

### **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	
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	<ul> <li>Students are able to find their way around selected special areas of management within the scope of business management.</li> <li>Students are able to explain basic theories, categories, and models in selected special areas of business management.</li> <li>Students are able to interrelate technical and management knowledge.</li> </ul>
Skills	<ul> <li>Students are able to apply basic methods in selected areas of business management.</li> <li>Students are able to explain and give reasons for decision proposals on practical issues in areas of business management.</li> </ul>
Personal Competence	
Social Competence	Students are able to communicate in small interdisciplinary groups and to jointly develop solutions for complex problems
Autonomy	Students are capable of acquiring necessary knowledge independently by means of research and preparation of material.
Workload in Hours	Depends on choice of courses
Credit points	6

#### Courses

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

Module M0524: Non-technical Courses for Master		
Module Responsible	Dagmar Richter	
<b>Admission Requirements</b>	None	
Recommended Previous	None	
Knowledge		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results	
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#### **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)

	Students will be able
	to learn to collaborate in different manner,
	<ul> <li>to present and analyze problems in the abovementioned fields in a partner or group situation in a manner appropriate to the addressees,</li> </ul>
	<ul> <li>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),</li> </ul>
	to explain nontechnical items to auditorium with technical background knowledge.
Autonomy	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
	<ul> <li>to organize themselves as an entrepreneurial subject country (as far as this study-focus would be chosen)</li> </ul>
Workload in Hours	Depends on choice of courses
Credit points	

#### Courses

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

odule M1246: Techr	nical Complementary Course for IMPICS (according to Subject Specific Regul	ations)
Courses		
itle	Typ Hrs/wk	СР
Module Responsible	Prof. Andreas Timm-Giel	
Admission Requirements	None	
Recommended Previous		
Knowledge		
<b>Educational Objectives</b>	After taking part successfully, students have reached the following learning results	
<b>Professional Competence</b>		
Knowledge		
Skills		
<b>Personal Competence</b>		
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	mation Theory and Coding			
Courses				
Title Information Theory and Coding (LO- Information Theory and Coding (LO-		Typ Lecture Recitation Section (large)	Hrs/wk 3 2	<b>CP</b> 4 2
Module Responsible	Prof. Gerhard Bauch			
Admission Requirements	None			
Recommended Previous Knowledge	Mathematics 1-3	. from lecture "Fundamentals	of Communica	itions and Random
<b>Educational Objectives</b>	After taking part successfully, students have reached the follow	ring learning results		
<b>Professional Competence</b>				
	The students know the basic definitions for quantification of information in the sense of information theory. They know Shannon's source coding theorem and channel coding theorem and are able to determine theoretical limits of data compression and error-free data transmission over noisy channels. They understand the principles of source coding as well as error-detecting and error-correcting channel coding. They are familiar with the principles of decoding, in particular with modern methods of iterative decoding. They know fundamental coding schemes, their properties and decoding algorithms.  The students are able to determine the limits of data compression as well as of data transmission through noisy channels and based on those limits to design basic parameters of a transmission scheme. They can estimate the parameters of an error-detecting or error-correcting channel coding scheme for achieving certain performance targets. They are able to compare the properties of basic channel coding and decoding schemes regarding error correction capabilities, decoding delay, decoding complexity and to decide for a suitable method. They are capable of implementing basic coding and decoding schemes in software.			
Personal Competence				
Social Competence	The students can jointly solve specific problems.			
Autonomy	The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system.			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and	90 min			
scale	Sharking Foreign and a Consideration Information 1.0	Carting Contains Floridge C		
-	Electrical Engineering: Specialisation Information and Commun	, ,	,	
Following Curricula	Computational Science and Engineering: Specialisation II. Engir Information and Communication Systems: Core Qualification: C	-	sui y	
	International Management and Engineering: Specialisation II. El Mechatronics: Technical Complementary Course: Elective Comp	ectrical Engineering: Elective Co	mpulsory	

Course L0436: Information Th	heory and Coding	
Тур	Lecture	
Hrs/wk	3	
СР	4	
	Independent Study Time 78, Study Time in Lecture 42	
•	Prof. Gerhard Bauch	
Language		
Cycle	SoSe	
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	
	<ul> <li>Decoding principles: Maximum-A-Posteriori Decoding, Maximum-Likelihood Decoding, Hard-Decision-Decoding and Soft-Decision-Decoding</li> </ul>	
	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
Research Project (L1761)		Projection Course	10	15
Seminar (L0817)		Seminar	2	3
Module Responsible	Prof. Riccardo Scandariato			
Admission Requirements	None			
Recommended Previous	Basic knowledge and techniques in the chosen f	ield of specialization.		
Knowledge				
<b>Educational Objectives</b>	After taking part successfully, students have rea	ched the following learning results		
Professional Competence				
Knowledge	Students are able to acquire advanced knowledge	ge in a specific field of Computer Science o	or a closely related s	ubject.
Skills	Students are able to work self-dependent in a fig	eld of Computer Science or a closely relate	d field.	
Personal Competence				
Social Competence				
Autonomy				
Workload in Hours	Independent Study Time 372, Study Time in Lec	ture 168		
Credit points	18			
Course achievement	None			
Examination	Study work			
Examination duration and	Presentation of a current research topic (25-30 r	min and 5 min discussion).		
scale				
Assignment for the	Information and Communication Systems: Core	Qualification: Compulsory		
Following Curricula				

Course L1761: Research Project	
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	(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 Ra	andom Processes		
Educational Objectives	After taking part successfully, students have rea	ached the following learning results		
Professional Competence				
Knowledge	The students are able to understand, compare a	and design modern digital information trans	mission schemes.	They are familiar with
	the properties of linear and non-linear digital m	odulation methods. They can describe disto	rtions caused by t	ransmission channels
	and design and evaluate detectors including	channel estimation and equalization. The	know the princi	ples of single carrier
	transmission and multi-carrier transmission as v	vell as the fundamentals of basic multiple a	ccess schemes.	
Skills	The students are able to design and analyse a	digital information transmission scheme inc	uding multiple acc	ess. They are able to
	choose a digital modulation scheme taking into	·	•	
	properties. They can design an appropriate detector including channel estimation and equalization taking into account			
	performance and complexity properties of suboptimum solutions. They are able to set parameters of a single carrier or multi carrier			
	transmission scheme and trade the properties of	f both approaches against each other.		
Personal Competence				
Social Competence	The students can jointly solve specific problems	•		
Autonomy	The students are able to acquire relevant in	nformation from appropriate literature so	irces. They can o	control their level of
Autonomy	knowledge during the lecture period by solving		-	control then level of
	morneage daming the rectare period by sorting			
Workload in Hours	Independent Study Time 110, Study Time in Led	ture 70		
Credit points				
Course achievement	Compulsory Bonus Form	Description		
	Yes None Written elaboration			
	Written exam			
Examination duration and	90 min			
scale				
Assignment for the	Electrical Engineering: Core Qualification: Comp	ulsory		
Following Curricula	, , , , , , , , , , , , , , , , , , , ,			
	Information and Communication Systems: Speci	·	-	
	Information and Communication Systems: Speci	alisation Secure and Dependable IT System	s, Focus Networks	: Elective Compulsory
	International Management and Engineering: Spe			
	International Management and Engineering: Spe		e Compulsory	
	Microelectronics and Microsystems: Core Qualifi	cation: 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	<ul> <li>Digital modulation methods</li> <li>Coherent and non-coherent detection</li> <li>Channel estimation and equalization</li> <li>Single-Carrier- and multi carrier transmission schemes, multiple access schemes (TDMA, FDMA, CDMA, OFDM)</li> <li>K. Kammeyer: Nachrichtenübertragung, Teubner</li> </ul>
	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 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.		

Module M0710: Micro	wave Engineerin	ıg				
Courses						
Title Microwave Engineering (L0573) Microwave Engineering (L0574) Microwave Engineering (L0575)				Typ Lecture Recitation Section (large) Practical Course	Hrs/wk 2 2	CP 3 2
Module Responsible	Prof. Alexander Kölpin			Tractical course	-	1
Admission Requirements						
Recommended Previous Knowledge	Fundamentals of comm line theory and theoreti			evices and circuits. Basics o	f Wave propagatio	n from transmission
Educational Objectives	After taking part succes	sfully, students have re	ached the followi	ng learning results		
Professional Competence Knowledge	and components. They	can name different typ	es of antennas an	and related phenomena. T d describe the main charac ristic numbers and select th	teristics of antenn	as. They can explain
Skills	configure simple receiv	ver circuits. They can c noise of receivers and	alculate the char	etic waves. They can analy: acteristic of simple antenna se-ratio of transmission sys	as and arrays base	ed on the geometry.
Personal Competence Social Competence	Students work together	in small groups during	the practical cour	ses. Together they docume	nt, evaluate and di	scuss 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 Time	e 110, Study Time in Le	cture 70			
Credit points	6					
Course achievement	Yes None	Form Subject theoretical practical work	<b>Description</b> and			
Examination	Written exam					
Examination duration and scale	90 min					
Assignment for the Following Curricula	Information and Commu International Manageme	unication Systems: Specent and Engineering: Sp	cialisation Commu ecialisation II. Ele	inication Systems: Elective of ctrical Engineering: Elective on and Signal Processing: El	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
	Prof. Alexander Kölpin
Language	
Cycle	
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 En	ourse L0574: Microwave Engineering		
Тур	Recitation Section (large)		
Hrs/wk	2		
СР	2		
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28		
Lecturer	Prof. Alexander Kölpin		
Language	DE/EN		
Cycle	WiSe		
Content	See interlocking course		
Literature	See interlocking course		

Course L0575: Microwave En	ourse 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	Fundamental stochastics			
Knowledge		ou accompaniantian tachnalagias is banafisi	.1	
	Basic understanding of computer networks and/c	or communication technologies is beneficia	31	
Educational Objectives	After taking part successfully, students have reached the	ne following learning results		
Professional Competence				
Knowledge	Students are able to describe the principles and stru	ctures of communication networks in de	tail. They ca	an explain the formal
	description methods of communication networks an	d their protocols. They are able to ex	plain how	current and complex
	communication networks work and describe the curren	t research in these examples.		
G1 ''11				
Skills	Students are able to evaluate the performance of communication networks using the learned methods. They are able to work out			
	problems themselves and apply the learned methods.	They can apply what they have learned	autonomousi	y on further and new
	communication networks.			
Personal Competence				
Social Competence	Students are able to define tasks themselves in small teams and solve these problems together using the learned methods. They			
	can present the obtained results. They are able to discu	uss and critically analyse the solutions.		
A saka ma mass	Children are able to obtain the passessory average linear	uladas for understanding the functionality		manaa sanahilitias of
Autonomy	Students are able to obtain the necessary expert know	wiedge for understanding the functionalit	y and perior	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 at	out 30 min per student. Topics of the col	loquium are	the posters from the
scale	previous poster session and the topics of the module.			
Assignment for the	Electrical Engineering: Specialisation Information and C	ommunication Systems: Elective Compuls	ory	
Following Curricula	Electrical Engineering: Specialisation Control and Powe	r Systems Engineering: Elective Compulso	ry	
	Aircraft Systems Engineering: Core Qualification: Elective	ve Compulsory		
	Computational Science and Engineering: Specialisation	I. Computer Science: Elective Compulsory	,	
	Information and Communication Systems: Specialisatio	n Secure and Dependable IT Systems, Foo	us Networks	: Elective Compulsory
	Information and Communication Systems: Specialisatio	n Communication Systems: Elective Comp	oulsory	
	International Management and Engineering: Specialisat	ion II. Information Technology: Elective Co	ompulsory	
	Mechatronics: Technical Complementary Course: Electi	ve Compulsory		
	Microelectronics and Microsystems: Specialisation Com	munication and Signal Processing: Elective	e Compulsor	y

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	on 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	on 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

Title Typ Hrswk CP Selected Topics of Modern Wireless Systems (L1982) Project-/problem-based Learning 2 3 Modern Wireless Systems (L0296) Reasonsible Dr. Rainer Grünheid  Admission Requirements Recommended Previous Knowledge  Lecture "Advanced Concepts of Wireless Communications"  Lecture "Advanced Topics of Wireless Communications"	Module M0638: Mode	rn Wireless Sys	tems					
Selected Topics of Modern Wireless Systems (11982)  Modern Wireless Systems (10296)  Modern Wireless Systems (10296)  Module Responsible  Admission Requirements  None  Recommended Previous  Knowledge  Lecture "Digital Communications"  Lecture "Advanced Concepts of Wireless Systems of different size and complexity. They understand the technical solutions from the perspective of the physical and data link layer. They have developed a system view and are aware of the technical arguments, considering the respective applications and associated constraints. For several examples (e.g., Lon Term Evolution, LTE), students have are able to explain different concepts in a very deep technical detail.  Skills Students have developed a system view. They can transfer their knowledge to evaluate other systems, not discussed in the lecture, and to understand the respective technical solutions. Given specific contraints and technical requirements, students are a position to make proposals for certain design aspects by an appropriate assessment and the consideration of alternatives.  Personal Competence  Social Competence  Social Competence  Social Competence  Autonomy  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker question exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communicat	Courses							
Module Responsible   Dr. Rainer Grünheid   None	Title					Тур	Hrs/wk	СР
Module Responsible   Admission Requirements   Admission Requirements   Recommended Previous   Educational Objectives   Educational Objectives   Educational Objectives   After taking part successfully, students have reached the following learning results	1	S Systems (L1982)						
Admission Requirements Recommended Previous Knowledge  • Lecture "Digital Communications" • Lecture "Advanced Concepts of Wireless Communications"  Educational Objectives Professional Competence Knowledge  Students have an overview of a variety of contemporary wireless systems of different size and complexity. They understand the technical solutions from the perspective of the physical and data link layer. They have developed a system view and are aware of the technical arguments, considering the respective applications and associated constraints. For several examples (e.g., Lon Term Evolution, LTE), students are able to explain different concepts in a very deep technical detail.  Students have developed a system view. They can transfer their knowledge to evaluate other systems, not discussed in the lecture, and to understand the respective technical solutions. Given specific contraints and technical requirements, students are a position to make proposals for certain design aspects by an appropriate assessment and the consideration of alternatives.  Personal Competence Social Competence Social Competence Students can jointly elaborate tasks in small groups and present their results in an adequate fashion.  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker question exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours  Course achievement Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination  Examination duration and	Modern Wireless Systems (L0296)					Lecture	3	3
Recommended Previous Knowledge  Lecture "Digital Communications" Letture "Advanced Concepts of Wireless Communications"  Educational Objectives  Professional Competence Knowledge  Knowledge  Students have an overview of a variety of contemporary wireless systems of different size and complexity. They understand the technical solutions from the perspective of the physical and data link layer. They have developed a system view and are aware of the technical arguments, considering the respective applications and associated constraints. For several examples (e.g., Lon Term Evolution, LTE), students are able to explain different concepts in a very deep technical detail.  Skills  Students have developed a system view. They can transfer their knowledge to evaluate other systems, not discussed in the lecture, and to understand the respective technical solutions. Given specific contraints and technical requirements, students are a position to make proposals for certain design aspects by an appropriate assessment and the consideration of alternatives.  Personal Competence  Social Competence  Social Competence  Autonomy  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker question exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours  Course achievement  Course achievement  Course achievement  Examination  Oral exam  40 min  Examination duration and scale	Module Responsible	Dr. Rainer Grünheid						
** Lecture "Digital Communications"*     ** Lecture "Advanced Concepts of Wireless Communications"  Educational Objectives  Professional Competence  **Knowledge**  Students have an overview of a variety of contemporary wireless systems of different size and complexity. They understand the technical solutions from the perspective of the physical and data link layer. They have developed a system view and are aware of the technical arguments, considering the respective applications and associated constraints. For several examples (e.g., Lon Term Evolution, LTE), students are able to explain different concepts in a very deep technical detail.  Skills  Students have developed a system view. They can transfer their knowledge to evaluate other systems, not discussed in the lecture, and to understand the respective technical solutions. Given specific contraints and technical requirements, students are in a position to make proposals for certain design aspects by an appropriate assessment and the consideration of alternatives.  Personal Competence  Students can jointly elaborate tasks in small groups and present their results in an adequate fashion.  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker question exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours  Course achievement  Course ach	Admission Requirements	None						
Educational Objectives     After taking part successfully, students have reached the following learning results  Professional Competence     Knowledge     Students have an overview of a variety of contemporary wireless systems of different size and complexity. They understand the technical solutions from the perspective of the physical and data link layer. They have developed a system view and are aware the technical arguments, considering the respective applications and associated constraints. For several examples (e.g., Lon Term Evolution, LTE), students are able to explain different concepts in a very deep technical detail.  Skills     Stills Students have developed a system view. They can transfer their knowledge to evaluate other systems, not discussed in the lecture, and to understand the respective etchnical solutions. Given specific contraints and technical requirements, students are 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 elaborate tasks in small groups and present their results in an adequate fashion.  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker question exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours  Independent Study Time 110, Study Time in Lecture 70  Credit points  Course achievement  Compulsory Bonus Form Description Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination duration and Scale	Recommended Previous	• Locture "Digita	Communications	-11				
Educational Objectives  After taking part successfully, students have reached the following learning results  Professional Competence  Knowledge  Students have an overview of a variety of contemporary wireless systems of different size and complexity. They understand the technical solutions from the perspective of the physical and data link layer. They have developed a system view and are aware of the technical arguments, considering the respective applications and associated constraints. For several examples (e.g., Lon Term Evolution, LTE), students are able to explain different concepts in a very deep technical detail.  Skills  Students have developed a system view. They can transfer their knowledge to evaluate other systems, not discussed in the lecture, and to understand the respective technical solutions. Given specific contraints and technical requirements, students are in a position to make proposals for certain design aspects by an appropriate assessment and the consideration of alternatives.  Personal Competence  Social Competence  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker question exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours  Credit points  Compulsory Bonus form Description  Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination duration and 40 min  scale	Knowledge	_				II		
Professional Competence Knowledge  Students have an overview of a variety of contemporary wireless systems of different size and complexity. They understand the technical solutions from the perspective of the physical and data link layer. They have developed a system view and are aware of the technical arguments, considering the respective applications and associated constraints. For several examples (e.g., Lon Term Evolution, LTE), students are able to explain different concepts in a very deep technical detail.  Skills Students have developed a system view. They can transfer their knowledge to evaluate other systems, not discussed in the lecture, and to understand the respective technical solutions. Given specific contraints and technical requirements, students are it 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 elaborate tasks in small groups and present their results in an adequate fashion.  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker question exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours  Workload in Hours  Credit points  Compulsory Bonus Form Description Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination duration and 40 min		• Lecture Advan	ced Concepts of v	wireless Co	mmunications			
Students have an overview of a variety of contemporary wireless systems of different size and complexity. They understand the technical solutions from the perspective of the physical and data link layer. They have developed a system view and are aware of the technical arguments, considering the respective applications and associated constraints. For several examples (e.g., Lon Term Evolution, LTE), students are able to explain different concepts in a very deep technical detail.  Skills  Skills  Students have developed a system view. They can transfer their knowledge to evaluate other systems, not discussed in the lecture, and to understand the respective technical solutions. Given specific contraints and technical requirements, students are in a position to make proposals for certain design aspects by an appropriate assessment and the consideration of alternatives.  Personal Competence  Social Competence  Social Competence  Students can jointly elaborate tasks in small groups and present their results in an adequate fashion.  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker questions exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours  Credit points  Compulsory Bonus Form Description Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation  Examination duration and 40 min	Educational Objectives	After taking part succ	essfully, students	have reacl	ned the followi	ng learning results		
technical solutions from the perspective of the physical and data link layer. They have developed a system view and are aware of the technical arguments, considering the respective applications and associated constraints. For several examples (e.g., Lon Term Evolution, LTE), students are able to explain different concepts in a very deep technical detail.  Skills  Skills  Students have developed a system view. They can transfer their knowledge to evaluate other systems, not discussed in the lecture, and to understand the respective technical solutions. Given specific contraints and technical requirements, students are in 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 elaborate tasks in small groups and present their results in an adequate fashion.  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker questions exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours  Workload in Hours  Independent Study Time 110, Study Time in Lecture 70  Credit points  Compulsory Bonus Form Description Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation  Examination duration and practical work  Examination duration and 40 min	<b>Professional Competence</b>							
the technical arguments, considering the respective applications and associated constraints. For several examples (e.g., Lon Term Evolution, LTE), students are able to explain different concepts in a very deep technical detail.  Skills  Students have developed a system view. They can transfer their knowledge to evaluate other systems, not discussed in the lecture, and to understand the respective technical solutions. Given specific contraints and technical requirements, students are in a position to make proposals for certain design aspects by an appropriate assessment and the consideration of alternatives.  Personal Competence  Students can jointly elaborate tasks in small groups and present their results in an adequate fashion.  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker question exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours  Independent Study Time 110, Study Time in Lecture 70  Credit points  Compulsory Bonus Form Description  Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation  practical work  Examination duration and scale	Knowledge	Students have an ove	erview of a variet	y of conter	mporary wirele	ss systems of different size a	nd complexity.	They understand the
Term Evolution, LTE), students are able to explain different concepts in a very deep technical detail.  Students have developed a system view. They can transfer their knowledge to evaluate other systems, not discussed in the lecture, and to understand the respective technical solutions. Given specific contraints and technical requirements, students are in a position to make proposals for certain design aspects by an appropriate assessment and the consideration of alternatives.  Personal Competence  Students can jointly elaborate tasks in small groups and present their results in an adequate fashion.  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker questions exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours  Independent Study Time 110, Study Time in Lecture 70  Credit points  Course achievement  Compulsory Bonus Form Description Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation  practical work  Examination duration and Scale		technical solutions fro	m the perspectiv	e of the ph	ysical and dat	a link layer. They have develo	ped a system vi	ew and are aware of
Skills  Students have developed a system view. They can transfer their knowledge to evaluate other systems, not discussed in the lecture, and to understand the respective technical solutions. Given specific contraints and technical requirements, students are in 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 elaborate tasks in small groups and present their results in an adequate fashion.  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker questions exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours  Independent Study Time 110, Study Time in Lecture 70  Credit points  6  Compulsory Bonus Form Description Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination Oral exam  Examination duration and scale		the technical argume	nts, considering	the respec	tive application	ons and associated constraint	s. For several e	examples (e.g., Long
lecture, and to understand the respective technical solutions. Given specific contraints and technical requirements, students are in 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 elaborate tasks in small groups and present their results in an adequate fashion.    Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker question: exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".    Workload in Hours   Independent Study Time 110, Study Time in Lecture 70		Term Evolution, LTE),	students are able	e to explain	different conc	epts in a very deep technical o	letail.	
Personal Competence Social Competence Social Competence Students can jointly elaborate tasks in small groups and present their results in an adequate fashion.  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker question: exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours Credit points 6 Course achievement Compulsory Bonus Form Description Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination duration and scale  40 min	Skills	Students have develo	oped a system v	iew. They	can transfer t	heir knowledge to evaluate o	ther systems,	not discussed in the
Personal Competence Social Competence Social Competence Students can jointly elaborate tasks in small groups and present their results in an adequate fashion.  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker questions exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours Independent Study Time 110, Study Time in Lecture 70 Credit points 6 Course achievement Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination duration and Scale		lecture, and to unders	tand the respecti	ive technica	al solutions. Gi	ven specific contraints and ted	hnical requirem	ents, students are in
Students can jointly elaborate tasks in small groups and present their results in an adequate fashion.  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker questions exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours  Independent Study Time 110, Study Time in Lecture 70  Credit points 6  Course achievement  Compulsory Bonus Form Description  Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination duration and 40 min		a position to make pro	posals for certain	n design as	pects by an ap	propriate assessment and the	consideration o	f alternatives.
Autonomy  Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. The can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker questions exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours  Independent Study Time 110, Study Time in Lecture 70  Credit points  Course achievement  Compulsory Bonus Form Description  Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination Oral exam  Examination duration and 40 min	Personal Competence							
can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker question: exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours Independent Study Time 110, Study Time in Lecture 70  Credit points 6  Course achievement Compulsory Bonus Form Description Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination Oral exam  Examination duration and scale	Social Competence	Students can jointly e	laborate tasks in s	small group	s and present	their results in an adequate fa	shion.	
exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topic of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours Independent Study Time 110, Study Time in Lecture 70  Credit points 6  Course achievement Compulsory Bonus Form Description Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination Oral exam  Examination duration and scale	Autonomy	Students are able to e	xtract necessary	informatio	n from given lit	terature sources and put it into	the perspectiv	e of the lecture. They
of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".  Workload in Hours Independent Study Time 110, Study Time in Lecture 70  Credit points 6  Course achievement Compulsory Bonus Form Description Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination Oral exam  Examination duration and scale		can continuously che	ck their level of e	expertise w	ith the help of	accompanying measures (su	ch as online tes	ts, clicker questions,
Workload in Hours Independent Study Time 110, Study Time in Lecture 70  Credit points 6  Course achievement Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination Oral exam  Examination duration and scale		exercise tasks) and, b	ased on that, to s	steer their	learning proce	ss accordingly. They can relat	e their acquired	knowledge to topics
Credit points 6  Course achievement Yes None Subject theoretical and PBL-Kurs mit Poster präsentation practical work  Examination Oral exam  Examination duration and scale		of other lectures, e.g.	"Digital Commur	nications" a	nd "Advanced	Topics of Wireless Communication	ations".	
Credit points 6  Course achievement Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination Oral exam  Examination duration and scale	Workload in Hours	Independent Study Ti	ne 110. Study Tir	me in Lectu	re 70			
Course achievement Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination Oral exam  Examination duration and scale			ne 110, Study III	THE III LECTO	10 70			
Yes None Subject theoretical and PBL-Kurs mit Posterpräsentation practical work  Examination Oral exam  Examination duration and scale	•		Form		Description			
Examination Oral exam  Examination duration and scale	course acmevement	Yes None	Subject theor	retical an	dPBL-Kurs mit	Posterpräsentation		
Examination duration and scale 40 min			practical work					
scale	Examination	Oral exam						
	Examination duration and	40 min						
	scale							
Assignment for the   Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory	Assignment for the	Electrical Engineering	: Specialisation In	nformation	and Communic	ation Systems: Elective Comp	ulsory	
Following Curricula Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory	_		•				-	

Course L1982: Selected Topic	cs of Modern Wireless Systems
Тур	Project-/problem-based Learning
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Rainer Grünheid
Language	EN
Cycle	WiSe
Content	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 •
Litavatuva	will be avaided describe as the given toxics
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
	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	· · ·	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			
	After taking part successfully, students have reached the follow	wing learning results		
Professional Competence				
Knowledge	Students are able to explain the necessary stochastics, the c	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	rformance evaluation to different	, also not prac	ticed, problems of
	communication networks. The students can analyse the obtain	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, pre	sent the results, and discuss solu	tion approaches	and results. They
,	are able to work out solutions for new problems in small teams			Í
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	is 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				
_	Electrical Engineering: Specialisation Information and Commur	•	sory	
Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Com			
	Information and Communication Systems: Specialisation Comm	•	-	- the Comment
	Information and Communication Systems: Specialisation Secur			ective Compulsory
	International Management and Engineering: Specialisation II. II	ntormation Technology: Elective Co	ompuisory	

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 M0637: Adva	nced Concepts of Wireless Communic	ations		
Courses				
<b>Title</b> Advanced Concepts of Wireless Cor	mmunications (L0297)	<b>Typ</b> Lecture	Hrs/wk	<b>CP</b> 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.  Susing 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				
	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 Cor	ourse 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
<b>Educational Objectives</b>	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 literature.
Worldood in H	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	<ul> <li>Image representation, definition of images and volume data sets, illumination, radiometry, multispectral imaging, reflectivities, shape from shading</li> <li>Perception of luminance and color, color spaces and transforms, color matching functions, human visual system, color appearance models</li> <li>imaging sensors (CMOS, CCD, HDR, X-ray, IR), sensor characterization(EMVA1288), lenses and optics</li> <li>spatio-temporal sampling (interpolation, decimation, aliasing, leakage, moiré, flicker, apertures)</li> <li>features (filters, edge detection, morphology, invariance, statistical features, texture)</li> <li>optical flow (variational methods, quadratic optimization, Euler-Lagrange equations)</li> <li>segmentation (distance, region growing, cluster analysis, active contours, level sets, energy minimization and graph cuts)</li> <li>registration (distance and similarity, variational calculus, iterative closest points)</li> </ul>
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 Filte	rs		
Courses				
<b>Title</b> Digital Signal Processing and Digital Digital Signal Processing and Digital		<b>Typ</b> Lecture Recitation Section (large)	Hrs/wk 3 2	<b>CP</b> 4 2
Module Responsible	Prof. Gerhard Bauch			
Admission Requirements	None			
Recommended Previous Knowledge	<ul> <li>Mathematics 1-3</li> <li>Signals and Systems</li> <li>Fundamentals of signal and system theory as</li> <li>Fundamentals of spectral transforms (Fourier)</li> </ul>	·	ısform)	
Educational Objectives	After taking part successfully, students have reached	the following learning results		
Professional Competence		<u> </u>		
Skills  Personal Competence  Social Competence	The students know and understand basic algorithms of digital signal processing. They are familiar with the spectral transforms of discrete-time signals and are able to describe and analyse signals and systems in time and image domain. They know basic structures of digital filters and can identify and assess important properties including stability. They are aware of the effects caused by quantization of filter coefficients and signals. They are familiar with the basics of adaptive filters. They can perform traditional and parametric methods of spectrum estimation, also taking a limited observation window into account. The students are able to apply methods of digital signal processing to new problems. They can choose and parameterize suitable filter striuctures. In particular, the can design adaptive filters according to the minimum mean squared error (MMSE) criterion and develop an efficient implementation, e.g. based on the LMS or RLS algorithm. Furthermore, the students are able to apply methods of spectrum estimation and to take the effects of a limited observation window into account.  The students can jointly solve specific problems.			
	knowledge during the lecture period by solving tutor	al problems, software tools, clicker sy	rstem.	
Workload in Hours	Independent Study Time 110, Study Time in Lecture	70		
Credit points	6		-	
Course achievement	None			
Examination				
Examination duration and scale	90 min			
	Electrical Engineering: Specialisation Control and Pov	war Systams Engineering: Elective Cor	mouleon/	
Following Curricula	Computational Science and Engineering: Specialisation Information and Communication Systems: Specialisation Mechanical Engineering and Management: Specialisation Mechatronics: Specialisation Intelligent Systems and Microelectronics and Microsystems: Specialisation Communication Report Information Report Properties of Prope	on II. Engineering Science: Elective Co tion Communication Systems, Focus S tion Mechatronics: Elective Compulso Robotics: Elective Compulsory ommunication and Signal Processing:	impulsory iignal Processing: El ry Elective Compulsory	, ,

Course L0446: Digital Signal	Processing and Digital Filters
Тур	Lecture
Hrs/wk	3
СР	
	Independent Study Time 78, Study Time in Lecture 42
	Prof. Gerhard Bauch
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	ourse 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				
Skills	Die Studierenden können die grundlegenden Verfahren und Methoden der digitalen Audiosignalverarbeitung erklären. Sie können die wesentlichen physikalischen Effekte bei der Sprach- und Audiosignalverarbeitung erläutern und in Kategorien einordnen. Sie können einen Überblick der numerischen Methoden und messtechnischen Charakterisierung von Algorithmen zur Audiosignalverarbeitung geben. Sie können die erarbeiteten Algorithmen auf weitere Anwendungen im Bereich der Informationstechnik und Informatik abstrahieren.  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			
Personal Competence Social Competence	applets. They can study parameter modifications and evaluation of applications beyond audio signal processing. Storder to give objective and subjective quality measures with the students can work in small groups to study special that adequate methods during the exercise.	tudents can perform measurementh respect 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	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 Computer Graphics (L0145) Computer Graphics (L0768)		Typ Lecture Recitation Section (small)	Hrs/wk 2 2	<b>CP</b> 3 3
Module Responsible	Prof. Tobias Knopp	, , , , , , , , , , , , , , , , , , , ,		
Admission Requirements	None			
Recommended Previous				
Knowledge	Linear Algebra (in particular matrix/vector comput	ation)		
	Basic programming skills in C/C++			
Educational Objectives	After taking part successfully, students have reached the	following learning results		
Professional Competence				
Knowledge	Students can explain and describe basic algorithms in 3D	computer graphics.		
Skills	Students are capable of			
	<ul> <li>implementing a basic 3D rendering pipeline. This of surface using a virtual camera.</li> <li>apply geometric transformations (e.g. rotation, scan using well-known 2D/3D APIs (OpenGL, Cairo) for scan using well-known 2D/3D APIs (OpenGL, Cairo)</li> </ul>	aling) in 2D and 3D computer graph	-	spheres) onto a 2D
Personal Competence Social Competence	Students can collaborate in a small team on the realizatio	n and validation of a 3D computer	graphics pipeline.	
Autonomy	Students are able to solve simple tasks independe     Students are able to solve detailed problems independents.	•		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement				
Examination	Written exam			
Examination duration and scale	90 min			
Assignment for the	Computer Science: Specialisation I. Computer and Softwa	re Engineering: Elective Compulsor	Ту	
Following Curricula	Information and Communication Systems: Specialisation (		-	
	Information and Communication Systems: Specialisation	on Secure and Dependable IT S	Systems, Focus So	oftware and Signal
	Processing: Elective Compulsory	II Information Technology 51	in Committee :	
	International Management and Engineering: Specialisation	ı ii. iiiformation Technology: Electiv	ve compulsory	

Course L0145: Computer Gra	aphics
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
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	SoSe	
Content	See interlocking course	
Literature	See interlocking course	

Module M1700: Satell	lite Communications and Na	vigation		
Courses				
Title		Тур	Hrs/wk	СР
Radio-Based Positioning and Naviga	ation (L2711)	Lecture	2	3
Satellite Communications (L2710)		Lecture	2	3
Module Responsible	Prof. Gerhard Bauch			
Admission Requirements	None			
Recommended Previous				
Knowledge				
Educational Objectives	After taking part successfully, students h	nave reached the following learning results		
<b>Professional Competence</b>				
Knowledge				
Skills				
Personal Competence				
Social Competence				
Autonomy				
Workload in Hours	Independent Study Time 124, Study Tim	e in Lecture 56		
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and	30 min			
scale				
Assignment for the	Electrical Engineering: Specialisation Info	ormation and Communication Systems: Ele	ctive Compulsory	
Following Curricula	Information and Communication System	s: Specialisation Communication Systems,	Focus Signal Processing: Ele	ective Compulsory
	Information and Communication Syste	ems: Specialisation Secure and Dependa	able IT Systems, Focus S	oftware and Signal
	Processing: Elective Compulsory			
	Microelectronics and Microsystems: Spec	cialisation Communication and Signal Proce	essing: 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 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				
<b>Educational Objectives</b>	After taking part successfully, students have reached the follo	owing learning results		
<b>Professional Competence</b>				
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	Engineering: Elective Compulsory		
Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess			
3	Bioprocess Engineering: Specialisation B - Industrial Bioproce		/	
	Bioprocess Engineering: Specialisation B - Industrial Bioproce			
	Bioprocess Engineering: Specialisation C - Bioeconomic Prod			Technology: Elective
	Compulsory			
	Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective			
	Compulsory			
	Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory			
	Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory			
	Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory			
	Chemical and Bioprocess Engineering: Specialisation Bioproce	ess Engineering: Elective Compulsor	У	
	Chemical and Bioprocess Engineering: Specialisation Chemical	al Process Engineering: Elective Con	npulsory	
	Chemical and Bioprocess Engineering: Specialisation Chemical	al Process Engineering: Elective Con	npulsory	
	Computer Science: Specialisation II: Intelligence Engineering:	Elective Compulsory		
	Information and Communication Systems: Specialisation Com	nmunication Systems, Focus Signal F	Processing: Ele	ective Compulsory
	International Management and Engineering: Specialisation II.	Process Engineering and Biotechno	logy: Elective	Compulsory
	Theoretical Mechanical Engineering: Specialisation Robotics a	and Computer Science: Elective Com	pulsory	
	Theoretical Mechanical Engineering: Specialisation Robotics a	and Computer Science: Elective Com	pulsory	
	Process Engineering: Specialisation Process Engineering: Elec			
	Process Engineering: Specialisation Process Engineering: Elec	• •		
	Process Engineering: Specialisation Chemical Process Engineer	, ,		
	Process Engineering: Specialisation Chemical Process Engineer			
	Process Engineering: Specialisation Environmental Process En			
	Process Engineering: Specialisation Environmental Process En			
	Water and Environmental Engineering: Specialisation Environ			
	Water and Environmental Engineering: Specialisation Environ	• •		
	Water and Environmental Engineering: Specialisation Water:			
	Water and Environmental Engineering: Specialisation Water:	Elective Compulsory		

Course L2723: Process Imagi	ourse 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, Dr. Stefan Benders	
Language	EN	
Cycle	SoSe	
Content		
Literature		

Module M1598: Image	Processing			
Module M1596. Illiage	e Frocessing			
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				
<b>Educational Objectives</b>	After taking part successfully, students have reached the fol	lowing learning results		
<b>Professional Competence</b>				
Knowledge	The students know about			
	visual perception			
	multidimensional signal processing			
	sampling and sampling theorem			
	• filtering			
	image enhancement			
	edge detection			
	<ul> <li>multi-resolution procedures: Gauss and Laplace pyrar</li> </ul>	nid, wavelets		
	image compression			
	image segmentation			
	morphological image processing			
Skills	The students can			
	<ul> <li>analyze, process, and improve multidimensional image</li> </ul>	e data		
	implement simple compression algorithms			
	<ul> <li>design custom filters for specific applications</li> </ul>			
Personal Competence				
•	Students can work an complex problems both independently	, and in toams. Thou can exchang	o idoas with oach	other and use their
30ciai Cumpetence	Students can work on complex problems both independently individual strengths to solve the problem.	and in teams. They can exchang	e ideas with eath	Tottler and use their
	individual strengths to solve the problem.			
Autonomy	Students are able to independently investigate a complex pr	roblem 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			
Following Curricula	Data Science: Specialisation I. Mathematics/Computer Scien			
	Electrical Engineering: Specialisation Information and Comm		oulsory	
	Electrical Engineering: Specialisation Medical Technology: El			6 16 1
	Information and Communication Systems: Specialisation	Secure and Dependable IT Sy	stems, Focus S	ortware and Signal
	Processing: Elective Compulsory Information and Communication Systems: Specialisation Cor	mmunication Systems Focus Sign	al Processing: Ela	ctive Compulsory
	International Management and Engineering: Specialisation II			cave compuisory
	Mechatronics: Specialisation Intelligent Systems and Robotic		. Compuisory	
	Mechatronics: Specialisation intelligent Systems and Robotic  Mechatronics: Specialisation System Design: Elective Compu			
	Microelectronics and Microsystems: Specialisation Communi		tive Compulsorv	
	Theoretical Mechanical Engineering: Specialisation Robotics	-		

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	

ourse L2444: Image Processing		
	Recitation Section (small)	
Hrs/wk		
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)		Recitation Section (small)	2	3
Module Responsible	Prof. Sibylle Schupp			
Admission Requirements	None			
Recommended Previous	Automata theory and formal language	s		
Knowledge	Computational logic	5		
	Object-oriented programming, algorith	nms, and data structures		
	Functional programming or procedura			
	Concurrency			
Educational Objectives	After taking part successfully, students have	reached the following learning results		
<b>Professional Competence</b>				
Knowledge				
		ues in model checking and deductive verificati		-
		I assess the expressivity of different logics as		-
	formal properties of software systems. They	find flaws in formal arguments, arising from me	odeling artifacts or	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 neces		a and, where necessary, adapt model or prope	rty. They construc	t proofs and propert
	checks by hand or using tools for model chec	king or deductive verification, and reflect on the	ne scope of the res	sults. Presented with
	verification problem in natural language, the	y select the appropriate verification technique	and justify their ch	noice.
Personal Competence				
Social Competence	Students discuss relevant tenies in class. The	ey defend their solutions orally. They communic	cata in English	
Social Competence	students discuss relevant topics in class. The	ey defend their solutions orally. They communic	ate in English.	
Autonomy	Using accompanying on-line material for s	elf study, students can assess their level of	knowledge contin	nuously and adjust
	appropriately. Working on exercise problem	ns, they receive additional feedback. Within I	imits, they can se	et their own learning
	goals. Upon successful completion, students	can identify and precisely formulate new prob	lems in academic	or applied research i
	the field of software verification. Within this	field, they can conduct independent studies $% \frac{1}{2}\left( \frac{1}{2}\right) =\frac{1}{2}\left( \frac{1}{2}\right) =1$	to acquire the nec	essary 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	Compulsory Bonus Form	Description		
	Yes 15 % Excercises			
Examination	Written exam			
Examination duration and	90 min			
scale				
Assignment for the	Computer Science: Specialisation I. Compute	r and Software Engineering: Elective Compulso	ory	
Following Curricula		cialisation I. Computer Science: Elective Comp	-	
-		ecialisation Communication Systems, Focus So	•	ompulsory
	Information and Communication Systems: Sp	pecialisation Secure and Dependable IT System	s: Compulsory	•
	International Management and Engineering:	Consisting II Information Tasks along Flori	iua Camanulaanu	

Course L0629: Software Verification		
Тур	Lecture	
Hrs/wk	2	
CP	3	
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28	
Lecturer	Prof. Sibylle Schupp	
Language	EN	
Cycle	WiSe	
Content	<ul> <li>Syntax and semantics of logic-based systems</li> <li>Deductive verification         <ul> <li>Specification</li> <li>Proof obligations</li> <li>Program properties</li> <li>Automated vs. interactive theorem proving</li> </ul> </li> <li>Model checking         <ul> <li>Foundations</li> <li>Property languages</li> <li>Tool support</li> </ul> </li> <li>Timed automata</li> <li>Recent developments of verification techniques and applications</li> </ul>	
Literature	<ul> <li>C. Baier and J-P. Katoen, Principles of Model Checking, MIT Press 2007.</li> <li>M. Huth and M. Bryan, Logic in Computer Science. Modelling and Reasoning about Systems, 2nd Edition, 2004.</li> <li>Selected Research Papers</li> </ul>	

Course L0630: Software Veri	ourse L0630: Software Verification	
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 M0733: Softw	vare Analysis			
Courses				
Title		Тур	Hrs/wk	CP
Software Analysis (L0631)		Lecture	2	3
Software Analysis (L0632)		Recitation Section (small)	2	3
Module Responsible	Prof. Sibylle Schupp			
Admission Requirements	None			
Recommended Previous				
Knowledge		ies		
	Discrete algebraic structures	laka akusaksusa		
	Object-oriented programming, algorithms, and continued programming or Programming are programming.			
	Functional programming or Procedural programming	ming		
<b>Educational Objectives</b>	After taking part successfully, students have reached t	he following learning results		
<b>Professional Competence</b>				
Knowledge	Students apply the major approaches to data-flow	analysis, control-flow analysis, and t	pe-based analy	sis, along with their
	classification schemes, and employ abstract interpre	etation. They explain the standard fo	rms of internal	representations and
	models, including their mathematical structure and pro-	operties, and evaluate their suitability	for a particular a	nalysis. They explain
	and categorize the major analysis algorithms. They	distinguish precise solutions from a	pproximative ap	proaches, and show
	termination and soundness properties.			
Skills	Presented with an analytical task for a software artifac	t students select appropriate approach	nes from software	analysis and justify
Skins	s 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 modifying standard representations. They develop customized analyses and			
				-
	devise them as safe overapproximations. They formulate analyses in a formal way and construct arguments for their correctness, behavior, and precision.			
	,			
Personal Competence				
Social Competence	Students discuss relevant topics in class. They defend	their solutions orally. They communica	te in English.	
Autonomy	Using accompanying on-line material for self study,	students can assess their level of k	nowledge contin	uously and adjust it
j	appropriately. Working on exercise problems, they r			
	goals. Upon successful completion, students can identi	ify and precisely formulate new proble	ns in academic o	r applied research in
	the field of software analysis. Within this field, they ca	an conduct independent studies to acq	uire the necessa	ry competencies and
	compile their findings in academic reports. They can de	evise plans to arrive at new solutions o	r assess existing	ones.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 50			
Credit points		J		
Course achievement				
Examination				
Examination duration and				
scale				
Assignment for the	Information and Communication Systems: Specialisation	on Communication Systems, Focus Soft	ware: Elective Co	mpulsory
Following Curricula	· ·	·		
_	Processing: Elective Compulsory			3
	International Management and Engineering: Specialisa	tion II. Information Technology: Elective	e Compulsory	

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

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

Tries in the comment of the comment	Systems"					_
Tries in the comment of the comment	Module M13	801: Software Testing				
Software Testing (1379)   Software Engineering   Project-jupishiem-based Learning   2   3	Courses					
Software Testing (1379)   Software Engineering   Project-jupishiem-based Learning   2   3	Title		Tvp	Hrs/wk	СР	
Module   Rosponsible		.1791)				
Admission   Admi	Software Testing (L1	.1792)	Project-/problem-based Lear	ning 2	3	
Admission Requirements  Requirements  **Requirements  **Secondary Competence Statistics  **Professional Competence Knowledge Statistics  **Subject Statist	Module	Prof. Sibylle Schupp				_
Software Engineering	Responsible					
Software Engineering   Higher Programming Languages   Object-Oriented Programming Languages   Object-Oriented Programming Languages   Object-Oriented Programming   Algorithms and Data Structures   Experience with (Small) Software Projects   Statistics   Statistics   Statistics   Statistics   Statistics   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.    Statistics   Statistics   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-tests escenarios. They write and analyze test specifications. They apply bug finding techniques for non-trivial problems.    Personal Competence   Social 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-tests escenarios. They write and analyze test specifications. They apply bug finding techniques for non-trivial problems.    Personal Competence   Social Students and security testing	Admission	None				
Solution	Requirements					
**Nowledge** **Nowledge** - Object-Oriented Programming Languages	Recommended	Coffee on Francisco				
Competence 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 apply bug finding techniques for on-trivial problems.  Personal Competence  **Allorithms of the sexplain 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 types and technique. They explain algorithms used for particular testing techniques and describe possible advantages and limitations.  **Skilli**  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 analyze test specifications. They apply bug finding techniques for non-trivial problems.  **Personal**  Competence**  **Skuldents*  Students can assess their level of knowledge continuously and adjust it appropriately, based on feedback and on selfguided studies. Within limits, they can over learning goals. Upon successful completion, students can identify and precisely formulate new problems 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 devise plans to arrive at new solutions or assess existing ones  **One of the problems**  **Students**  **One of the problems**  **One of the problems**  **One of the problems**  **One of the problems**  **Allorenthms**  **One of the problems**  **O	Previous					
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### Educational Objectives  Professional Competence **Knowledge**  **Knowledge**  **Lidents 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 techniques and describe possible advantages and limitations.  **Skills**  **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 anon-trivial problems.  Personal Competence  **Social**  **Autonomy**  **Autonomy**  **Autonomy**  **Autonomy**  **Workload in Mours**  **Workload in Independent Study Time 124, Study Time in Lecture 56*  **Competence**  **Credit points**  **Original Independent Study Time 124, Study Time in Lecture 56*  **Credit points**  **Outpetence**  **Outpetence**  **Social**  **Workload in Independent Study Time 124, Study Time in Lecture 56*  **Credit points**  **Outpetence**  **Social**  **Outpetence**  **Outpetence**  **Social**  **Workload in Independent Study Time 124, Study Time in Lecture 56*  **Credit points**  **Outpetence**  **Social**  **Software**  **Outpetence**  **Social**  **Software**  **Credit points**  **Software**  **Credit points**  **Software**  **Software**  **Credit points**  **Software**  **Software**  **Software**  **Credit points**  **Software**  **						
After taking part successfully, students have reached the following learning results  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  Social  Competence  Autonomy  Students discuss relevant topics in class. They defend their solutions orally.  They communicate in English.  Autonomy  High thin this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports, devise plants to arrive at new solutions or assess existing ones  Workload in Independent Study Time 124, Study Time in Lecture 56  Course  None  achievement  Examination  Subject theoretical and practical work  Examination  Subject theoretical and practical work  Examination  Subject theoretical and practical work  Examination  Software  Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory						
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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   Social   Students discuss relevant topics in class. They defend their solutions orally. They communicate in English.    Autonomy   Students discuss relevant topics in class. They defend their solutions orally. They communicate in English.    Workload in Hours   House of the properties of the properti		After taking part successfully, students have reached the follow	ing learning results			
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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	-					
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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 They communicate in English.  Autonomy 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 of testing. Within this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports, devise plans to arrive at new solutions or assess existing ones  Workload in Hours Hours 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 own learning goals. Upon successful completion, students can identify and precisely formulate new problems 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, devise plans to arrive at new solutions or assess existing ones  Credit points  6  Course achievement  Subject theoretical and practical work  Examination Guardina and practi		Students identify the appropriate testing type and t	technique for a given			
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 seen to see the social Social Competence Social Social Social Competence Social So						
analyze test specifications. They apply bug finding techniques for non-trivial problems.  Personal Competence Social Competence Hot Competence They communicate in English.  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 own learning goals. Upon successful completion, students can identify and precisely formulate new problems 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 devise plans to arrive at new solutions or assess existing ones  Personal Competence 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 own learning goals. Upon successful completency students can identify and precisely formulate new problems 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. 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. In the field of testing, within this field, they can conduct independent studies. Within limits, they can own learning goals. Upon successful complete on the field of testing, within this field, they can conduct independent studies. Within limits, they can own learning goals. Upon successful completes in dependent studies. Within limits, they can own learning goals. Upon successful completes in adjust it appropriately, based on feedback and on self-guided studies. Within limits, they can own learning goals. Within this field, they can own learning goa						
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Personal Competence Social Competence Autonomy Autonomy Workload in Hours  Credit points Examination Examination Ausonamiation Examination duration and scale Assignment  Competence Competence Autonomy Autonomy Competence Autonomy 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 of testing. Within this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports, devise plans to arrive at new solutions or assess existing ones  Workload in Hours  Credit points  6  None Software  Assignment  Course achievement  Software  Course achievement  Course achieve		analyze test specifications. They apply bug finding	techniques for			
Competence Social Competence Social Competence Autonomy Autonomy Workload in Hours  Credit points achievement Examination duration and scale  Assignment  Competence Social Competence Social Competence Social Competence Social Competence Autonomy 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 of testing. Within this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports. Independent Study Time 124, Study Time in Lecture 56  Course achievement  Examination duration and scale Assignment Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory		non-trivial problems.				
Competence Social Competence Social Competence Autonomy Autonomy Workload in Hours  Credit points achievement Examination duration and scale  Assignment  Competence Social Competence Social Competence Social Competence Social Competence Autonomy 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 of testing. Within this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports. Independent Study Time 124, Study Time in Lecture 56  Course achievement  Examination duration and scale Assignment Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory						
Social Competence Competence Autonomy 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 of testing. Within this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports. devise plans to arrive at new solutions or assess existing ones  Workload in Hours  Credit points 6  Course achievement Examination duration and scale  Assignment Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory						
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Autonomy 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 of testing. Within this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports. devise plans to arrive at new solutions or assess existing ones    Workload in Hours   Hours			tions orany.			
own learning goals. Upon successful completion, students can identify and precisely formulate new problems 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 devise plans to arrive at new solutions or assess existing ones    Workload in Hours   Independent Study Time 124, Study Time in Lecture 56	Competence	They communicate in English.				
testing. Within this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports devise plans to arrive at new solutions or assess existing ones  Workload in Hours  Credit points  6  Course achievement  Examination duration and scale  Assignment  Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory						
devise plans to arrive at new solutions or assess existing ones  Workload in Hours  Credit points 6  Course achievement Examination duration and scale  Assignment Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory						
Workload in Hours  Credit points 6  Course achievement  Examination duration and scale  Assignment  Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory			es to acquire the necessary competencies	and compile their	findings in academic	c reports.
Hours  Credit points 6  Course achievement  Examination duration and scale  Assignment Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory		devise plans to arrive at new solutions or assess existing ones				
Hours  Credit points 6  Course achievement  Examination duration and scale  Assignment Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory	Workload in	Independent Study Time 124, Study Time in Lecture 56				
Course achievement  Examination Subject theoretical and practical work  Examination duration and scale  Assignment Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory		, , , , , , , , , , , , , , , , , , , ,				
Course achievement  Examination Subject theoretical and practical work  Examination duration and scale  Assignment Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory	Credit noints	6				
achievement  Examination Subject theoretical and practical work  Examination duration and scale  Assignment Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory	-					
Examination Subject theoretical and practical work  Examination duration and scale  Assignment Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory		INOTIC				
Examination duration and scale  Assignment Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory	+	Subject theoretical and practical work				
duration and scale  Assignment Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory						
scale Assignment Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory		Software				
Assignment Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory	auration and					
	scale					
for the Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory		Computer Science: Specialisation I. Computer and Software Eng	ineering: Flective Compulsory			
	Assignment			e Compulsorv		
Curricula	Assignment for the	Information and Communication Systems: Specialisation Commu	unication Systems, Focus Software: Electiv		essing: Elective Com	pulsorv

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	<ul> <li>Fundamentals of software testing</li> <li>Model-based testing</li> <li>Test automation</li> <li>Criteria-based testing</li> </ul>	
Literature	<ul> <li>M. Pezze and M. Young, Software Testing and Analysis, John Wiley 2008.</li> <li>P. Ammann and J. Offutt, "Introduction to Software Testing", 2nd edition 2016.</li> <li>A. Zeller: "Why Programs Fail: A Guide to Systematic Debugging", 2nd edition 2012.</li> </ul>	

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	<ul> <li>M. Pezze and M. Young, Software Testing and Analysis, John Wiley 2008.</li> <li>P. Ammann and J. Offutt, "Introduction to Software Testing", 2nd edition 2015.</li> </ul>		

Module M1682: Secur	e Software Engineering			
Courses				
Title	Тур		Hrs/wk	СР
Secure Software Engineering (L266	7) Lectur	re	2	3
Secure Software Engineering (L266	8) Project	ct-/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 lear	rning 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 Engineerin	ng: Elective Compulsory		
Following Curricula	Information and Communication Systems: Specialisation Secure a	and Dependable IT Syste	ms, Focus S	oftware and Signa
	Processing: Elective Compulsory			
	Information and Communication Systems: Specialisation Communication	on Systems, Focus Softwar	e: Elective Co	mpulsory

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 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 above	ut data structures and al	gorithms			
Knowledge						
<b>Educational Objectives</b>	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	ol chocking			
	_	an reasoning engines ar	-			
		3 3		tional effort for model checki	na	
	• the impact of s	pecification and modelin	ing on the computa	donar enort for moder checki	ng.	
Skills	Students can					
	a cumbin and inc		data atministrato fau	mandal abandina		
	·	<ul> <li>explain and implement algorithms and data structures for model checking,</li> <li>decide whether a given problem can be solved using Boolean reasoning or model checking, and</li> </ul>				
		r a given problem can be respective algorithms.	e solved using Book	ean reasoning or model chec	King, and	
	• Implement the	respective algorithms.				
Personal Competence						
Social Competence	Students					
	diameter and sever					
		discuss relevant topics in class and				
	defend their so	olutions orally.				
Autonomy	Using accompanying	material students inde	pendently learn in	-depth relations between co	oncepts explained	d in the lecture and
	additional solution str	ategies.				
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56					
Credit points	6					
Course achievement	Compulsory Bonus	Form	Description			
	Yes None	Subject theoretical	andDie Aufgabe	wird im Rahmen von Volresu	ıng und Prüfung (	definiert. Die Lösung
		practical work	der Aufgabe i	st Zulassungsvoraussetzung	für die Prüfung.	
Examination	Oral exam					
Examination duration and	30 min					
scale						
Assignment for the	Computer Science: Sp	pecialisation I. Computer	and Software Engi	neering: Elective Compulsory	,	
Following Curricula	Information and Com	munication Systems: Spe	ecialisation Commu	nication Systems, Focus Soft	ware: Elective Co	mpulsory
	Information and Com	munication Systems: Spe	ecialisation Secure	and Dependable IT Systems:	Elective Compuls	sory

Course L1979: Model Checkin	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 Checki	ourse L1980: Model Checking - Proof Engines and Algorithms		
Тур	Recitation Section (small)		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Lecturer	Prof. Görschwin Fey		
Language	DE/EN		
Cycle	SoSe		
Content	See interlocking course		
Literature	See interlocking course		

Module M0924: Softw	are for Embedo	ded Systems				
Courses						
Title				Тур	Hrs/wk	СР
Software for Embdedded Systems (	(L1069)			Lecture	2	3
Software for Embdedded Systems (	(L1070)			Recitation Section (small)	3	3
Module Responsible	Prof. Bernd-Christian	Renner				
Admission Requirements	None					
Recommended Previous	a Cood Impulade		in nunnunununina lanaus	C		
Knowledge			in programming languag	je C		
		ge in software engi	-			
	Basic understa	nding of assembly	language			
Educational Objectives	After taking part succ	essfully, students	have reached the followi	ing learning results		
Professional Competence						
Knowledge	Students know the ba	asic principles and	procedures of software	engineering for embedded s	systems. They are	able to describe the
	usage and pros of	event based pro	gramming using interru	ipts. They know the comp	onents and func	tions of a concrete
	microcontroller. The	participants explai	n requirements of real t	time systems. They know at	least three sched	duling algorithms for
	real time operating sy	stems including th	neir pros and cons.			
Skills	Skills Students build interrupt-based programs for a concrete microcontroller. They build and use a preemptive scheduler. T peripheral components (timer, ADC, EEPROM) to realize complex tasks for embedded systems. To interface with			scheduler. They use		
				rface with external		
	components they util	ze serial protocols				
Personal Competence						
Social Competence						
Autonomy						
Workload in Hours	Independent Study Ti	me 110, Study Tin	ne in Lecture 70			
Credit points	6					
Course achievement	Compulsory Bonus	Form	Description			
	No 10 %	Attestation				
Examination	Written exam					
Examination duration and	90 min					
scale						
Assignment for the	Computer Science: Sp	pecialisation I. Com	nputer and Software Eng	ineering: Elective Compulsor	У	
Following Curricula	Electrical Engineering	: Specialisation Inf	ormation and Communic	cation Systems: Elective Con	npulsory	
	Information and Com	munication System	ns: Specialisation Commi	unication Systems, Focus Sof	tware: Elective Co	mpulsory
	Mechatronics: Techni	cal Complementar	y Course: Elective Comp	ulsory		
	Mechatronics: Specia	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory				
	Mechatronics: Specia	lisation System De	sign: Elective Compulsor	ry .		
	Microelectronics and	Microsystems: Spe	cialisation Embedded Sy	stems: Elective Compulsory		

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

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

Module M1774: Adva	nced Internet Computing			
Courses				
Title		Тур	Hrs/wk	СР
Advanced Internet Computing (L29		Lecture	2	3
Advanced Internet Computing (L29		Project-/problem-based Learning	2	3
Module Responsible	Prof. Stefan Schulte			
Admission Requirements	None			
Recommended Previous	Good programming skills are necessary. Previous knowled	ge in the field of distributed systems is	helpful.	
Knowledge				
Educational Objectives	After taking part successfully, students have reached the	following learning results		
Professional Competence				
Knowledge	After successful completion of the course, students are ab	le to:		
	Describe basic concepts of Cloud Computing, the In	ternet of Things (IoT) and blockchain t	echnologies	
	Discuss and assess critical aspects of Cloud Compu	- ·	_	
	Select and apply cloud and loT technologies for par		.05	
	Design and develop practical solutions for the integration of smart objects in IoT, Cloud, and blockchain software			
	Implement IoT services			
	p			
Skills	The students acquire the ability to model Internet-based	d distributed systems and to work wit	th these syste	ms. This comprises
	especially the ability to select and utilize fitting technologies for different application areas. Furthermore, students are able to			
	critically assess the chosen technologies.			
Personal Competence				
	Students can work on complex problems both independen	itly and in teams. They can exchange in	deas with each	other and use their
, , , , , , , , , , , , , , , , , , , ,	individual strengths to solve the problem.	,		
	3			
Autonomy	Students are able to independently investigate a complex	problem and assess which competenci	es 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	Computer Science: Specialisation I. Computer and Softwar	re Engineering: Elective Compulsory		
Following Curricula	Computational Science and Engineering: Specialisation I. (	Computer Science: Elective Compulsory	,	
	Information and Communication Systems: Specialisation C	Communication Systems, Focus Softwar	e: Elective Cor	npulsory
	Information and Communication Systems: Specialisation S	secure and Dependable IT Systems, Foc	us Networks: E	Elective Compulsory

Course L2916: Advanced Inte	ernet Computing
Тур	Lecture
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Stefan Schulte
Language	EN
Cycle	SoSe
Content	This lecture discusses modern Internet-based distributed systems in three blocks: (i) Cloud computing, (ii) the Internet of Things, and (iii) blockchain technologies. The following topics will be covered in the single lectures:  Cloud Computing Elastic Computing Technologies for identification for the IoT: RFID & EPC Communication in the IoT: Standards and protocols Security and trust in the IoT: Concerns and solution approaches Edge and Fog Computing Application areas: Smart factories, smart cities, smart healthcare Blockchain technologies Consensus
Literature	Will be discussed in the lecture

Course L2917: Advanced Inte	ernet Computing
Тур	Project-/problem-based Learning
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Stefan Schulte
Language	EN
Cycle	SoSe
Content	This project-/problemoriented part of the module augments the theoretical content of the lecture by a concrete technical problem, which needs to be solved by the students in group work during the semester. Possible topics are (blockchain-based) sensor data integration, Big Data processing, Cloud-based redundant data storages, and Cloud-based Onion Routing.
Literature	Will be discussed in the lecture.

#### **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	rare Verification			
Courses				
<b>Title</b> Software Verification (L0629) Software Verification (L0630)		<b>Typ</b> Lecture Recitation Section (small)	Hrs/wk 2 2	<b>CP</b> 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  Social Competence	Students apply the major verification techniques in model and semantics of the underlying logics, and assess the formal properties of software systems. They find flaws in formal properties of software systems. They find flaws in formal properties of software systems. They find flaws in formal 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 a students discuss relevant topics in class. They defend the Using accompanying on-line material for self study, students discuss relevant completion, students can identify a the field of software verification. Within this field, they can dompile their findings in academic reports. They can defer the software verification and compile their findings in academic reports.	expressivity of different logics as formal arguments, arising from motion in a formal language. They denecessary, adapt model or proper ctive verification, and reflect on the appropriate verification technique aris solutions or ally. They communicated can assess their level of eive additional feedback. Within liand precisely formulate new problem conduct independent studies to	well as their limit ideling artifacts or velop logic-based of the result	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 essary competencies
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56	·		
Credit points				
Course achievement	Compulsory Bonus Form Descrip Yes 15 % Excercises	tion		
Examination	Written exam			
Examination duration and	90 min			
scale Assignment for the	Computer Science, Specialisation I. Computer and Seffuse	ro Engineering, Floctive Commutes	P1.	
Following Curricula	Computer Science: Specialisation I. Computer and Softwar Computational Science and Engineering: Specialisation I. (Information and Communication Systems: Specialisation Communication C	Computer Science: Elective Compu Communication Systems, Focus So	ulsory ftware: Elective Co	mpulsory
	Information and Communication Systems: Specialisation S International Management and Engineering: Specialisation	, ,	. ,	

Course L0629: Software Veri	fication
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	<ul> <li>Syntax and semantics of logic-based systems</li> <li>Deductive verification         <ul> <li>Specification</li> <li>Proof obligations</li> <li>Program properties</li> <li>Automated vs. interactive theorem proving</li> </ul> </li> <li>Model checking         <ul> <li>Foundations</li> <li>Property languages</li> <li>Tool support</li> </ul> </li> <li>Timed automata</li> <li>Recent developments of verification techniques and applications</li> </ul>
Literature	<ul> <li>C. Baier and J-P. Katoen, Principles of Model Checking, MIT Press 2007.</li> <li>M. Huth and M. Bryan, Logic in Computer Science. Modelling and Reasoning about Systems, 2nd Edition, 2004.</li> <li>Selected Research Papers</li> </ul>

Course L0630: Software Veri	ourse L0630: Software Verification		
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 M0942: Softw	are 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	e reached the following learning results		
Professional Competence				
Knowledge	Students can			
	name the main causes for security vi			
	explain current methods for identifying			
	<ul> <li>explain the fundamental concepts of</li> </ul>	code-based access control		
Skills	Students are capable of			
	<ul> <li>performing a software vulnerability a</li> </ul>	nalysis		
	developing secure code			
Personal Competence				
Social Competence	None			
Autonomy	Students are capable of acquiring knowled	edge independently from professional publ	ications, technical	standards, and other
	sources, and are capable of applying newly	acquired knowledge 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. Comput	er and Software Engineering: Elective Compu	ulsory	
Following Curricula	Computational Science and Engineering: Sp	ecialisation I. Computer Science: Elective Co	mpulsory	
	Information and Communication Systems: S	specialisation Secure and Dependable IT Syst	ems: Elective Comp	ulsory

Course L1103: Software Secu	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	<ul> <li>Reliabilty and Software Security</li> <li>Attacks exploiting character and integer representations</li> <li>Buffer overruns</li> <li>Vulnerabilities in memory managemet: double free attacks</li> <li>Race conditions</li> <li>SQL injection</li> <li>Cross-site scripting and cross-site request forgery</li> <li>Testing for security; taint analysis</li> <li>Type safe languages</li> <li>Development proceses for secure software</li> <li>Code-based access control</li> </ul>
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)

Course L1104: Software Security	
Тур	Recitation Section (small)
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	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 al	gorithms			
Knowledge						
<b>Educational Objectives</b>	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	ol chocking			
	-	an reasoning engines an	-			
		5 5		tional effort for model checki	na	
	• the impact of s	pecification and modelin	ig on the computa	donar enort for moder checki	ng.	
Skills	Students can					
	a symlain and inc		data atmirativusa fau	mandal abandina		
	·	plement algorithms and		-	line and	
		<ul> <li>decide whether a given problem can be solved using Boolean reasoning or model checking, and</li> <li>implement the respective algorithms.</li> </ul>				
	• implement the	respective algorithms.				
Personal Competence						
Social Competence	Students					
		A boots to store and				
		nt topics in class and				
	defend their so	iutions orally.				
Autonomy	Using accompanying	material students inde	pendently learn in	-depth relations between co	ncepts 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	6					
Course achievement	Compulsory Bonus	Form	Description			
	Yes None	Subject theoretical	andDie Aufgabe	wird im Rahmen von Volresu	ıng und Prüfung (	definiert. Die Lösung
		practical work	der Aufgabe i	st Zulassungsvoraussetzung	für die Prüfung.	
Examination	Oral exam					
Examination duration and	30 min					
scale						
Assignment for the	Computer Science: Sp	pecialisation I. Computer	and Software Engi	neering: Elective Compulsory	,	
Following Curricula	Information and Com	munication Systems: Spe	ecialisation Commu	nication Systems, Focus Soft	ware: Elective Co	mpulsory
	Information and Com	munication Systems: Spe	ecialisation Secure	and Dependable IT Systems:	Elective Compuls	sory

Course L1979: Model Checkin	ng - Proof Engines and Algorithms
Тур	
Hrs/wk	
CP Workload in Hours	
Lecturer	Prof. Görschwin Fey
Cycle	
Content	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 Checki	ourse L1980: Model Checking - Proof Engines and Algorithms		
Тур	Recitation Section (small)		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Lecturer	Prof. Görschwin Fey		
Language	DE/EN		
Cycle	SoSe		
Content	See interlocking course		
Literature	See interlocking course		

Module M1400: Desig	n of Dependable	Systems				
Courses						
Title				Тур	Hrs/wk	СР
Designing Dependable Systems (L2	2000)			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 success	sfully, students have re	eached the following	ng learning results		
Professional Competence						
Knowledge	In the following "depend	lable" summarizes the	concepts Reliabilit	ty, Availability, Maintainabili	ty, Safety and Secu	urity.
	Knowledge about approa	aches for designing de	pendable systems	, e.g.,		
	Structural solution	ns like modular redund	lancy			
	Algorithmic soluti	ons like handling byza	ntine faults or che	ckpointing		
	Knowledge about metho	ods for the analysis of o	dependable system	ns		
Skills	Ability to implement dep	pendable systems usin	g the above appro	aches.		
	Ability to analyzs the de	pendability of systems	using the above n	nethods for analysis.		
Personal Competence						
Social Competence	Students					
	discuss relevant t	opics in class and				
	<ul> <li>present their solu</li> </ul>	•				
Autonomy			pendently learn in	-depth relations between c	oncepts explained	in the lecture and
Washing die Harris	additional solution strate					
Workload in Hours	' '	e 124, Study Time in Le	ecture 56			
Credit points	6 Compulsory Bonus F	form	Description			
Course achievement		Subject theoretical	•	einer Aufgabe ist Zuslassun	gsvoraussetzung 1	ür die Prüfung. Die
		oractical work	_	in Vorlesung und Übung de	-	3
Examination	Oral exam					
Examination duration and	30 min					
scale						
Assignment for the	Computer Science: Spec	cialisation I. Computer	and Software Engi	neering: Elective Compulsor	У	
Following Curricula	Computational Science	and Engineering: Speci	ialisation I. Compu	ter Science: Elective Compu	Isory	
	Information and Commu	inication Systems: Spe	cialisation Secure	and Dependable IT Systems	: Elective Compuls	ory
	Mechatronics: Specialisa	ation System Design: E	lective Compulsor	у		
	Microelectronics and Mic	crosystems: Specialisa	tion Embedded Sys	stems: 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 De	ourse L2001: Designing Dependable Systems		
Тур	Recitation Section (small)		
Hrs/wk	2		
СР	3		
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28		
Lecturer	Prof. Görschwin Fey		
Language	DE/EN		
Cycle	SoSe		
Content	See interlocking course		
Literature	See interlocking course		

#### **Focus Networks**

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	(L0646)	Practical Course	1	1
Module Responsible	Prof. Gerhard Bauch			
Admission Requirements	None			
Recommended Previous	<ul> <li>Mathematics 1-3</li> </ul>			
Knowledge	Signals and Systems			
	Fundamentals of Communications and Random	Processes		
	Tundamentals of Communications and Random	FIUCESSES		
Educational Objectives	After taking part successfully, students have reached	the following learning results		
Professional Competence				
Knowledge	The students are able to understand, compare and de	sign modern digital information transm	ission schemes. T	They are familiar with
	the properties of linear and non-linear digital modulat	ion methods. They can describe distort	ions caused by t	ransmission channels
	and design and evaluate detectors including chann	el estimation and equalization. They	know the princip	oles of single carrier
	transmission and multi-carrier transmission as well as	the fundamentals of basic multiple acc	ess schemes.	
Skills	The students are able to design and analyse a digital	information transmission scheme inclu	ding multiple acc	ess. They are able to
	choose a digital modulation scheme taking into accou	nt transmission rate, required bandwid	th, error probabili	ty, and further signal
	properties. They can design an appropriate detector including channel estimation and equalization taking into account			
	performance and complexity properties of suboptimur	n solutions. They are able to set param	eters of a single	carrier or multi carrier
	transmission scheme and trade the properties of both approaches against each other.			
Personal Competence				
Social Competence	The students can jointly solve specific problems.			
Autonomy	The students are able to acquire relevant informa	tion from appropriate literature sour	ces They can c	ontrol their level of
, accinemy	knowledge during the lecture period by solving tutoria		-	one or enem rever or
		,		
	, , ,	0		
Credit points	6			
Course achievement		scription		
Examination	Yes None Written elaboration Written exam			
Examination duration and scale	90 min			
	Flactured Familian Company Company			
_	Electrical Engineering: Core Qualification: Compulsory		oulcon.	
Following Curricula	, , , , , , , , , , , , , , , , , , , ,		-	
	Information and Communication Systems: Specialisati	·	-	Flootius Commulation
	Information and Communication Systems: Specialisati	·		Elective Compulsory
	International Management and Engineering: Specialisa	3,		
	International Management and Engineering: Specialisa Microelectronics and Microsystems: Core Qualification		Compuisory	
	Pricipelectionics and Pricipsystems. Core Qualification	. Liective Compuisory		

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	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.	

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	Fire de se code l'abordo activo			
Knowledge	Fundamental stochastics  Paging understanding of computer patricular and for	annon unication tachualagias is banafisi	ما	
	<ul> <li>Basic understanding of computer networks and/or</li> </ul>	communication 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 struct	tures of communication networks in de	tail. They ca	in explain the formal
	description methods of communication networks and	their protocols. They are able to ex	kplain how o	current and complex
	communication networks work and describe the current	esearch in these examples.		
Chille	Charles to a ship to a subject the same of a supplied		- 4 la - al Tla - a	
SKIIIS	Students are able to evaluate the performance of comm	-	-	
	problems themselves and apply the learned methods. T communication networks.	ney 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 teams and solve these problems together using the learned methods. They			
	can present the obtained results. They are able to discuss and critically analyse the solutions.			
Autonomy	Students are able to obtain the necessary expert know	edge for understanding the functionalit	v and perfor	mance canabilities of
Autonomy	new communication networks independently.	eage for understanding the functionality	y and perior	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 abo	ut 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 Co	mmunication Systems: Elective Compuls	sory	
Following Curricula	Electrical Engineering: Specialisation Control and Power 9	Systems Engineering: Elective Compulso	ry	
	Aircraft Systems Engineering: Core Qualification: Elective	Compulsory		
	Computational Science and Engineering: Specialisation I.	Computer Science: Elective Compulsory	/	
	Information and Communication Systems: Specialisation	Secure and Dependable IT Systems, Foo	us Networks	Elective Compulsory
	Information and Communication Systems: Specialisation	Communication Systems: Elective Comp	oulsory	
	International Management and Engineering: Specialisation	n II. Information Technology: Elective Co	ompulsory	
	Mechatronics: Technical Complementary Course: Elective	e Compulsory		
	Microelectronics and Microsystems: Specialisation Comm	unication and Signal Processing: Electiv	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	on 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	on 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: Simulation of Communication Networks				
Courses				
Title Typ			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			
	After taking part successfully, students have reached the follow	wing learning results		
Professional Competence				
Knowledge	Students are able to explain the necessary stochastics, the c	discrete event simulation technolo	gy and modelli	ng of networks for
	performance evaluation.			
Skills	Students are able to apply the method of simulation for performance evaluation to different, also not practiced, problems of			
	communication networks. The students can analyse the obtain	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			
,	are able to work out solutions for new problems in small teams			•
Autonomy	Students are able to transfer independently and in discussion problems. They can identify missing knowledge and acquire the	·	od and expert	knowledge to new
	problems. They can identify missing knowledge and acquire th	is 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				
_	Electrical Engineering: Specialisation Information and Commur	•	sory	
Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Com			
	Information and Communication Systems: Specialisation Comm		-	antina Camanul
	Information and Communication Systems: Specialisation Secur International Management and Engineering: Specialisation II. II			ective Compulsory
	international Management and Engineering: Specialisation II. II	normation rechnology: Elective Co	unpuisory	

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 M1774: Adva	nced Internet Computing			
Courses				
Title		Тур	Hrs/wk	СР
Advanced Internet Computing (L29		Lecture	2	3
Advanced Internet Computing (L29	T	Project-/problem-based Learning	2	3
Module Responsible	Prof. Stefan Schulte			
Admission Requirements	None			
Recommended Previous	Good programming skills are necessary. Previous knowledge	e in the field of distributed systems is	helpful.	
Knowledge				
Educational Objectives	After taking part successfully, students have reached the fo	llowing learning results		
Professional Competence				
Knowledge	After successful completion of the course, students are able	to:		
	Describe basic concepts of Cloud Computing, the Inter-	ernet of Things (IoT) and blockchain t	echnologies	
	Discuss and assess critical aspects of Cloud Computing	- · · · · · · · · · · · · · · · · · · ·	_	
	Select and apply cloud and IoT technologies for particle		.03	
	1	Design and develop practical solutions for the integration of smart objects in IoT, Cloud, and blockchain software		
	Implement IoT services	acon or smare objects in lorr, cloud, a.	ia biocitariani	ooreman c
Skills	The students acquire the ability to model Internet-based distributed systems and to work with these systems. This comprises			
	especially the ability to select and utilize fitting technologies for different application areas. Furthermore, students are able to			
	critically assess the chosen technologies.			
Personal Competence				
	Students can work on complex problems both independentl	v and in teams. They can exchange in	deas with each	other and use their
	individual strengths to solve the problem.	,,		
Autonomy	Students are able to independently investigate a complex p	roblem and assess which competenci	ies 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	Computer Science: Specialisation I. Computer and Software	Engineering: Elective Compulsory		
Following Curricula	Computational Science and Engineering: Specialisation I. Co	omputer Science: Elective Compulsory	/	
	Information and Communication Systems: Specialisation Co	mmunication Systems, Focus Softwar	e: Elective Co	mpulsory
	Information and Communication Systems: Specialisation Se	cure and Dependable IT Systems, Foo	us Networks:	Elective Compulsory

Course L2916: Advanced Inte	ernet Computing
Тур	Lecture
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Stefan Schulte
Language	EN
Cycle	SoSe
Content	This lecture discusses modern Internet-based distributed systems in three blocks: (i) Cloud computing, (ii) the Internet of Things, and (iii) blockchain technologies. The following topics will be covered in the single lectures:  Cloud Computing Elastic Computing Technologies for identification for the IoT: RFID & EPC Communication in the IoT: Standards and protocols Security and trust in the IoT: Concerns and solution approaches Edge and Fog Computing Application areas: Smart factories, smart cities, smart healthcare Blockchain technologies Consensus
Literature	Will be discussed in the lecture

Course L2917: Advanced Inte	ernet Computing
Тур	Project-/problem-based Learning
Hrs/wk	2
СР	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Stefan Schulte
Language	EN
Cycle	SoSe
Content	This project-/problemoriented part of the module augments the theoretical content of the lecture by a concrete technical problem, which needs to be solved by the students in group work during the semester. Possible topics are (blockchain-based) sensor data integration, Big Data processing, Cloud-based redundant data storages, and Cloud-based Onion Routing.
Literature	Will be discussed in 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	01)	Recitation Section (small)	1	2
Module Responsible	Prof. Andreas Timm-Giel			
Admission Requirements	None			
Recommended Previous Knowledge	Fundamentals of communication or computer ne     Stochastics	etworks		
<b>Educational Objectives</b>	After taking part successfully, students have reached t	ne following learning results		
Professional Competence				
Knowledge	Students are able to describe methods for planning, optimisation and performance evaluation of communication networks.			
Skills	Students are able to solve typical planning and optimisation tasks for communication networks. Furthermore they are able to evaluate the network performance using queuing theory.			
	Students are able to apply independently what they have learned to other and new problems. They can present their results in front of experts and discuss them.			
Personal Competence				
Social Competence				
Autonomy	Students are able to acquire the necessary exper communication networks independently.	t knowledge to understand the fun	ctionality and p	performance of new
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	Computer Science: Specialisation I. Computer and Soft	ware Engineering: Elective Compulsory		
Following Curricula	Electrical Engineering: Specialisation Information and C	Communication Systems: Elective Comp	oulsory	
	Information and Communication Systems: Specialisation	n 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

Courses				
Title		Тур	Hrs/wk	CP
Digital Audio Signal Processing (L0650)		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				
<b>Educational Objectives</b>	After taking part successfully, students have	reached the following learning results		
<b>Professional Competence</b>				
20.00	Die Studierenden können die grundlegenden Verfahren und Methoden der digitalen Audiosignalverarbeitung erklären. Sie können die wesentlichen physikalischen Effekte bei der Sprach- und Audiosignalverarbeitung erläutern und in Kategorien einordnen. Si können einen Überblick der numerischen Methoden und messtechnischen Charakterisierung von Algorithmen zu Audiosignalverarbeitung geben. Sie können die erarbeiteten Algorithmen auf weitere Anwendungen im Bereich de Informationstechnik und Informatik abstrahieren.			
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 s adequate methods during the exercise.	tudy special tasks and problems and will be	e enforced to pres	ent their results wit
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 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and	60 min			
scale		<u></u>		
Assignment for the	Electrical Engineering: Specialisation Information	ion and Communication Systems: Elective Co	mpulsory	
Following Curricula	Information and Communication Systems:	Specialisation Secure and Dependable IT	Systems, Focus	Software and Sign
	Processing: Elective Compulsory Information and Communication Systems: Spo	ecialisation Communication Systems, Focus S	gnal Processing: El	ective 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. Zőlzer (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 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	a structures		
	Functional programming or Procedural programming			
Educational Objectives	After taking part successfully, students have reached the	following learning results		
Professional Competence				
Knowledge	Students apply the major approaches to data-flow and			-
	classification schemes, and employ abstract interpreta-			·
	models, including their mathematical structure and prope	•	•	
	and categorize the major analysis algorithms. They di	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 modifying standard representations. They develop customized analyses and			
	devise them as safe overapproximations. They formulate analyses in a formal way and construct arguments for their correctness,			
	behavior, and precision.			
Personal Competence				
Social Competence	Students discuss relevant topics in class. They defend the	eir solutions orally. They communicat	e in English.	
,	seasons disease relevant topics in class. They detend dien solutions of any. They communicate in English.			
Autonomy	Using accompanying on-line material for self study, students can assess their level of knowledge continuously and adjust it			
	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 the field of software analysis. Within this field, they can conduct independent studies to acquire the necessary competencies and			
	compile their findings in academic reports. They can devis			
	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 presenta	tion		
scale				
Assignment for the	Information and Communication Systems: Specialisation (	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 Anal	lysis		
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			
Literature	<ul> <li>Modeling: Control-Flow Modeling, Data Dependences, Intermediate Languages)</li> <li>Classical Bit-Vector Analyses (Reaching Definition, Very Busy Expressions, Liveness, Available Expressions, May/Must, Forward/Backward)</li> <li>Monotone Frameworks (Lattices, Transfer Functions, Ascending Chain Condition, Distributivity, Constant Propagation)</li> <li>Theory of Data-Flow Analysis (Tarski's Fixed Point Theorem, Data-Flow Equations, MFP Solution, MOP Solution, Worklist Algorithm)</li> <li>Non-Classical Data-Flow Analyses</li> <li>Abstract Interpretation (Galois Connections, Approximating Fixed Points, Construction Techniques)</li> <li>Type Systems (Type Derivation, Inference Trees, Algorithm W, Unification)</li> <li>Recent Developments of Analysis Techniques and Applications</li> </ul>		
Literature	<ul> <li>Flemming Nielsen, Hanne Nielsen, and Chris Hankin. Principles of Program Analysis. Springer, 2nd. ed. 2005.</li> <li>Uday Khedker, Amitabha Sanyal, and Bageshri Karkara. Data Flow Analysis: Theory and Practice. CRC Press, 2009.</li> <li>Benjamin Pierce, Types and Programming Languages, MIT Press.</li> <li>Selected research papers</li> </ul>		

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	I Image Analysis			
Courses				
Title		Тур	Hrs/wk	СР
Digital Image Analysis (L0126)		Lecture	4	6
Module Responsible	Prof. Rolf-Rainer Grigat			
Admission Requirements	None			
	System theory of one-dimensional signals (convolution and of			
Knowledge	transform, linear time-invariant systems), linear algebra (E (expectation values, influence of sample size, correlation and co	-		
	basics in optics	ovariance, normal ais	and its paramete	13), busies of Flucial
Educational Objectives	After taking part successfully, students have reached the follow	ving learning results		
<b>Professional Competence</b>				
Knowledge	Students can			
	Describe imaging processes			
	Describe imaging processes     Depict the physics of sensorics			
	Explain linear and non-linear filtering of signals			
	Establish interdisciplinary connections in the subject area	a and arrange them i	n their context	
	Interpret effects of the most important classes of imagi			ethods and physica
	models.			
Skills	Students are able to			
	Use highly sophisticated methods and procedures of the	subject area		
	Identify problems and develop and implement creative s	olutions.		
	Students can solve simple arithmetical problems relating to the	a specification and d	locian of image processing	and image analysi
	Students can solve simple arithmetical problems relating to th systems.	e specification and d	lesign of image processing	and image analysis
	systems.			
	Students are able to assess different solution approaches in mu	ıltidimensional decisi	on-making areas.	
	Students can undertake a prototypical analysis of processes in	Matlab.		
Personal Competence				
Social Competence	ν Δ			
Social Competence	N.A.			
Autonomy	Students can solve image analysis tasks independently using the	ne relevant literature.		
	Indoor dock Charles Time 201 Ct. 1 The 197			
Workload in Hours  Credit points	Independent Study Time 124, Study Time in Lecture 56			
Course achievement				
Examination				
Examination duration and	60 Minutes, Content of Lecture and materials in StudIP			
scale	and materials in stadil			
	Computer Science: Specialisation II: Intelligence Engineering: E	lective Compulsory		
Following Curricula	Electrical Engineering: Specialisation Information and Communi		tive Compulsory	
-	Electrical Engineering: Specialisation Medical Technology: Elect		• •	
	Information and Communication Systems: Specialisation Comm	unication Systems, F	ocus Signal Processing: Ele	ective Compulsory
	Information and Communication Systems: Specialisation Se	ecure and Dependal	ble IT Systems, Focus S	oftware and Signa
	Processing: Elective Compulsory			
	International Management and Engineering: Specialisation II. In		y: Elective Compulsory	
	Mechatronics: Specialisation Intelligent Systems and Robotics: I			
	Microelectronics and Microsystems: Specialisation Communicat			
	Theoretical Mechanical Engineering: Specialisation Robotics and	d Computer Science:	Elective Compulsory	

Course L0126: Digital Image Analysis		
Тур	Lecture	
Hrs/wk	4	
СР	6	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56	
Lecturer	Prof. Rolf-Rainer Grigat	
Language	EN	
Cycle	WiSe	
Content	<ul> <li>Image representation, definition of images and volume data sets, illumination, radiometry, multispectral imaging, reflectivities, shape from shading</li> <li>Perception of luminance and color, color spaces and transforms, color matching functions, human visual system, color appearance models</li> <li>imaging sensors (CMOS, CCD, HDR, X-ray, IR), sensor characterization(EMVA1288), lenses and optics</li> <li>spatio-temporal sampling (interpolation, decimation, aliasing, leakage, moiré, flicker, apertures)</li> <li>features (filters, edge detection, morphology, invariance, statistical features, texture)</li> <li>optical flow (variational methods, quadratic optimization, Euler-Lagrange equations)</li> <li>segmentation (distance, region growing, cluster analysis, active contours, level sets, energy minimization and graph cuts)</li> <li>registration (distance and similarity, variational calculus, iterative closest points)</li> </ul>	
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	

Systems"	II				
Module M13	301: Software Testing				
Courses					
Title Software Testing (I		Typ Lecture	Hrs/wk	<b>CP</b> 3	
Software Testing (I		Project-/problem-based Learning	2	3	
Module Responsible					
Admission					
Requirements					
Recommended	i				
Previous					
Knowledge	Higher Programming Languages     Object Oriented Programming				
	Object-Oriented Programming     Algorithms and Data Structures				
	Experience with (Small) Software Projects				
	• Statistics				
Educational Objectives		earning results			
Professional					
Competence					
Knowledge					
_	Students explain the different phases of testing, descr				
	techniques of different types of testing, and paraphras				
	principles of the corresponding test process. They give	•			
	software development scenarios and the correspondin technique. They explain algorithms used for particular				
	techniques and describe possible advantages and limi	5			
Skills	Students identify the appropriate testing type and tecl problem. They adapt and execute respective algorithm concrete test technique properly. They interpret testin execute corresponding steps for proper re-test scenarianalyze test specifications. They apply bug finding tecnon-trivial problems.	ns to execute a g results and los. They write and			
Personal					
Competence					
Social		s orally.			
Competence					
Autonomy	own learning goals. Upon successful completion, students can ident testing. Within this field, they can conduct independent studies to devise plans to arrive at new solutions or assess existing ones	ify and precisely formulate new problems in	academic or	applied research in	the field o
Workload in Hours					
Credit points	6				
Course	None				
achievement					
Examination					
Examination					
duration and					
Scale		pring: Floctive Compulsory			
Assignment for the			nulsory		
Following				essing: Elective Cor	npulsory
Curricula		, , , , , , , , , , , , , , , , , , , ,	J	3	,
Curricula	1				

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	<ul> <li>Fundamentals of software testing</li> <li>Model-based testing</li> <li>Test automation</li> <li>Criteria-based testing</li> </ul>	
Literature	<ul> <li>M. Pezze and M. Young, Software Testing and Analysis, John Wiley 2008.</li> <li>P. Ammann and J. Offutt, "Introduction to Software Testing", 2nd edition 2016.</li> <li>A. Zeller: "Why Programs Fail: A Guide to Systematic Debugging", 2nd edition 2012.</li> </ul>	

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	<ul> <li>Fundamentals of software testing</li> <li>Model-based testing</li> <li>Test automation</li> <li>Criteria-based testing</li> </ul>		
Literature	<ul> <li>M. Pezze and M. Young, Software Testing and Analysis, John Wiley 2008.</li> <li>P. Ammann and J. Offutt, "Introduction to Software Testing", 2nd edition 2015.</li> </ul>		

Module M1682: Secur	re Software Engineering			
Courses				
Title	Тур		Hrs/wk	СР
Secure Software Engineering (L266	(7) Lectur	re	2	3
Secure Software Engineering (L266	8) Project	ct-/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 lear	rning 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 Engineering	g: Elective Compulsory		
Following Curricula	Information and Communication Systems: Specialisation Secure ar	ind Dependable IT Syste	ms, Focus So	oftware and Signal
	Processing: Elective Compulsory			
	Information and Communication Systems: Specialisation Communicatio	on Systems, Focus Softwar	e: Elective Cor	mpulsory

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 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 Na	vigation		
Courses				
Title		Тур	Hrs/wk	СР
Radio-Based Positioning and Naviga	ation (L2711)	Lecture	2	3
Satellite Communications (L2710)		Lecture	2	3
Module Responsible	Prof. Gerhard Bauch			
Admission Requirements	None			
Recommended Previous				
Knowledge				
<b>Educational Objectives</b>	After taking part successfully, students h	ave reached the following learning results		
<b>Professional Competence</b>				
Knowledge				
Skills				
Personal Competence				
Social Competence				
Autonomy				
Workload in Hours	Independent Study Time 124, Study Time	e in Lecture 56		
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and	30 min			
scale				
Assignment for the	Electrical Engineering: Specialisation Info	rmation and Communication Systems: Electiv	e Compulsory	
Following Curricula	Information and Communication Systems	:: Specialisation Communication Systems, Foc	us Signal Processing: Ele	ective Compulsory
	Information and Communication Syste	ms: Specialisation Secure and Dependable	e IT Systems, Focus S	oftware and Signal
	Processing: Elective Compulsory			
	Microelectronics and Microsystems: Spec	ialisation Communication and Signal Processi	ng: Elective Compulsory	

Course L2711: Radio-Based I	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 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 Computer Graphics (L0145)		Typ Lecture	Hrs/wk	<b>CP</b> 3
Computer Graphics (L0768)		Recitation Section (small)	2	3
Module Responsible	Prof. Tobias Knopp			
Admission Requirements	None			
Recommended Previous Knowledge	<ul> <li>Linear Algebra (in particular matrix/vector computatio</li> <li>Basic programming skills in C/C++</li> </ul>	n)		
<b>Educational Objectives</b>	After taking part successfully, students have reached the follo	owing learning results		
Professional Competence				
Knowledge	Students can explain and describe basic algorithms in 3D con	nputer graphics.		
Skills	Students are capable of			
	<ul> <li>implementing a basic 3D rendering pipeline. This consumptions of the surface using a virtual camera.</li> <li>apply geometric transformations (e.g. rotation, scaling using well-known 2D/3D APIs (OpenGL, Cairo) for solvi</li> </ul>	j) in 2D and 3D computer graphi		e, spheres) onto a 20
Personal Competence				
Social Competence	Students can collaborate in a small team on the realization ar	nd validation of a 3D computer g	raphics pipeline.	
Autonomy	Students are able to solve simple tasks independently     Students are able to solve detailed problems independently			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	90 min			
Assignment for the	Computer Science: Specialisation I. Computer and Software E	ngineering: Elective Compulsory	,	
Following Curricula				ective Compulsory
	Information and Communication Systems: Specialisation Processing: Elective Compulsory	Secure and Dependable IT Sy	stems, Focus S	Software and Signa
	International Management and Engineering: Specialisation II.	Information Technology: Elective	e Compulsory	

Course L0145: Computer Graphics		
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	
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 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 M1598: Image	e Processing
Courses	
Title	Typ Hrs/wk CP
Image Processing (L2443)	Lecture 2 4
Image Processing (L2444)	Recitation Section (small) 2 2
Module Responsible	
Admission Requirements	
Recommended Previous	Signal and Systems
Knowledge	
Educational Objectives	
Professional Competence	
Knowledge	The students know about
	visual perception
	multidimensional signal processing
	sampling and sampling theorem
	• filtering
	image enhancement
	edge detection
	multi-resolution procedures: Gauss and Laplace pyramid, wavelets
	image compression
	image segmentation
	morphological image processing
Skills	The students can
	analyze, process, and improve multidimensional image data
	implement simple compression algorithms
	design custom filters for specific applications
Personal Competence	
Social Competence	Students can work on complex problems both independently and in teams. They can exchange ideas with each other and use the
	individual strengths to solve the problem.
Autonomy	Ctudents are able to independently investigate a complex problem and access which competencies are required to colve it
Autonomy	
Workload in Hours	
Credit points  Course achievement	
	Written exam
Examination duration and	
scale	
	Data Science: Core Qualification: Elective Compulsory
-	
Following Curricula	Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory
	Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory
	Electrical Engineering: Specialisation Medical Technology: Elective Compulsory
	Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Sign
	Processing: Elective Compulsory
	Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory
	International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory
	Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory
	Mechatronics: Specialisation System Design: Elective Compulsory
	Mechatronics: Specialisation System Design: Elective Compulsory  Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective 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	<ul> <li>Visual perception</li> <li>Multidimensional signal processing</li> <li>Sampling and sampling theorem</li> <li>Filtering</li> <li>Image enhancement</li> <li>Edge detection</li> <li>Multi-resolution procedures: Gauss and Laplace pyramid, wavelets</li> <li>Image Compression</li> <li>Segmentation</li> <li>Morphological image processing</li> </ul>
Literature	Bredies/Lorenz, Mathematische Bildverarbeitung, Vieweg, 2011 Pratt, Digital Image Processing, Wiley, 2001 Bernd Jähne: Digitale Bildverarbeitung - Springer, Berlin 2005

Course L2444: Image Proces	ourse L2444: Image Processing	
Тур	Recitation Section (small)	
Hrs/wk	2	
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	rity of Cyber-Physical Systems			
Courses				
Title		Тур	Hrs/wk	СР
Security of Cyber-Physical Systems (L2691)		Lecture Recitation Section (small)	2	3
Security of Cyber-Physical Systems  Module Responsible		Recitation Section (Smail)	2	3
Admission Requirements	None			
	IT security, programming skills, statistics			
Knowledge				
<b>Educational Objectives</b>	After taking part successfully, students have reache	ed the following learning results		
<b>Professional Competence</b>				
Knowledge	The students know and can explain			
	- the threats posed by cyber attacks to cyber-physic	cal systems (CPS)		
	- concrete attacks at a technical level, e.g. on bus s	ystems		
	- security solutions specific to CPS with their capabi	lities 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	given CPS		
	- apply attack toolkits to analyse a networked cont	rol system, and detect attacks beyond thos	e taught in class	
	- identify and apply security solutions suitable to the	ne requirements		
	- follow security engineering processes to develop	a security architecture for a given CPS		
	- recognize challenges and limitations, e.g. posed by	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-orie	ented fashion wit	th experts and non-
	- foster a security culture with respect to CPS and t	ne 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 incident	:s
	- master a new topic within the area by self-study a	nd self-initiated interaction with experts ar	id peers.	
Workload in Hours	Independent Study Time 124, Study Time in Lecture	e 56		
Credit points				<del></del>
Course achievement		Description	shoul atou	
Examination	No 10 % Excercises Written exam	Die Übungsaufgaben finden semesterbegle	entenu Statt.	
Examination duration and	120 min			
scale				
Assignment for the	Computer Science: Specialisation I. Computer and S	Software Engineering: Elective Compulsory		
Following Curricula	Computer Science in Engineering: Specialisation I. (	Computer Science: Elective Compulsory		
	Information and Communication Systems: Speci	alisation Secure and Dependable IT Sy	stems, Focus S	oftware and Signal
	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	r Thesis
Courses	
Title	Typ Hrs/wk CP
Module Responsible	Professoren der TUHH
Admission Requirements	According to General Regulations §21 (1):
	At least 60 credit points have to be achieved in study programme. The examinations board decides on exceptions.
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	<ul> <li>The students can use specialized knowledge (facts, theories, and methods) of their subject competently on specialized issues.</li> </ul>
	<ul> <li>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.</li> </ul>
	<ul> <li>The students can place a research task in their subject area in its context and describe and critically assess the state of research.</li> </ul>
Skills	The students are able:
	<ul> <li>To select, apply and, if necessary, develop further methods that are suitable for solving the specialized problem in question.</li> <li>To apply knowledge they have acquired and methods they have learnt in the course of their studies to complex and/or incompletely defined problems in a solution-oriented way.</li> <li>To develop new scientific findings in their subject area and subject them to a critical assessment.</li> </ul>
Personal Competence	
Social Competence	Students can
	Both in writing and orally outline a scientific issue for an expert audience accurately, understandably and in a structured
	<ul> <li>Deal with issues competently in an expert discussion and answer them in a manner that is appropriate to the addressees while upholding their own assessments and viewpoints convincingly.</li> </ul>
Autonomy	Students are able:
	<ul> <li>To structure a project of their own in work packages and to work them off accordingly.</li> <li>To work their way in depth into a largely unknown subject and to access the information required for them to do so.</li> <li>To apply the techniques of scientific work comprehensively in research of their own.</li> </ul>
Workload in Hours	Independent Study Time 900, Study Time in Lecture 0
Credit points	
Course achievement	
Examination	
Examination duration and	According to General Regulations
scale	According to defleral negulations
	Civil Engineering: Thesis: Compulsory
Assignment for the	
Following Curricula	Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory
	Computer Science: Thesis: Compulsory
	Electrical Engineering: Thesis: Compulsory
	Energy Systems: Thesis: Compulsory
	Environmental Engineering: Thesis: Compulsory
	Aircraft Systems Engineering: Thesis: Compulsory
	Global Innovation Management: Thesis: Compulsory
	Computer Science in Engineering: Thesis: Compulsory
	Information and Communication Systems: Thesis: Compulsory
	Interdisciplinary Mathematics: Thesis: Compulsory
	International Production Management: 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

## Module Manual M.Sc. "Information and Communication Systems"

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