Ckilla	Chudanta are concluded			
SKIIIS	Students are capable of			
	 implementing a basic 3D rendering pipeline. This cons 	sts of projecting simple 3D struc	ctures (e.g. cube	, spheres) onto a 2D
	surface using a virtual camera.			
	 apply geometric transformations (e.g. rotation, scaling) in 2D and 3D computer graphics. using well-known 2D/3D APIs (OpenGL, Cairo) for solving a given problem statement. 			
	• using well-known 2D/3D APIS (OpenGL, Cairo) for solving a given problem statement.			
Personal Competence				
Social Competence	Students can collaborate in a small team on the realization an	d validation of a 3D computer gr	aphics pipeline.	
Autonomy	Students are able to solve simple tasks independently	with reference to the contents o	f the lectures an	d the exercise sets
	Students are able to solve detailed problems independ			
			- 1 - 3 - 3	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points Course achievement				
Examination				
Examination duration and				
scale				
Assignment for the	Computer Science: Specialisation I. Computer and Software E	igineering: Elective Compulsory		
Following Curricula	Information and Communication Systems: Specialisation Com	nunication Systems, Focus Signa	al Processing: Ele	ective Compulsory
	Information and Communication Systems: Specialisation S	secure and Dependable IT Sy	stems, Focus S	oftware and Signal
	Processing: Elective Compulsory			
	International Management and Engineering: Specialisation II.	nformation Technology: Elective	Compulsory	

Course L0145: Computer Gra	phics
Тур	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	EN
Cycle	SoSe
Content	Computer graphics and animation are leading to an unprecedented visual revolution. The course deals with its technological foundations: Object-oriented Computer Graphics Projections and Transformations Polygonal and Parametric Modelling Illuminating, Shading, Rendering Computer Animation Techniques Kinematics and Dynamics Effects Students will be be working on a series of mini-projects which will eventually evolve into a final project. Learning computer graphics and animation resembles learning a musical instrument. Therefore, doing your projects well and in time is essential for performing well on this course.
Literature	Alan H. Watt: 3D Computer Graphics. Harlow: Pearson (3rd ed., repr., 2009). Dariush Derakhshani: Introducing Autodesk Maya 2014. New York, NY: Wiley (2013).

Course L0768: Computer Gra	ourse L0768: Computer Graphics		
Тур	Recitation Section (small)		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Lecturer	Prof. Tobias Knopp		
Language	EN		
Cycle	Cycle SoSe		
Content	See interlocking course		
Literature	See interlocking course		

Module M1598: Image	e Processing			
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			
Recommended Previous	Signal and Systems			
Knowledge				
Educational Objectives	After taking part successfully, students have reached	the following learning results		
Professional Competence				
Knowledge	The students know about			
	visual perception			
	multidimensional signal processing			
	sampling and sampling theorem			
	filtering			
	image enhancement			
	edge detection			
	multi-resolution procedures: Gauss and Laplac	e pyramid, wavelets		
	image compression			
	image segmentation			
	 morphological image processing 			
Skills	The students can			
	analyze, process, and improve multidimension	al image data		
	implement simple compression algorithms	aage aata		
	design custom filters for specific applications			
Personal Competence				
Social Competence	Students can work on complex problems both indepe	indently and in teams. They can exchang	e ideas with each	other and use their
Social competence	individual strengths to solve the problem.	indentity and in teams. They can exchang	je ideas with each	other and ase then
	individual strengths to solve the prosterin			
Autonomy	Students are able to independently investigate a con	nplex problem and assess which compete	encies are require	d 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 Compulsory	1		
Following Curricula			oulsory	
	Electrical Engineering: Specialisation Medical Techno			
	Information and Communication Systems: Specialisat			
	Information and Communication Systems: Special	isation Secure and Dependable IT Sy	stems, Focus S	oftware and Signa
	Processing: Elective Compulsory			
	International Management and Engineering: Specialis			
	Microelectronics and Microsystems: Specialisation Co	mmunication and Signal Processing: Elec	tive Compulsory	

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

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

Module M1694: Secur	ity of Cyber-Physical Systems			
Courses				
Title Security of Cyber-Physical Systems		Typ Lecture	Hrs/wk 2 2	CP 3 3
Security of Cyber-Physical Systems		Recitation Section (small)	2	3
Module Responsible Admission Requirements				
	IT security, programming skills, statistics			
Knowledge				
Educational Objectives	After taking part successfully, students have reache	ed the following learning results		
Professional Competence				
Knowledge	The students know and can explain			
	- the threats posed by cyber attacks to cyber-physi	cal systems (CPS)		
	- concrete attacks at a technical level, e.g. on bus s	systems		
	- security solutions specific to CPS with their capab	ilities and limitations		
	- examples of security architectures for CPS and the	e requirements they guarantee		
	- standard security engineering processes for CPS			
Skills	The students are able to			
	- identify security threats and assess the risks for a	a given CPS		
	- apply attack toolkits to analyse a networked cont	rol system, and detect attacks beyond tho	se taught in class	
	- identify and apply security solutions suitable to th	ne requirements		
	- follow security engineering processes to develop	a security architecture for a given CPS		
	- recognize challenges and limitations, e.g. posed l	by novel types of attack		
Personal Competence				
Social Competence	The students are able to			
	- expertly discuss security risks and incidents of experts	CPS and their mitigation in a solution-ori	ented fashion wi	th experts and non
	- foster a security culture with respect to CPS and t	he corresponding critical infrastructures		
Autonomy	The students are able to			
	- follow up and critically assess current developmer	nts in the security of CPS including relevant	security inciden	rs .
	- master a new topic within the area by self-study a	and self-initiated interaction with experts a	nd peers.	
Workload in Hours	Independent Study Time 124, Study Time in Lectur	e 56		
Credit points				
Course achievement				
	Written exam			
Examination duration and scale	120 min			
Assignment for the	Computer Science: Specialisation I. Computer and S	Software Engineering: Elective Compulsory		
Following Curricula	Information and Communication Systems: Special	, ,		oftware and Signa
-	Processing: Elective Compulsory			

Course L2691: Security of Cy	ber-Physical Systems
Тур	Lecture
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sibylle Fröschle
Language	EN
Cycle	WiSe
Content	Embedded systems in energy, production, and transportation are currently undergoing a technological transition to highly networked automated cyber-physical systems (CPS). Such systems are potentially vulnerable to cyber attacks, and these can have physical impact. In this course we investigate security threats, solutions and architectures that are specific to CPS. The topics are as follows:
	Fundamentals and motivating examples
	Networked and embedded control systems Bus system level attacks
	Intruder detection systems (IDS), in particular physics-based IDS System security architectures, including cryptographic solutions
	Adversarial machine learning attacks in the physical world
	Aspects of Location and Localization
	Wireless networks and infrastructures for critical applications Communication security architectures and remaining threats
	Intruder detection systems (IDS), in particular data-centric IDS
	Resilience against multi-instance attacks Security Engineering of CPS: Process and Norms
Literature	Recent scientific papers and reports in the public domain.

Course L2692: Security of Cyber-Physical Systems	
Тур	Recitation Section (small)
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sibylle Fröschle
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Thesis

Module M-002: Maste	er Thesis
Courses	
Title Title	Typ Hrs/wk CP
Module Responsible	Professoren der TUHH
Admission Requirements	
	According to General Regulations §21 (1):
	At least 60 credit points have to be achieved in study programme. The examinations board decides on exceptions.
Recommended Previous	
Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• The students can use specialized knowledge (facts, theories, and methods) of their subject competently on specialize
	issues.
	The students can explain in depth the relevant approaches and terminologies in one or more areas of their subject.
	describing current developments and taking up a critical position on them.
	• The students can place a research task in their subject area in its context and describe and critically assess the state
	research.
Skills	The students are able:
	To select, apply and, if necessary, develop further methods that are suitable for solving the specialized problem in questio
	To apply knowledge they have acquired and methods they have learnt in the course of their studies to complex and/
	incompletely defined problems in a solution-oriented way.
	To develop new scientific findings in their subject area and subject them to a critical assessment.
	3
Personal Competence	
Social Competence	Students can
	Both in writing and orally outline a scientific issue for an expert audience accurately, understandably and in a structure
	way.
	 Deal with issues competently in an expert discussion and answer them in a manner that is appropriate to the addresse
	while upholding their own assessments and viewpoints convincingly.
	3,
Autonomy	Students are able:
,	
	 To structure a project of their own in work packages and to work them off accordingly.
	To work their way in depth into a largely unknown subject and to access the information required for them to do so.
	To apply the techniques of scientific work comprehensively in research of their own.
Workload in Hours	Independent Study Time 900, Study Time in Lecture 0
Credit points	
Course achievement	
Examination	
Examination duration and	
scale	According to deficial negalations
	Civil Engineering: Thesis: Compulsory
Assignment for the Following Curricula	
. Jonowing Curricula	Chemical and Bioprocess Engineering: Thesis: Compulsory
	Computer Science: Thesis: Compulsory
	Electrical Engineering: Thesis: Compulsory
	Energy and Environmental Engineering: Thesis: Compulsory
	Energy Systems: Thesis: Compulsory
	Environmental Engineering: Thesis: Compulsory
	Aircraft Systems Engineering: Thesis: Compulsory
	Global Innovation Management: Thesis: Compulsory
	Computational Science and Engineering: Thesis: Compulsory
	Information and Communication Systems: Thesis: Compulsory
	Interdisciplinary Mathematics: Thesis: Compulsory
	International Management and Engineering: Thesis: Compulsory
	Joint European Master in Environmental Studies - Cities and Sustainability: Thesis: Compulsory
	Logistics, Infrastructure and Mobility: Thesis: Compulsory
	Materials Science: Thesis: Compulsory
	Mechanical Engineering and Management: Thesis: Compulsory
	Mechatronics: Thesis: Compulsory
	Biomedical Engineering: Thesis: Compulsory
	Microelectronics and Microsystems: Thesis: Compulsory
	Product Development, Materials and Production: Thesis: Compulsory
	Renewable Energies: Thesis: Compulsory

Systems	
	Naval Architecture and Ocean Engineering: Thesis: Compulsory
	Ship and Offshore Technology: Thesis: Compulsory
	Teilstudiengang Lehramt Metalltechnik: Thesis: Compulsory
	Theoretical Mechanical Engineering: Thesis: Compulsory
	Process Engineering: Thesis: Compulsory
	Water and Environmental Engineering: Thesis: Compulsory
	Certification in Engineering & Advisory in Aviation: Thesis: Compulsory