# M.Sc. Information and Communication Engineering (PO 2023)

Module handbook FB 18 Date: 04.07.2024



TECHNISCHE UNIVERSITÄT DARMSTADT

FB 18

Module handbook: M.Sc. Information and Communication Engineering (PO 2023)

Date: 04.07.2024

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## **1 Core Competencies**

Please note that 18-sm-2010 Communication networks II can be replaced by 18-sm-2340 Resilient Communication Networks

	<b>dule nr.</b> ho-2010	-		Self-study 120 h	Module duration 1 Term	<b>Module cycle</b> Winter term
	<b>ıguage</b> çlish			<b>Module owner</b> Prof. DrIng. Kla	us Hofmann	
1	CMOS Circu	stor Models, CMOS its, Synchonous CMC	OS Circuits, Perfor	mance and Power	n Rules, Static and D Characterisation, Des s, Data-Converters (A	sign Techniques and
2	<ul> <li>Learning objectives</li> <li>A student is, after successful completion of this module, able to <ul> <li>understand the short-channel effects of modern CMOS transistors,</li> <li>derive and analyse the most important circuit concepts for digital logic gates,</li> <li>understand the design flow of digital ASICs based on standard cells (design, layout, simulation/verification),</li> <li>know the pros and cons of synchronous vs. asynchronous logic, multiclockphase systems,</li> <li>understand the differential design methods of integrated circuits (ASIC, ASIP, Full-custom/Semicustom, PLA, PLD, FPGA),</li> <li>understand basic circuitry of logic and arithmetic units (adders, multipliers, PLL/DLL),</li> <li>understand the concepts of A/D and D/A-converters, and their fundamental technical properties and architectures,</li> <li>know the design principles and properties of integrated semiconductor memory (DRAM, SRAM, Flash. MRAM, FeRAM)</li> </ul> </li> </ul>					
3	Recomment Lecture "Ele	<b>ded prerequisites fo</b> ctronics"	r participation			
4	Form of examination Module exam: • Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)					
5		e for the award of cr				
6	Grading Module exan • Modul	n: e exam (Technical ex	amination, Exam	ination, Weighting	: 100 %)	
7	-	<b>the module</b> DT, M.Sc. etit - SAE,	M.Sc. iCE, M.Sc.	iST, M.Sc. WI-etit		
8	Grade bonu	s compliant to §25	( <b>1</b> )			

	pies	References Lecture Slide Copies						
John P. Uyemura: Fundamentals of MOS Digital Integrated Circuits								
irses	1							
<b>Course nr.</b> 18-ho-2010-vl								
Instructor Prof. DrIng. Klaus Hofmann		<b>Type</b> Lecture	<b>SWS</b> 3					
<b>Course nr.</b> 18-ho-2010-ue	<b>Course name</b> Advanced Digital Integrated Circuit Design		'					
Instructor		Туре	SWS					
	rses Course nr. 18-ho-2010-vl Instructor Prof. DrIng. Kla Course nr. 18-ho-2010-ue	Course nr. 18-ho-2010-vlCourse name Advanced Digital Integrated Circuit DesignInstructor Prof. DrIng. Klaus HofmannCourse nr. 18-ho-2010-ueCourse name Advanced Digital Integrated Circuit Design	rses Course nr. 18-ho-2010-vl Advanced Digital Integrated Circuit Design Instructor Prof. DrIng. Klaus Hofmann Course nr. 18-ho-2010-ue Course name Advanced Digital Integrated Circuit Design					

Language       Module owner         English       Prof. DrIng. Rolf Jakoby         1       Teaching content         Overview of most important antenna parameters types as well as their applications. Fundamental Fourier transform for far-field pattern calculations, antenna modeling techniques, antenna synthesis image theory, determination of field regions of line sources, of the average radiated power density and directivity and gain. Antennas as key elements in power budgets of radio links, introducing the effective of an antenna, deriving the relation between gain and effective aperture. Array antennas are a key for beamforming and smart antenna systems: fundamentals of phased-scanning arrays, non-uniforml equally spaced linear arrays, multi-dimensional planar arrays and mutual coupling effects. Wire anter the most prevalent of all antenna forms, relatively simple in concept, easy to construct, very inexpensive. radiation fields and antenna parameters for different types of antennas are derived from Maxwell's capplied for aperture antennas (horns, lenses or reflector antennas) and printed antennas (microstrip-proplanar-slot antennas) forms, lenses or reflector antennas) and printed antennas (microstrip-proplanar-slot antennas) for problems. Smart antennas in communication and radar systems, with focus steering and adaptive beamforming.         2       Learning objectives         3       Students will know basic antenna field regions, reactive near-field, near-field and far-field, and the far-field pattern of an antenna can be determined from given current distributions along the by using Fourier transformation or integral solutions with distributed ideal dipoles as basic elements incorporated into the different adaptive beamforming techniques, antenna modeling and far-field anatenna Meory: impedance marchi	18-jk-2020	Credit points	Workload	Self-study	Module duration	Module cycle	
English       Prof. DrIng. Rolf Jakoby         1       Teaching content         Overview of most important antenna parameters types as well as their applications. Fundamental Fourier transform for far-field pattern calculations, antenna modeling techniques, antenna synthesis image theory, determination of field regions of line sources, of the average radiated power density at directivity and gain. Antennas as key elements in power budgets of radio links, introducing the effective of an antenna, deriving the relation between gain and effective aperture. Array antennas are a key for beamforming and smart antenna systems: fundamentals of phased-scanning arrays, non-uniformly equally spaced linear arrays, multi-dimensional planar arrays and mutual coupling effects. Wire anter the most prevalent of all antenna forms, relatively simple in concept, easy to construct, very inexpensive. radiation fields and antenna parameters for different types of antennas are derived from Maxwell 's e applied for aperture antennas (horns, lense or reflector antennas) and printed antennas (microstrip-p coplanar-slot antennas) Some basic numerical calculation methods: in the frequency domain, physical optics and uniform theory of diffraction are briefly summarized and com antennas and scattering problems. Smart antennas in communication and radar systems, with focus steering and adaptive beamforming.         2       Learning objectives         Students will know basic antenna parameters: pattern, gain, directivity, half-power beamwidth, side- he efficiency and input impedance to compare, assess and evaluate different antennas for various applica operating frequencies. The antenna field regions, reactive near-field and far-field, can be diffe and the far-field pattern of an antenna ac be determined from given current distributions along the by using Fourier transformation or i	00000	6 CP	180 h	120 h	1 Term	Winter term	
Overview of most important antenna parameters types as well as their applications. Fundamental Fourier transform for far-field pattern calculations, antenna modeling techniques, antenna synthesis image theory, determination of field regions of line sources, of the average radiated power density ar directivity and gain. Antennas as key elements in power budgets of radio links, introducing the effective of an antenna, deriving the relation between gain and effective aperture. Array antennas are a key I for beamforming and smart antenna systems: fundamentals of phased-scanning arrays, non-uniformly equally spaced linear arrays, multi-dimensional planar arrays and mutual coupling effects. Wire anter the most prevalent of all antenna forms, relatively simple in concept, easy to construct, very inexpensive. radiation fields and antenna parameters for different types of antennas are derived from Maxwell's e applied for aperture antennas (horns, lenses or reflector antennas) and printed antennas (microstrip-p coplanar-slot antennas) Some basic numerical calculation methods: integral equation methods in the frequency domain, physical optics and uniform theory of diffraction are briefly summarized and com antennas and scattering problems. Smart antennas in communication and radar systems, with focus steering and adaptive beamforming.         2       Learning objectives         Students will know basic antenna parameters: pattern, gain, directivity, half-power beamwidth, side- lefficiency and input impedance to compare, assess and evaluate different antennas for various applicar operating frequencies. The antenna field regions, reactive near-field, and far-field, and far-field pattern of an antenna can be determined from given current distributions along the by using Fourier transformation or integral solutions with distributed ideal dipoles as basic elements analysis, antenna synthesis, image theory and fundamental limits of elect					f Jakoby		
<ul> <li>Learning objectives         Students will know basic antenna parameters: pattern, gain, directivity, half-power beamwidth, side-le efficiency and input impedance to compare, assess and evaluate different antennas for various applicat operating frequencies. The antenna field regions, reactive near-field, near-field and far-field, can be different and the far-field pattern of an antenna can be determined from given current distributions along the by using Fourier transformation or integral solutions with distributed ideal dipoles as basic elements analysis). To assess in general physical requirements, constrains and limitations of antennas, stud use fundamental antenna theory: impedance matching techniques, antenna modeling and far-field analysis, antenna synthesis, image theory and fundamental limits of electrically small antennas. Affincorporated into the different adaptive beamforming techniques, the array theory enables the student antenna systems that are assembled of a certain number of separate elements, feeding network, beam network etc. for phased-scanning or smart antennas in communications and sensing. Moreover, stud able to determine, analyze and evaluate the most important classes of antennas in wireless technology applications, operating frequencies, desired requirements or practical constrains: (1.) wire-dipole a (2.) planar antennas, lens antennas, Cassegrain and Gregorian double-reflector configurations), (4.) br and frequency-independent antennas (V antennas, biconical antennas, helical antennas, spiral and log antennas). </li> <li>Recommended prerequisites for participation Fundamental 1</li> <li>Form of examination Module exam:     <ul> <li>Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)</li> </ul> </li> </ul>	Overview of Fourier tran image theo directivity a of an anten for beamfor equally spa the most pro- radiation fie applied for coplanar-sle frequency of antennas an	Overview of most important antenna parameters types as well as their applications. Fundamental theories: Fourier transform for far-field pattern calculations, antenna modeling techniques, antenna synthesis methods, image theory, determination of field regions of line sources, of the average radiated power density and power, directivity and gain. Antennas as key elements in power budgets of radio links, introducing the effective aperture of an antenna, deriving the relation between gain and effective aperture. Array antennas are a key hardware for beamforming and smart antenna systems: fundamentals of phased-scanning arrays, non-uniformly excited, equally spaced linear arrays, multi-dimensional planar arrays and mutual coupling effects. Wire antennas: still the most prevalent of all antenna forms, relatively simple in concept, easy to construct, very inexpensive. Antenna radiation fields and antenna parameters for different types of antennas are derived from Maxwell 's equations, applied for aperture antennas (horns, lenses or reflector antennas) and printed antennas (microstrip-patch and coplanar-slot antennas) Some basic numerical calculation methods: integral equation methods in the time and frequency domain, physical optics and uniform theory of diffraction are briefly summarized and compared for antennas and scattering problems. Smart antennas in communication and radar systems, with focus on beam steering and adaptive beamforming.					
<ul> <li>Recommended prerequisites for participation Fundamentals of Communications, Microwave Engineering 1</li> <li>Form of examination Module exam:         <ul> <li>Module exam:</li> <li>Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)</li> </ul> </li> <li>Prerequisite for the award of credit points</li> </ul>	Students wi efficiency a operating fr and the far by using Fo analysis). use fundan analysis, ar incorporate	Students will know basic antenna parameters: pattern, gain, directivity, half-power beamwidth, side- lobe-level, efficiency and input impedance to compare, assess and evaluate different antennas for various applications and operating frequencies. The antenna field regions, reactive near-field, near-field and far-field, can be differentiated and the far-field pattern of an antenna can be determined from given current distributions along the antenna by using Fourier transformation or integral solutions with distributed ideal dipoles as basic elements (antenna analysis). To assess in general physical requirements, constrains and limitations of antennas, students can use fundamental antenna theory: impedance matching techniques, antenna modeling and far-field pattern analysis, antenna synthesis, image theory and fundamental limits of electrically small antennas. After being incorporated into the different adaptive beamforming techniques, the array theory enables the student to design antenna systems that are assembled of a certain number of separate elements, feeding network, beamforming network etc. for phased-scanning or smart antennas in communications and sensing. Moreover, students are able to determine, analyze and evaluate the most important classes of antennas in wireless technology for many applications, operating frequencies, desired requirements or practical constrains: (1.) wire-dipole antennas, (2.) planar antennas (microstrip, dipole and slot antennas), (3.) aperture antennas (horn antennas, parabolic reflector antennas, lens antennas, Cassegrain and Gregorian double-reflector configurations), (4.) broadband					
<ul> <li>Module exam:         <ul> <li>Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)</li> </ul> </li> <li>5 Prerequisite for the award of credit points</li> </ul>	network et able to dete application (2.) planar reflector an and frequen	s, operating frequenc antennas (microstrip tennas, lens antenna	valuate the most ir eies, desired requir , dipole and slot a s, Cassegrain and	nportant classes of rements or practica ntennas), (3.) aper Gregorian double-1	antennas in wireless al constrains: (1.) wi ture antennas (horn reflector configuration	the student to design twork, beamformin preover, students a technology for ma ire- dipole antenna antennas, parabo ons), (4.) broadban	
-	network et able to dete application (2.) planar reflector an and frequer antennas). 3 Recommen	s, operating frequence antennas (microstrip tennas, lens antennas icy-independent anter ded prerequisites for	valuate the most ir eies, desired requir , dipole and slot a s, Cassegrain and nnas (V antennas, or participation	nportant classes of rements or practica ntennas), (3.) aper Gregorian double-1 biconical antennas	antennas in wireless al constrains: (1.) wi ture antennas (horn reflector configuration	the student to design twork, beamformin preover, students a technology for ma ire- dipole antenna antennas, parabo ons), (4.) broadban	
Passing the final module examination	<ul> <li>network et able to dete application (2.) planar reflector an and frequer antennas).</li> <li>3 Recommer Fundament</li> <li>4 Form of ex Module examples and antennas</li> </ul>	s, operating frequence antennas (microstrip) tennas, lens antennas cy-independent anter ded prerequisites for als of Communication amination m:	valuate the most ir eies, desired requir , dipole and slot a s, Cassegrain and nnas (V antennas, or participation ns, Microwave Eng	nportant classes of rements or practica ntennas), (3.) aper Gregorian double-1 biconical antennas	antennas in wireless al constrains: (1.) wi rture antennas (horn reflector configuratio , helical antennas, sp	the student to design twork, beamformin preover, students a technology for ma ire- dipole antenna antennas, parabo ons), (4.) broadban piral and log-period	

	Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)					
7	Usability of the					
	B.Sc. WI-etit, M.	Sc. etit - KTS, M.Sc. etit - SAE, M.Sc. iCE, M.Sc. WI-etit, B	Sc. und M.Sc. iST, M	.Sc. CE		
8	Grade bonus co	mpliant to §25 (2)				
<ul> <li>9 References Skriptum "Antennas and Adaptive Beamforming" will be provided electronically at the beginning</li> <li>Courses</li> </ul>						
	<b>Course nr.</b> 18-jk-2020-vl	<b>Course name</b> Antennas and Adaptive Beamforming				
	Instructor DrIng. Martin Schüßler, DrIng. Alejandro Sáez, M.Sc. Jesús Pastor		<b>Type</b> Lecture	<b>SWS</b> 3		
	<b>Course nr.</b> 18-jk-2020-ue	<b>Course name</b> Antennas and Adaptive Beamforming				
	<b>Instructor</b> DrIng. Martin S	chüßler, DrIng. Alejandro Sáez, M.Sc. Jesús Pastor	<b>Type</b> Practice	<b>SWS</b> 1		

	<b>dule nr.</b> kl-2010	Credit points 5 CP	Workload 150 h	Self-study 90 h	Module duration	Module cycle Winter term
Laı	<b>1guage</b> glish			Module owner Prof. DrIng. Ang		
1		nonlinear digital mo acity, channel model				
2	<ul> <li>Learning objectives</li> <li>After completion of the lecture, students possess: <ul> <li>the ability of comparing, evaluating, classifying an analyzing linear and nonlinear modulation schemes by means of signal space representations;</li> <li>the ability to understand, describe and analyze the influence of AWGN on the signal;</li> <li>the ability to understand and derive optimum receivers in case of AWGN channels;</li> <li>the ability to understand, describe and analyze the influence of multipath propagation on the signal;</li> <li>the ability to understand, describe and analyze the influence of multipath propagation on the signal;</li> <li>the ability to describe the influence of a multipath channel mathematically (channel model) and estimate the multipath channel at the receiver;</li> <li>the knowledge of equalizing the received signal in order to undo the influence of multipath propagation, as well as the ability to derive and design several equalizer structures;</li> <li>the ability to analyze and evaluate the properties and application areas of multicarrier transmission systems, e.g. OFDM-systems;</li> <li>the ability to design and evaluate the system parameters of multicarrier schemes for the application in realistic wireless communication scenarios;</li> <li>the ability to mathematically express and analyze all above system models in matrix-vector-notation.</li> </ul> </li> </ul>					
3	Determinist	<b>ded prerequisites fo</b> ische Signale und Syst istics/Probability The	teme, Communica		Basics of Telecommun	ication, Mathematic
4	Form of exa Module exa	amination			90 Min., Default RS)	
5		e for the award of cr final module examina				
6	<b>Grading</b> Module exa			ination, Weighting	: 100 %)	
	Usability of the module M.Sc. etit - KTS, M.Sc. etit - VAS, M.Sc. iCE, M.Sc. WI-etit, B.Sc. und M.Sc. iST, M.Sc. CE					
7	•		M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	M.Sc. iST, M.Sc. CE	

<b>Course nr.</b> 18-kl-2010-	Course nr.Course name18-kl-2010-vlCommunication Technology II					
<b>Instructor</b>	Instructor		<b>SWS</b>			
Prof. DrIng	Prof. DrIng. Anja Klein		2			
<b>Course nr.</b> 18-kl-2010-1	e Course name Communication Technology II					
Instructor	Instructor		<b>SWS</b>			
Prof. DrIng	Prof. DrIng. Anja Klein, M.Sc. Sumedh Dongare, M.Sc. Yi Wang		2			

	Module name Convex Optimization in Signal Processing and Communications					
Мо	<b>dule nr.</b> pe-2020	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Summer term
	iguage	0 CP	100 11	Module owner	1 10111	Summer term
Eng	glish			Prof. DrIng. Mar	rius Pesavento	
1	applications Outline: Intr SOCP, SDP, C optimization distributed of Bound methor method, con BSUM methor	te course introduces t in communication sy roduction, convex sets GP), Lagrange duality n tools, convex inne optimization, discrete od, Branch-and-Cut n jugate gradient metho	vstems and signal and convex function and KKT condition r and outer appro- optimization, mix- nethod, customized od, block coordinal cimization, different	processing. ions, convex problem ns, basics of numeric oximations for nor sted integer linear a d iterative optimizate te descent method,	ms and classes of conv cal algorithms and in a convex problems, and non-linear progra ttion, Newton methoc successive convex ap	use with many recent vex problems (LP, QP, terior point methods, sparse optimization, amming, Branch-and- d, gradient projection proximation method, ze selection, optimal
2	Learning objectivesAfter completing the module, students will have become familiar with advanced topics in modern communication.This includes in particular the basic theory of convex optimization and its application in digital signal processing and mobile communication systems.					
3	<b>Recommended prerequisites for participation</b> Knowledge in linear algebra and the basic concepts of signal processing and communications.					
4	The examin less than 14	n: e exam (Technical ex ation takes place in	form of a written e examination wi	n exam (duration: Il be an oral exam	120 minutes). If or	n., Default RS) ne can estimate that 0 min.). The type of
5		e for the award of c				
6	Grading Module exar • Modul	n: e exam (Technical ex	kamination, Oral/	written examinatio	n, Weighting: 100 %	)
7			M.Sc. etit - KTS, M	l.Sc. etit - VAS, M.S	c. iCE, M.Sc. WI-etit,	B.Sc. und M.Sc. iST,
8	Grade bonu	s compliant to §25	(2)			
9	References					
	<ul> <li>S. Boyd and L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004. (online Verfügbar: http://www.stanford.edu/ boyd/cvxbook/)</li> <li>D. P. Bertsekas, Nonlinear Programming, Athena Scientific, Belmont, Massachusetts, 2nd Ed., 1999.</li> <li>Daniel P. Palomar and Yonina C. Eldar, Convex Optimization in Signal Processing and Communications, Cambridge University Press, 2009.</li> </ul>					
Coi	ırses					

<b>Course nr.</b>	Course name				
18-pe-2020-vl	Convex Optimization in Signal Processing and Communications				
<b>Instructor</b>	arius Pesavento	<b>Type</b>	SWS		
Prof. DrIng. M		Lecture	2		
<b>Course nr.</b> 18-pe-2020-ue					
Instructor	arius Pesavento, M.Sc. Yufan Fan	<b>Type</b>	<b>SWS</b>		
Prof. DrIng. M		Practice	1		
<b>Course nr.</b> 18-pe-2020-pr	<b>Course name</b> Convex Optimization in Signal Processing and C	Communications Lab			
<b>Instructor</b>	arius Pesavento	<b>Type</b>	<b>SWS</b>		
Prof. DrIng. M		Lab	1		

	dule nr. zo-2060	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycl Winter term	e	
Laı	<b>1guage</b> glish	0.01	100 11	Module owner Prof. DrIng. Abo		Winter term		
1	<ol> <li>Digital Fil</li> <li>Impulse Resp</li> <li>Digital Sp</li> </ol>	ime Signals and Lin ter Design - Filter D oonse Filters; Impler ectral Analysis - Ra imation; Application	esign Principles; L nentations ndom Signals; No	inear Phase Filters	ruction of Analog Sig ; Finite Impulse Resp ods for Spectrum Est	oonse Filters; Ir		
2	Students und Furthermore the basics of	<b>Learning objectives</b> Students understand basic principles of signal processing. They can design and analyze FIR and IIR filters. Furthermore, they are able to analyze statistical signals in the time and frequency domain. The students know the basics of spectral estimation and can design non-parametric as well as parametric spectral estimators and analyze them with respect to their performance.						
3		ed prerequisites for c signals and system						
4	Module exan	<ul> <li>Form of examination</li> <li>Module exam:</li> <li>Module exam (Technical examination, Examination, Duration: 180 Min., Default RS)</li> </ul>						
5		for the award of c						
6	Grading Module exan • Module	n: e exam (Technical ez	xamination, Exam	ination, Weighting	: 100 %)			
7	Usability of M.Sc. etit - K und M.Sc. iS	TS, M.Sc. etit - SAE	E, M.Sc. etit - VAS,	M.Sc. iCE, M.Sc.	MEC, M.Sc. MedTec	, M.Sc. WI-etit	, B.S	
8	Grade bonus	s compliant to §25	(2)					
9								
Co	urses							
	Course nr.	Course name						
	18-zo-2060-v	l Digital Signal	Processing					

<b>Course nr.</b> 18-zo-2060-ue	<b>Course name</b> Digital Signal Processing		
Instructor Prof. DrIng. Abc	lelhak Zoubir, M.Sc. Christian Eckrich, M.Sc. Christian Schroth	<b>Type</b> Practice	<b>SWS</b> 1

	dule name	leling - Machine Leaı	rning			
Мо	dule nr.	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration	Module cycle
Lar	kp-2110 <b>1guage</b> glish	6 CP	180 h	Module owner Prof. Dr. techn. H	1 Term Jeinz Köppl	Summer term
1						
2	Learning objectives         Students are able to interpret and categorize specific engineering problems from the ICT domain in terms of machine learning problems.         They are able to reduce such problems to standard machine learning problems and are able to determine suitable solution methods for them.					
	<ul><li>They are able to implement all necessary algorithms from scratch, but they are also familiar with t state-of-the-art libraries in machine learning.</li><li>They are able to determine the involved computational complexity of a method and choose an app priate solution algorithms based on application constraints.</li><li>They are able to apply the acquired methods to other domains, such as data analysis in biomedia</li></ul>					d choose an appro-
3	engineering, analysis of social network data, etc.					- -
4	The examin less than 10	<b>amination</b> m: le exam (Technical e: nation takes place in	form of a written ne examination w	n exam (duration: ill be an oral exam	120 minutes). If or	n., Default RS) ne can estimate that 0 min.). The type of

5		Prerequisite for the award of credit points Passing the final module examination				
6	Grading Module exam: • Module exa	am (Technical examination, Oral/written examination, Weight	ting: 100 %)			
7	B.Sc. WI-etit, M	Usability of the module B.Sc. WI-etit, M.Sc. etit - CMEE, M.Sc. etit - DT, M.Sc. etit - KTS, M.Sc. etit - VAS, M.Sc. iCE, M.Sc. WI-etit, B.Sc. und M.Sc. iST, B.Sc. CE, M.Sc. CE				
8	Grade bonus compliant to §25 (2)					
9 Cot	<ul> <li>References</li> <li>Kevin P. Murphy. Machine Learning - A probabilistic perspective, MIT Press, 2012</li> <li>Christopher M. Bishop. Pattern recognition and Machine Learning, Springer, 2006</li> <li>Peter Bühlmann und Sara van de Geer. Statistics of high-dimensional data - Methods, theory and applications, Springer, 2011</li> </ul>					
	<b>Course nr.</b> 18-kp-2110-vl	Course name Data-driven Modeling - Machine Learning				
	<b>Instructor</b> Prof. Dr. techn. H	leinz Köppl	<b>Type</b> Lecture	<b>SWS</b> 2		
	<b>Course nr.</b> 18-kp-2110-ue	<b>Course name</b> Data-driven Modeling - Machine Learning				
	InstructorTypeSWProf. Dr. techn. Heinz KöpplPractice1					
	<b>Course nr.</b> 18-kp-2110-pr	<b>Course name</b> Data-driven Modeling - Machine Learning Lab				
	<b>Instructor</b> Prof. Dr. techn. H	leinz Köppl	<b>Type</b> Lab	<b>SWS</b> 1		

	Module name Matrix Analysis and Computations						
	<b>dule nr.</b> pe-2070	<b>Credit points</b> 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Summer term	
	i <b>guage</b> lish			<b>Module owner</b> Prof. DrIng. Ma	rius Pesavento		
1	1 <b>Teaching content</b> This graduate course is a foundation class on matrix analysis and computations, which are widely used in many different fields, e.g., machine learning, computer vision, systems and control, signal and image processing, communications, networks, optimization, and many more Apart from the theory this course will also cover the design of efficient algorithm and it considers many different examples from the aforementioned fields including examples from social media and big data analysis, image processing and medical imaging, communication network optimization, and written text classification. Specific topics: (i) basic matrix concepts, subspace, norms, (ii) linear least squares (iii) eigendecomposition, singular value decomposition, positive semidenite matrices, (iv) linear system of equations, LU decomposition, Cholesky decomposition (v) pseudo-inverse, QR decomposition (vi) advanced tensor decomposition, advanced matrix calculus, compressive sensing, structured matrix factorization						
2			ced topics in matr	ix analysis and rela	ated algorithms at an	advanced level upon	
3		<b>led prerequisites fo</b> edge in linear algebra					
4	The examinates the states that 10	n: e exam (Technical ex ation takes place in	form of a written e examination wi	n exam (duration: Il be an oral exam	on, Duration: 120 Mir 120 minutes). If or ination (duration: 20	ne can estimate that	
5	Prerequisite Pass module	e <b>for the award of c</b> final exam.	redit points				
6							
7				etit - CMEE, M.Sc.	etit - KTS, M.Sc. iCI	E, M.Sc. MEC, M.Sc.	
8	Grade bonu	s compliant to §25	(2)				
9	References						

- Gene H. Golub and Charles F. van Loan, Matrix Computations (Fourth Edition), John Hopkins University Press, 2013.
- Roger A. Horn and Charles R. Johnson, Matrix Analysis (Second Edition), Cambridge University Press, 2012.
- Jan R. Magnus and Heinz Neudecker, Matrix Differential Calculus with Applications in Statistics and Econometrics (Third Edition), John Wiley and Sons, New York, 2007.
- Giuseppe Calaore and Laurent El Ghaoui, Optimization Models, Cambridge University Press, 2014.
- ECE 712 Course Notes by Prof. Jim Reilly, McMaster University, Canada (friendly notes for engineers) http://www.ece.mcmaster.ca/faculty/reilly/ece712/course\_notes.htm

#### Courses

<b>Course nr.</b> 18-pe-2070-vl	<b>Course name</b> Matrix Analysis and Computations		
Instructor Prof. DrIng. Marius Pesavento		<b>Type</b> Lecture	<b>SWS</b> 3
<b>Course nr.</b> 18-pe-2070-ue	<b>Course name</b> Matrix Analysis and Computations		·
Instructor Prof. DrIng. Marius Pesavento		<b>Type</b> Practice	<b>SW</b> 5

	dule name							
	Mobile Communications							
	<b>dule nr.</b> kl-2020	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Summer term		
	Language Module owner							
	English Prof. DrIng. Anja Klein							
1	<ul> <li>Teaching content         The lecture covers aspects of mobile communication systems with particular focus on the physical layer.         Mobile radio systems, services, market, standardization         Duplex and multiple access techniques, cellular concept         Mobile radio channel, deterministic and stochastic description         Modulation schemes         Code division multiple access (CDMA)         Orthogonal frequency division multiplexing (OFDM)         Optimum and suboptimum receiver techniques         Cellular radio capacity and spectrum efficiency         Diversity methods         Multiple input multiple output (MIMO) systems         Power control and handover         Architecture of mobile radio systems</li></ul>							
2	<ul> <li>Learning objectives         After completion of the module, students possess         • a profound understanding of physical layer aspects ,e.g., transmission schemes, multiple access schemes of mobile communication systems, duplex schemes, multi carrier schemes, receiver techniques, multi antenna schemes         • a profound understanding of signal propagation in mobile radio systems (mobile radio channel)         • the ability to understand and solve problems of the field of the physical layer         • the ability to compare, analyse and evaluate different system concepts         • knowledge on modelling of the transmission properties of the mobile radio channel     </li> </ul>							
3	Determinist	<b>ded prerequisites fo</b> ic Signals and Syster ntific Computing		on Technology I, M	athematics I to III, S	Statistics/Probability		
4	Form of exa Module exa • Modul		xamination, Exam	ination, Duration:	90 Min., Default RS)			
5		e for the award of c						
6	<ul> <li>Grading</li> <li>Module exam:</li> <li>Module exam (Technical examination, Examination, Weighting: 100 %)</li> </ul>							
7	•	<b>the module</b> KTS, M.Sc. etit - VAS,	, M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	M.Sc. iST			
8	Grade bonu	s compliant to §25	(2)					
9	References							

#### | will be announced in the lecture

will be annound	ed in the lecture					
Courses						
<b>Course nr.</b> 18-kl-2020-vl						
Instructor Prof. DrIng. Ar	ja Klein, DrIng. Lin Xiang	<b>Type</b> Lecture	<b>SWS</b> 3			
<b>Course nr.</b> 18-kl-2020-ue	Course name Mobile Communications					
<b>Instructor</b> Prof. DrIng. An Yilmaz	nstructor Prof. DrIng. Anja Klein, DrIng. Lin Xiang, M.Sc. Fengcheng Pei, M.Sc. Mustafa		<b>SWS</b> 1			

Uр	tical Commun	ications - Component	ts			
	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
18-	pr-1050	6 CP	180 h	120 h	1 Term	Summer term
Language English				Module owner Prof. Dr. rer. nat.	Sascha Preu	
1	munication of The nature of Wave of Polariz Absorp Mirron Waveguides Fiber-of Attenu Fiber t Conne Disper Kerr n Components Optica Wavele Magne Electro Lasers Erbiur Optica	discusses the working networks and optical of light equation zation otion, transmission, re s, HR-/AR coatings optic waveguides lation, modes, dispers ypes ctors and splices sion and dispersion conlinearity and self-p s, e.g.:	data transmission eflection, refraction sion ohase modulation lexers tical isolator / cir ' amplifiers (EDFL r / amplifier (lase	systems. The start on culator . / EDFA)		
2		<b>ojectives</b> derstand concepts, ba most important pass				component specifi
3	<b>Recommen</b> etit 1 + 2, P	<b>ded prerequisites fo</b> hysics	r participation			
4	Form of exa Module exa • Modul		amination, Exam	ination, Duration:	90 Min., Default RS)	
5		e for the award of cr final module examina				
5	Grading Module exa • Modul	n: e exam (Technical ex	amination, Exam	ination, Weighting	: 100 %)	
7	-	<b>the module</b> Sc. WI-etit, M.Sc. eti	it - KTS, M.Sc. eti	t - SAE, M.Sc. iCE,	M.Sc. WI-etit, B.Sc.	und M.Sc. iST, B.I

9	References					
	Lecture slides					
	Textbook (M. Cv	jetic, I. B. Djordjevic: "Advanced Optical Communication Sys	tems and Networks")			
Co	urses					
	Course nr. Course name					
	18-pr-1050-vl	<b>Optical Communications - Components</b>				
	Instructor		Туре	SWS		
	Prof. Dr. rer. nat.	Sascha Preu	Lecture	3		
	Course nr.	Course name				
	18-pr-1050-ue Optical Communications - Components					
	Instructor		Туре	SWS		
	Prof. Dr. rer. nat.	Sascha Preu	Practice	1		

	<b>dule name</b> hnical Electro	odynamics for iCE					
Мо	Module nr.Credit pointsWorkloadSelf-studyModule durationModule cycle18-dg-21505 CP150 h90 h1 TermWinter term						
Lar	<b>iguage</b> Ilish		100 11	Module owner Prof. DrIng. Her			
1	Teaching content						
	<ol> <li>Fundamentals of electromagnetic field theory - Maxwell's equations in differential and integral form; Electromagnetic waves: propagation in free space, polarization, reflection/refraction.</li> <li>Numerical solution of electromagnetic field problems - Space discretization with surface and volume meshes; Main numerical algorithms for discrete local approximation of Maxwell's equations; Finite Integration Technique; Time and frequency domain solution methods; Stability, convergence.</li> <li>Practical aspects of electromagnetic simulation - Introduction to accuracy issues; Preprocessing: 3D geometry, computational domain, boundary conditions, electromagnetic field sources; Time vs frequency domain; Postprocessing; Network parameter extraction.</li> <li>Application to typical high-frequency devices: Waveguide / resonator structures, planar structures</li> </ol>						
2	be able to m	<b>bjectives</b> ll understand fundan odel microwave comp vare tools for electror	oonents with simu				
3		ded prerequisites fo als of electrodynamic		r Elektrodynamik)			
4	Form of exa Module exa • Modul		amination, Exam	ination, Duration:	180 Min., Default RS	3)	
5		e for the award of cr final module examina					
6	Grading         Module exam:         • Module exam (Technical examination, Examination, Weighting: 100 %)						
7	Usability of M.Sc. iCE, M	t <b>he module</b> A.Sc. CE					
8	Grade bonu	is compliant to §25	(2)				
9 Со1	References         Course manuscript         Additional References:         • D.K. Cheng: Field and Wave Electromagnetics. Addison-Wesley, New York, 1992         • C.A. Balanis: Advanced Engineering Electromagnetics. Wiley, New York, 1989         • Andrew F. Peterson et al. Computational Methods for Electromagnetics. Wiley-IEEE Press, 1997.						

<b>Course nr.</b>	Course name				
18-dg-2150-vl	Technical Electrodynamics for iCE				
<b>Instructor</b>	unteanu, Prof. Dr. Peter Thoma	<b>Type</b>	SWS		
Prof. Dr. Irina M		Lecture	2		
<b>Course nr.</b> 18-dg-2150-ue	<b>Course name</b> Technical Electrodynamics for iCE				
<b>Instructor</b>	unteanu, Prof. Dr. Peter Thoma	<b>Type</b>	<b>SWS</b>		
Prof. Dr. Irina M		Practice	2		

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
	sm-2340	4 CP	120 h	75 h	1 Term	Summer term
	<b>1guage</b> glish			Module owner Prof. Dr. rer. nat. Björn Scheuermann		
1	<ul> <li>Resilie</li> <li>Resilie</li> <li>Import</li> <li>Requir</li> <li>Requir</li> <li>Methoto - W</li> <li>- W</li> <li>Resilie</li> </ul>	covers the following to nee in the different of nee in communication tance of resilience for tements for current of ds to increase resilient direless networks (e.g. dired networks nt network managemence through adaptivity	lisciplines in networks r communication n ommunication net nce in communiat g., mobile commun nent in software-c	tworks ion networks nications) lefined networks		
<u></u>	Learning objectives         Students are familiar with the idea and necessity of resilience in various disciplines with a focus on adaptive communication networks. They are familiar with various methods for increasing resilience, such as redundance and diversity, and can apply these methods to the design of communication networks.					
2	Students are communicat	e familiar with the ic ion networks. They a	re familiar with v	arious methods for	increasing resilience,	
	Students are communicat and diversit	e familiar with the ic ion networks. They a	re familiar with v e methods to the	arious methods for	increasing resilience,	
3	Students are communicat and diversit Recommend Form of exa Module exam • Modul The examina 10 students	e familiar with the ic ion networks. They a y, and can apply thes ded prerequisites for mination n: e exam (Technical ex ation takes place in f	re familiar with v e methods to the or participation camination, Oral/ orm of a written e tion will be an ora	arious methods for design of commun written examinatic exam (duration: 90	increasing resilience,	, such as redundan , Default RS) timate that less th
2 3 4 5	Students are communicat and diversit Recommend Form of exa Module exam • Modul The examina 10 students will be anno Prerequisite	e familiar with the ic ion networks. They a y, and can apply thes <b>ded prerequisites fo</b> <b>mination</b> n: e exam (Technical ex ation takes place in f register, the examina unced in the beginni e for the award of c	amination, Oral/ amination, Oral/ orm of a written e tion will be an ora ng of the lecture. redit points	arious methods for design of commun written examinatic exam (duration: 90	increasing resilience, ication networks. on, Duration: 90 Min. 0 min.). If one can est	, such as redundan , Default RS) timate that less th
3	Students are communicat and diversit Recommend Form of exa Module exam • Modul The examina 10 students will be anno Prerequisite Passing the Grading Module exam	e familiar with the ic ion networks. They a y, and can apply thes <b>ded prerequisites fo</b> <b>ded prerequisites for <b>ded prerequisites for <b>ded prerequisites fo</b> <b>ded prerequisites for <b>d</b></b></b></b>	amination, Oral/ amination, Oral/ orm of a written e tion will be an ora ng of the lecture. redit points ation	arious methods for design of communi written examinatio exam (duration: 90 al examination (du	increasing resilience, ication networks. on, Duration: 90 Min. 0 min.). If one can est	, such as redundan , Default RS) timate that less th type of examinati
3 4 5	Students are communicat and diversit Recommend Form of exa Module exam- Modul exam- 10 students will be anno Prerequisite Passing the Grading Module exam- Modul Usability of	e familiar with the ic ion networks. They a y, and can apply thes <b>ded prerequisites fo</b> <b>ded prerequisites fo</b> <b>e</b> exam (Technical examination) <b>e for the award of c</b> final module examination m: e exam (Technical examination) <b>the module</b>	amination, Oral/ amination, Oral/ form of a written or ang of the lecture. ation	arious methods for design of communi- written examinatio exam (duration: 90 al examination (du	increasing resilience, ication networks. on, Duration: 90 Min. 0 min.). If one can es ration: 30 min.) The	, such as redundan , Default RS) timate that less th type of examinati

A lecture notes or slides can be downloaded:

Moodle Platform

Advanced literature

- Smith, Paul, et al. "Network resilience: a systematic approach." IEEE Communications Magazine 49.7 (2011): 88-97
- Sterbenz, James PG, et al. "Resilience and survivability in communication networks: Strategies, principles, and survey of disciplines." Computer networks 54.8 (2010): 1245-1265
- Mauthe, Andreas, et. al. "Disaster-resilient communication networks: Principles and best practices." 2016 8th International Workshop on Resilient Networks Design and Modeling (RNDM). IEEE, 2016

#### Courses

Course nr.	Course name				
18-sm-2340-vl	Resilient Communication Networks				
Instructor		Туре	sws		
Prof. Dr. rer. nat.	Björn Scheuermann, DrIng. Tobias Meuser	Lecture	2		
Course nr.	Course name				
18-sm-2340-ue	Resilient Communication Networks				
Instructor		Туре	SWS		
Prof. Dr. rer. nat.	Björn Scheuermann, DrIng. Tobias Meuser	Practice	1		

# 2 Optionals

## 2.1 Communication Hardware

### 2.1.1 Communication Hardware - Lectures

<b>Module nr.</b> 16-17-5110		Credit points 4 CP		Self-study	Module duration	Module cycle	
Laı	nguage	4 CP	120 h	Module owner			
<u>En</u> § 1	electronics (	nnologies for functior	Activities for qua		orsam ystems); Design and i imples of application		
2	<ol> <li>Describe t</li> <li>Name ma materials on</li> <li>Classify a</li> <li>Explain b</li> <li>RFIDs, photo</li> <li>Describe</li> </ol>	Il completion of this the printing technolo terials that are appro- the design e.g. of ar nd rate different acti asic functions, config ovoltaics and batterie	gies that are appli opriate to printing atennas and OFET vites for quality a urations, material es. " as a multidiscip	icable for "Printed processes and to c 's. ssurance. ls, and specific prop	Electronics". lescribe the impact of perties of printed ant nsists of electrical er	ennas,	
3		<b>ded prerequisites fo</b> components and Meo		recommended			
4	<ul> <li>Mechanical components and Mechatronics I and II recommended</li> <li>Form of examination</li> <li>Module exam: <ul> <li>Module exam (Technical examination, Oral examination, Duration: 30 Min., Default RS)</li> <li>Oral exam 30 min</li> </ul> </li> </ul>						
5		e for the award of c	redit points				
	Passing the examination         Grading         Module exam:         • Module exam (Technical examination, Oral examination, Weighting: 100 %)						
6	Module exam:						

9	References			
	The current lectu	ire notes can be downloaded from the web pages of the institute	while the semester is in	session.
Cot	urses			
	Course nr.	Course name		
	16-17-5110-vl	Printed Electronics		
	Instructor		Туре	SWS
			Lecture	2

	<b>dule name</b> crosystem Tech	nology				
	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
	bu-2010	4 CP	120 h	75 h	1 Term	Winter term
	<b>iguage</b> man			Module owner Prof. Ph.D. Thom	as Burg	
1	sensors, acce to achieve giv	able to explain the s lerometers, biologic ven specifications, a naterials, devise basi	cal and chemical s nd to judge the in	ensors, micro-option npact of scaling on	tes for common applic cal systems), calculat the device performa ify compatibility issue	e design paramete ince. They can sele
2	sensors, acce to achieve giv	able to explain the s lerometers, biologic ven specifications, a naterials, devise basi	cal and chemical s nd to judge the in	ensors, micro-option npact of scaling on	tes for common applic cal systems), calculat the device performa ify compatibility issue	e design paramete ince. They can sele
3	Recommend	ed prerequisites fo	or participation			
4	Form of exam Module exam • Module	1:	xamination, Exam	ination, Duration:	90 Min., Default RS)	1
5		for the award of c				
6	Grading Module exam • Module	ı: exam (Technical ez	xamination, Exam	ination, Weighting	: 100 %)	
7	Usability of 1 M.Sc. etit - S.		e. MEC, M.Sc. Med	dTec, M.Sc. WI-etit	, B.Sc. und M.Sc. iS	Г, M.Sc. CE
8		s compliant to §25 bending on problem		articipation		
9	References Lecture notes	s, Moodle course		_		
Co	urses					
	<b>Course nr.</b> 18-bu-2010-v	Course name Microsystem T				
	<b>Instructor</b> Prof. Ph.D. Tl	nomas Burg			<b>Type</b> Lecture	<b>SW</b> 2
	<b>Course nr.</b> 18-bu-2010-u	Course name Microsystem T	echnology			
	Instructor	1 *	J•		Туре	SWS

	dule nr.	Cradit nainta	Workload	Colf study	Module duration	Modulo avalo
	bu-2030	Credit points 5 CP	150 h	Self-study 90 h	1 Term	Module cycle Summer term
Laı	nguage	e		Module owner		
	rman			Prof. Ph.D. Thom	as Burg	
	<ul> <li>Bioanalytical methods</li> <li>Opportunities and fundamental limitations of miniaturization</li> <li>Technology of microfluidic systems</li> <li>The solid-liquid-interface</li> <li>Transport processes</li> <li>Biosensors</li> <li>Single molecule methods</li> <li>PCR-based micro-analytical systems</li> <li>Single-cell sequencing</li> <li>Flow cytometry</li> <li>Optofluidics</li> <li>Organ-on-Chip-Technologies</li> </ul>					
	Students will learn to evaluate and compare conventional and microfluidic bioanalytical methods for laborato medicine and Point-of-Care applications. They become familiar with the underlying physical principles ar scaling laws and learn to analyze the impact of miniaturization quantitatively. The skills acquired in this cour will enable the participants to select appropriate techniques, to advance knowledge, and to address technologic gaps in the biomedical sciences with the help of microfluidic systems.					
	Students will medicine ar scaling laws will enable t gaps in the l	Il learn to evaluate an ad Point-of-Care app and learn to analyze he participants to selo	lications. They be the impact of mir ect appropriate tec vith the help of m	come familiar wit niaturization quant hniques, to advance	h the underlying ph itatively. The skills ac e knowledge, and to a	ysical principles an equired in this cours
2 3 4	Students will medicine ar scaling laws will enable t gaps in the l Recomment Form of exa Module exar • Modul Performance (<11), an o	Il learn to evaluate and ad Point-of-Care app and learn to analyze he participants to sele biomedical sciences v ded prerequisites for amination	lications. They be the impact of mir ect appropriate tec vith the help of m or participation wased on a written ered instead (dura	ecome familiar with niaturization quanti hniques, to advance icrofluidic systems. written examination final exam (durat tion: 30 min.). The	h the underlying phy itatively. The skills ac e knowledge, and to a n, Duration: 90 Min. ion: 90 min.). In cas	ysical principles an equired in this cours address technologica , Default RS) se of low enrollmer
3	Students will medicine ar scaling laws will enable t gaps in the l Recommend Form of exa Module exat • Modul Performance (<11), an o will be anno Prerequisite	Il learn to evaluate and ad Point-of-Care app and learn to analyze he participants to sele biomedical sciences v ded prerequisites for amination m: he exam (Technical exa he will be evaluated b ral exam may be offer	lications. They be the impact of mir ect appropriate tec vith the help of m or participation wased on a written ered instead (dura ing of each semest redit points	ecome familiar with niaturization quanti hniques, to advance icrofluidic systems. written examination final exam (durat tion: 30 min.). The	h the underlying phy itatively. The skills ac e knowledge, and to a n, Duration: 90 Min. ion: 90 min.). In cas	ysical principles an equired in this cours address technologica , Default RS) se of low enrollmer
3 4 5	Students will medicine ar scaling laws will enable t gaps in the l Recommend Form of exa Module exat • Modul Performance (<11), an o will be anno Prerequisite Passing the t Grading Module exat	Il learn to evaluate and and Point-of-Care appli- and learn to analyze he participants to sele- biomedical sciences v ded prerequisites for mination m: te exam (Technical ex- te will be evaluated b ral exam may be offe- bunced at the beginni- te for the award of co- final module examina-	lications. They be the impact of mir ect appropriate tec vith the help of m or participation examination, Oral/ based on a written ered instead (dura ing of each semest redit points ation	ecome familiar wit niaturization quant hniques, to advance icrofluidic systems. written examination final exam (durat tion: 30 min.). The rer.	h the underlying phy itatively. The skills ac e knowledge, and to a on, Duration: 90 Min. ion: 90 min.). In cas e mode of the final ex	ysical principles an equired in this cours address technologica , Default RS) se of low enrollmer cam (written or ora
3 4 5 6	Students will medicine ar scaling laws will enable t gaps in the l Recommend Form of exa Module exa • Modul Performance (<11), an o will be anno Prerequisite Passing the t Grading Module exa • Modul Usability of	Il learn to evaluate and ad Point-of-Care app and learn to analyze he participants to sele biomedical sciences v ded prerequisites for amination m: le exam (Technical exa e will be evaluated b ral exam may be offer bunced at the beginnit e for the award of c final module examination m:	lications. They be the impact of mir ect appropriate tec vith the help of m or participation ased on a written ered instead (durating of each semest redit points ation	ecome familiar wit niaturization quant hniques, to advance icrofluidic systems. written examination final exam (durat tion: 30 min.). The rer.	h the underlying phy itatively. The skills ac e knowledge, and to a on, Duration: 90 Min. ion: 90 min.). In cas e mode of the final ex	ysical principles an equired in this cours address technologica , Default RS) se of low enrollmer cam (written or ora
3	Students will medicine ar scaling laws will enable t gaps in the l Recommend Form of exa Module exan • Modul Performance (<11), an o will be anno Prerequisite Passing the Grading Module exan • Modul Usability of M.Sc. etit - 1	Il learn to evaluate and and Point-of-Care appli- and learn to analyze he participants to sele- biomedical sciences v ded prerequisites for mination m: e exam (Technical ex- e will be evaluated b ral exam may be offe- ounced at the beginni- e for the award of ca- final module examina- m: e exam (Technical ex- final module examina- m:	lications. They be the impact of mir ect appropriate tec with the help of m or participation wased on a written ered instead (dura ing of each semest redit points ation kamination, Oral/ c. MedTec	ecome familiar wit niaturization quant hniques, to advance icrofluidic systems. written examination final exam (durat tion: 30 min.). The rer.	h the underlying phy itatively. The skills ac e knowledge, and to a on, Duration: 90 Min. ion: 90 min.). In cas e mode of the final ex	ysical principles an equired in this cours address technologica , Default RS) se of low enrollmer cam (written or ora

<b>Course nr.</b> 18-bu-2030-v	Course name Lab-on-Chip Systeme					
<b>Instructor</b>	omas Burg	<b>Type</b>	<b>SWS</b>			
Prof. Ph.D. Th		Lecture	2			
<b>Course nr.</b> 18-bu-2030-u	<b>Course name</b> Lab-on-Chip Systems					
<b>Instructor</b>	omas Burg	<b>Type</b>	<b>SWS</b>			
Prof. Ph.D. Th		Practice	2			

	<b>dule name</b> v-Level Synthe	sis					
	<b>dule nr.</b> hb-2010	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration	Module cyc Summer ter	
Lar	nguage glish						
1	<b>Teaching co</b> The module approaches si two level min level is achie add geometr	deals with synthesi uitable for FPGAs. An nimizations, exact a eved by different d ic information to th	t the logic level diff nd heuristic multi ecomposition and ne technology map	raction layers belo erent types of minin level logic minimis structural mappin pped circuit. Analy	w the register tran mization are explaine zations). The transit ng techniques (Flow /tical and heuristic ough the PathFinder	ed (exact and h ion to the tech vMap). Place placers are dis	euristic nnology &Route
2	tasks. They c applicability	tion of the module, s	oproaches regardir ntation technologi	ng their time and sp les.	nthesis approaches a bace complexity, as v		
3	Knowledge o Reese/Thorr Digital Logic	ton: Introduction t	is on the basis of a o Logic Synthesis a). The student sh	Using Verilog Hdl	are description lang oder Brown/Vrane nowledge of at leas	sic: Fundame	ntals of
4	Form of exam Module exam • Module	1:	xamination, Oral e	examination, Durat	ion: 30 Min., Defau	lt RS)	
5		for the award of c					
6	Grading Module exan • Module	n: e exam (Technical e	xamination, Oral 6	examination, Weigl	nting: 100 %)		
7	<b>Usability of</b> M.Sc. etit - D	<b>the module</b> DT, M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	l M.Sc. iST			
8	Grade bonus	s compliant to §25	(2)				
9		the lecture will be o	listributed throug	h moodle.			
COL	ırses						
	<b>Course nr.</b> 18-hb-2010-v	Course namevlLow-Level Syr					
	<b>Instructor</b> Prof. DrIng.	Christian Hochberg	ger		<b>Type</b> Lecture		SWS 2

<b>Course nr.</b> 18-hb-2010-pr	Course name Low-Level Synthesis		
Instructor Prof. DrIng. Ch	ristian Hochberger	<b>Type</b> Lab	<b>SWS</b> 2

	<b>dule nr.</b> hb-2020	<b>Credit points</b> 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Winter term		
Laı	nguage glish	0 CP	100 11	Module owner         Prof. DrIng. Christian Hochberger				
1	<b>Teaching con</b> Mapping of b • Sub-tas • Exact o		luling, binding		nents) on FPGA and	CGRA structures		
2	Students that synthesis and	Learning objectives Students that have completed this module know alternative approaches for all of the tasks of the high level synthesis and can select appropriate ones for specific applications. They can evaluate the memory and time complexity of the given algorithms. They are enabled to adapt the algorithms for new constraints and new target rechnologies.						
3	Knowledge o Reese/Thorn Digital Logic	ton: Introduction t	is on the basis of a o Logic Synthesis n). The student sh	Using Verilog Hdl	are description langu oder Brown/Vranes nowledge of at least	ic: Fundamentals of		
4	Form of examination         Module exam:         • Module exam (Technical examination, Oral examination, Duration: 30 Min., Default RS)							
5		for the award of c nal module examin						
6	Grading Module exam • Module	ı: exam (Technical e	xamination, Oral e	examination, Weigh	nting: 100 %)			
7	<b>Usability of 1</b> M.Sc. etit - D	t <b>he module</b> T, M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	l M.Sc. iST				
8	Grade bonus	compliant to §25	(2)					
9	<b>References</b> English slides	s can be obtained th	nrough Moodle.					
Co	urses							
	<b>Course nr.</b> 18-hb-2020-v	Course name'lHigh-Level Sy						
	Instructor Prof. DrIng.	Christian Hochberg	ger		<b>Type</b> Lecture	<b>SWS</b> 2		
	<b>Course nr.</b> 18-hb-2020-p	or High-Level Sy						

	dule name	Systems				
Мо	<b>dule nr.</b> ho-2040	Credit points	Workload 120 h	Self-study 75 h	Module duration 1 Term	Module cycle
	nguage	4 CP	120 II	Module owner	1 Ierm	Summer term
	glish			Prof. DrIng. Kla	us Hofmann	
1	<b>Teaching co</b> Microproces	ontent ssor Architectures, DS	SP Architectures a	nd Hardware relat	ed Programming	
2	Learning ol	bjectives				
	Upon succes	ssful completion of th	ne module, studen	ts will be able to:		
	CISC, 2. under 3. under (USB,	Mikrocontroller, CPU stand the central buil	I, DSP), lding blocks of a C perties of the requ	CPU iired semiconducto	or memories, I/O blo	ocessor classes (RISC, ocks and data busses
	5. know t makro	the common software s, subprograms and s	development met subroutines),	hodologies for micr		er, pseudooperations, sing C.
3		ded prerequisites for mputer Architectures				
4	Form of exa Module exa • Modul	m:	xamination, Exam	ination, Duration:	90 Min., Default RS)	
5		e for the award of c				
6	Grading Module exame • Modul	m: le exam (Technical ex	xamination, Exam	ination, Weighting	: 100 %)	
7	•	<b>the module</b> DT, M.Sc. iCE, M.Sc.	MEC, B.Sc. und M	M.Sc. iST		
8	During the s influence or of tests. The achievable b points are ac of which mu more than th	n passing the final m e points achieved in ponus points 0 exam dded for a grade imp ust be on a different hree topics. The exact	n grade improvem odule examinatio the bonus system points are added rovement of 1.0. If topic. Several test t bonus system wil	n. Bonus points ar a are converted lin accordingly, from 9 Bonus points are sco s can be offered fo ll be presented at th	re awarded for the su early into exam poir 95% of the achievable ored from a maximur or each topic; tests ca	improvement has no accessful completion hts, with 50% of the e bonus points exam n of three tests, each in also be offered for burse. The aim of the l way.
9	<b>References</b> Slide Copies	3				
Co	ırses					

<b>Course nr.</b> 18-ho-2040-vl				
<b>Instructor</b>	s Rychetsky, M.Sc. Dirk Leiacker	<b>Type</b>	SWS	
DrIng. Matthias		Lecture	2	
<b>Course nr.</b> 18-ho-2040-ue	Course name Microprocessor Systems			
<b>Instructor</b>	s Rychetsky, M.Sc. Dirk Leiacker	<b>Type</b>	<b>SWS</b>	
DrIng. Matthias		Practice	1	

	<b>dule name</b> nputer Aided	Design for SoCs					
Мо	<b>dule nr.</b> ho-2200	Credit points 5 CP	Workload 150 h	Self-study 90 h	Module duration	Module cy Every Seme	
Lar	i <b>guage</b> Jish			Module owner Prof. DrIng. Klar			
1	Teaching co CAD-Concep	ntent ots for the design and	l simulation of int	egrated system-on-	chips		
2	<ul> <li>the mo electro</li> <li>selecte</li> <li>advance</li> <li>advance</li> </ul>	<b>jectives</b> after successful con st important design a nic systems, d algorithms for opt red methods for the d ced concepts of hard AMS, System-Verilo	nd verification abs imization, simulat esign and simulation dware description	tractions as well as tion and solving of on of analog integra	the design flow for t design tasks, ted circuits in mode	ern CMOS techr	nologies,
3	Lecture "Adv	<b>led prerequisites fo</b> anced Digital Integra "Logic Design"		" (can be attended i	in parallel) and "El	ectronic and Int	egrated
4	Form of exa Module exar • Module		xamination, Exam	ination, Duration:	90 Min., Default R	S)	
5		e for the award of c					
6	Grading Module exar • Module	n: e exam (Technical e:	xamination, Exam	ination, Weighting	: 100 %)		
7	<b>Usability of</b> M.Sc. etit - I	<b>the module</b> DT, M.Sc. etit - SAE,	M.Sc. iCE, M.Sc.	MEC, M.Sc. WI-etit	t, B.Sc. und M.Sc.	ST, M.Sc. CE	
8		<b>s compliant to §25</b> rovement of up to 1,0 ed labs.		s possible, which ca	n be earned by suc	cessful particip	ation in
9	<b>References</b> Slide Copies						
Coi	ırses	I					
	<b>Course nr.</b> 18-ho-2200-	vl Course name Computer Aid	ed Design for SoC	s			
	Instructor Prof. DrIng	. Klaus Hofmann			<b>Type</b> Lecture		SWS 2
	<b>Course nr.</b> 18-ho-2200-	ue Course name	ed Design for SoC	s			
	<b>Instructor</b> Prof. DrIng	. Klaus Hofmann			<b>Type</b> Practic	2	<b>SWS</b> 1

<b>Course nr.</b> 18-ho-2200-pr	<b>Course name</b> Computer Aided Design for SoCs		
<b>Instructor</b> Prof. DrIng. Kla	us Hofmann	<b>Type</b> Lab	<b>SWS</b> 1

	dule name					
	ustrial Electro		TAT- 11 1	0.10.1	ъл. <u>1. 1</u> . 1 •	ng. 1.1 1
	<b>dule nr.</b> ho-2210	Credit points 4 CP	Workload 120 h	Self-study 75 h	Module duration 1 Term	Module cycle Winter term
	iguage			Module owner		
	man/English			Prof. DrIng. Klau	us Hofmann	
1	Sensor Fron	ture of Industrial Ele	end, Supply and H	Reference Level), Fu		Blocks (Digital Core, nt Field Bus Systems,
2	<ol> <li>1. unders</li> <li>2. unders</li> <li>3. deeply</li> <li>4. unders</li> </ol>	<b>ojectives</b> sfull completion of the stand the use of elect stand the function of understand the func- stand relevant field be stand the regulatory	ronic components the building block ctioning of analog bus systemes,	s in typical industri ks of typical IE com bulding blocks,	ionents,	ents.
3		<b>ded prerequisites fo</b> ktronik" and "Electro		1 Circuits"		
4	The examina 5 students r	m: e exam (Technical ex ation takes place in fo	orm of a written ex ion will be an ora	am (duration: 90 m	ninutes). If one can es	, Default RS) stimate that less than type of examination
5		e for the award of c				
6	Grading Module exan • Modul	m: e exam (Technical ex	kamination, Oral/	written examinatio	n, Weighting: 100 %	)
7	•	t <b>he module</b> AUT, M.Sc. etit - DT,	M.Sc. etit - SAE, I	M.Sc. iCE, M.Sc. M	EC, M.Sc. WI-etit, B.	.Sc. und M.Sc. iST
8	Grade bonu	s compliant to §25	(2)			
9	Jörg O nik"; V • Gunter th Ed.	estreich, Oliver Gom Verlag Europa-Lehrm r Wellenreuther, Diet 2015. Tietze, Christoph Scl	ber, Albrecht Schi ittel, 11 th Ed. 20 er Zastrow; "Auto	lling: "Fachkunde I 13. matisieren mit SPS	ndustrieelektronik u - Theorie und Praxis	n, Günther Buchholz, nd Informationstech- "; Springer Verlag, 6 pringer Verlag, 15 th

<b>Course nr.</b> 18-ho-2210-vl				
<b>Instructor</b>	Steck	<b>Type</b>	<b>SWS</b>	
DrIng. Roland		Lecture	2	
<b>Course nr.</b> 18-ho-2210-ue	<b>Course name</b> Industrieelektronik			
<b>Instructor</b>	Steck	<b>Type</b>	<b>SWS</b>	
DrIng. Roland		Practice	1	

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle		
18	-me-2020	6 CP	180 h	120 h	1 Term	Winter term		
	<b>nguage</b> glish			<b>Module owner</b> Prof. Dr. rer. nat.	Markus Meinert			
1	<ul> <li>Basics</li> <li>Basics</li> <li>Introd</li> <li>Basic 1</li> <li>Magne</li> <li>Spin-d</li> <li>Magne</li> <li>Giant 2</li> <li>Tunne</li> <li>Spin-T</li> <li>Magne</li> <li>Spin-F</li> <li>Materia</li> <li>Magne</li> <li>Spintr</li> </ul>	ontent covers the following of atomic physics (st of solid state physics uction to electron tra- notions and simple m etism in thin films ependent electronic etoresistive effects, an magnetoresistance (C ling magnetoresistance transfer Torque etic microwave oscilla fall effect and other st als for spintronics (fe etic data storage onic devices as senso etic random-access m	ructure of the ato crystalline mate insport in solids (co odels of magnetis transport nisotropic magnet GMR) ace (TMR) ators spin-orbit effects erromagnets, antif	rials) :lassical treatment, m oresistance	band structures)			
	<b>Learning objectives</b> The students learn fundamental concepts of spintronics, from properties of magnetic materials to the design and application of spintronic devices in data storage and magnetic sensing. The students acquire the competence to make use of spintronic devices in applications. They further acquire the competence to understand current							
2	The students application to make use	s learn fundamental o of spintronic devices	in data storage as in applications.	nd magnetic sensir They further acqui	ng. The students acq	uire the competence		
2	The students application to make use scientific lite <b>Recommen</b>	s learn fundamental of of spintronic devices of spintronic devices	in data storage as s in applications. eeper into the fiele or participation	nd magnetic sensir They further acquir d.	ng. The students acq	uire the competence		
	The students application to make use scientific lite <b>Recommen</b> Module 11-0 <b>Form of exa</b> Module exam • Modul The examin less than 16	s learn fundamental of of spintronic devices of spintronic devices erature and to dive de ded prerequisites for 01-6419 Materials of mination	in data storage as s in applications. eeper into the field or participation Electrical Engineer kamination, Oral/ form of a writter the examination with	nd magnetic sensir They further acquir d. ering written examination n exam (duration: ill be an oral exam	ng. The students acq re the competence to on, Duration: 120 Min 120 minutes). If or	uire the competence o understand currer n., Default RS) ne can estimate tha		
3	The students application to make use scientific lite <b>Recommen</b> Module 11-( <b>Form of exa</b> Module exam • Modul The examin less than 16 examination <b>Prerequisit</b>	s learn fundamental of of spintronic devices of spintronic devices erature and to dive de <b>ded prerequisites fo</b> 01-6419 Materials of <b>mination</b> m: e exam (Technical ex ation takes place in students register, th	in data storage as in applications. eeper into the field or participation Electrical Enginee kamination, Oral/ form of a writter the examination with n the beginning o redit points	nd magnetic sensir They further acquir d. ering written examination n exam (duration: ill be an oral exam	ng. The students acq re the competence to on, Duration: 120 Min 120 minutes). If or	uire the competence o understand currer n., Default RS) ne can estimate tha		
3 4 5	The students application to make use scientific lite <b>Recommen</b> Module 11-0 <b>Form of exa</b> Module exam Module examin less than 16 examination <b>Prerequisite</b> Passing the <b>Grading</b> Module exam	s learn fundamental of of spintronic devices of spintronic devices erature and to dive de <b>ded prerequisites fo</b> 01-6419 Materials of <b>mination</b> m: e exam (Technical ex- ation takes place in students register, the will be announced i <b>e for the award of c</b> final module examina	in data storage a s in applications. eeper into the field or participation Electrical Enginee kamination, Oral/ form of a writter the examination with n the beginning o redit points ation	nd magnetic sensir They further acquis d. ering written examination n exam (duration: ill be an oral exam f the lecture.	ng. The students acq re the competence to on, Duration: 120 Min 120 minutes). If or ination (duration: 4	uire the competence o understand currer n., Default RS) ne can estimate tha 5 min.). The type o		
3	The students application to make use scientific lite <b>Recommen</b> Module 11-0 <b>Form of exa</b> Module examination <b>Prerequisite</b> Passing the standard <b>Grading</b> Module examination <b>Oreconstruction</b> <b>Module examination</b> <b>Prerequisite</b> <b>Construction</b>	s learn fundamental of of spintronic devices of spintronic devices erature and to dive de <b>ded prerequisites fo</b> 01-6419 Materials of <b>mination</b> m: e exam (Technical ex- ation takes place in students register, the will be announced i <b>e for the award of c</b> final module examina-	in data storage a s in applications. eeper into the field or participation Electrical Enginee kamination, Oral/ form of a writter the examination with n the beginning o redit points ation	nd magnetic sensir They further acquis d. ering written examination n exam (duration: ill be an oral exam f the lecture.	ng. The students acq re the competence to on, Duration: 120 Min 120 minutes). If or ination (duration: 4	uire the competence o understand currer n., Default RS) ne can estimate tha 5 min.). The type c		
3 4 5 6	The students application to make use scientific lite <b>Recomment</b> Module 11-0 <b>Form of exa</b> Module exam • Modul The examin less than 16 examination <b>Prerequisite</b> Passing the <b>Grading</b> Module exam • Modul <b>Usability of</b> M.Sc. etit - 5	s learn fundamental of of spintronic devices of spintronic devices erature and to dive de <b>ded prerequisites fo</b> 01-6419 Materials of <b>mination</b> m: e exam (Technical ex- ation takes place in students register, the will be announced i <b>e for the award of co</b> final module examina- m: e exam (Technical ex- final module examina- m:	in data storage a s in applications. eeper into the field or participation Electrical Enginee kamination, Oral/ form of a writter the examination with n the beginning of redit points ation	nd magnetic sensir They further acquis d. ering written examination n exam (duration: ill be an oral exam f the lecture.	ng. The students acq re the competence to on, Duration: 120 Min 120 minutes). If or ination (duration: 4	uire the competence o understand curren n., Default RS) ne can estimate tha 5 min.). The type o		

- A script will be made available electronically
- Coey, Magnetism and Magnetic Materials, 2009, Cambridge University Press
- Skomski, Simple Models of Magnetism, 2008, Oxford University Press
- Felser, Fecher, Spintronics: From Materials to Devices, 2013, Springer
- Dietl, Awschalom, Kaminska, Ohno, Spintronics, 2008, Academic Press
- Blachowicz, Ehrmann, Spintronics, 2019, de Gruyter
- Tsymbal, Zutic, Spintronics Handbook, Volume One: Metallic Spintronics, 2019, CRC Press
- Xu, Awschalom, Nitta, Handbook of Spintronics, 2016, Springer

## Courses Course nr. **Course name** 18-me-2020-vl Introduction to Spintronics Instructor Type SWS Prof. Dr. rer. nat. Markus Meinert Lecture 3 Course nr. Course name 18-me-2020-ue Introduction to Spintronics Instructor Туре SWS Prof. Dr. rer. nat. Markus Meinert Practice 1

	<b>dule name</b> ahertz System	ns and Applications				
Mo	<b>dule nr.</b> pr-2010	Credit points 4 CP	Workload 120 h	Self-study 75 h	Module duration	Module cycle Summer term
Lan	nguage glish	4 CP	120 11	Module owner Prof. Dr. rer. nat.		Summer term
1	Teaching co The lecture and semicor in detail for photomixer discussed de	ontent will give an overview aductor-based devices two types of highly s (photo-diode based evices will be derived will be used for a la	s and Terahertz sy important device l and photocondu for experimental	stems. Terahertz d s: Schottky diodes ctive). The exercis ly relevant cases, w	etection and generat (mixers, multi-plier e, where performane vill help to deepen th	ion will be discussed s and rectifiers) and ce parameters of the e understanding.
2	systems, and • A gene • Workin • Workin	•	radiation, with d he state of the art and limits of cont	eepened knowledge in Terahertz techn inuous-wave photo	e in: ology mixer systems	generation, detection, ge
3	Bachelor in	<b>ded prerequisites fo</b> Electrical engineering sic knowledge in sem	g, Physics, or Mat		l	
4	The examina 20 students		rm of a written ex tion will be an ora	am (duration: 90 m	ninutes). If one can es	stimate that less than
5		e for the award of c ile final exam	redit points			
6	Grading Module exame • Module	m: e exam (Technical ex	amination, Oral/	written examinatio	n, Weighting: 100 %	))
7	•	<sup>e</sup> <b>the module</b> KTS, M.Sc. iCE, M.Sc	. WI-etit, M.Sc. C	E		
8	Grade bonu	is compliant to §25	(2)			
9 Cot	• G. Car	nik Lee, "Principles of pintero et al., "Semic tion," Wiley 2015, IS	conductor Terahe	rtz Technology: De		1 978-0-387-09540-0 t Room Temperature

<b>Course nr.</b> 18-pr-2010-vl	<b>Course name</b> Terahertz Systems and Applications		
<b>Instructor</b>	. Sascha Preu	<b>Type</b>	<b>SWS</b>
Prof. Dr. rer. nat		Lecture	2
<b>Course nr.</b> 18-pr-2010-ue	<b>Course name</b> Terahertz Systems and Applications		
Instructor	. Sascha Preu	<b>Type</b>	<b>SWS</b>
Prof. Dr. rer. nat		Practice	1

10	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
18-	su-2020	6 CP	180 h	120 h	1 Term	Summer term
	<b>nguage</b> rman			Module owner Prof. Dr. rer. nat.	Andreas Schürr	
1	real-time sys laid on objec and used. Fu Scheduling	basically covers a m tems. This process is ct-oriented technique inthermore, fundame algorithms are discu- baya programming	more deeply expl es. In this context, ntal characteristics ussed to get insigh	ored in the exercise , a real-time specifi s of real-time system nts into real-time of	rocess which is spec e using an automotive c state-of-the-art CAS as and system architec operating systems. F al-time operating systems	e example. A focus is SE tool is introduced tures are introduced inally, a comparisor
2	techniques f following to classifi create applica	sful completion of the or the development pics: cation of real-time sy and analyze executa ation of real-time sch tion and comparison	of embedded real ystems ible models ieduling algorithm	-time systems. This	id evaluate model-ba s includes a deeper v ig languages as well a	inderstanding of the
3	Basic knowl	<b>led prerequisites fo</b> edge of software eng g language (preferal	gineering techniqu	ues and excellent k	nowledge of at least	one object-oriented
4	The examination 15 students	n: e exam (Technical ex ition takes place in fo	orm of a written ex tion will be an ora	am (duration: 90 n	n, Duration: 90 Min. ninutes). If one can es ration: 30 min.). The	timate that less that
5		e for the award of c				
5						
6	Grading Module exan • Modul		kamination, Oral/	written examinatio	n, Weighting: 100 %	)
	Module exan • Modul Usability of	e exam (Technical ex the module			n, Weighting: 100 % . und M.Sc. iST, M.S	
6	Module exan • Modul Usability of M.Sc. etit - I Grade bonu	e exam (Technical ex the module DT, M.Sc. iCE, M.Sc. s compliant to §25	iST, M.Sc. MEC, 1 (2)	M.Sc. WI-etit, B.Sc		c. CE

<b>Course nr.</b> 18-su-2020-vl					
Instructor Prof. Dr. rer. nat.	. Andreas Schürr	<b>Type</b> Lecture	<b>SWS</b> 3		
<b>Course nr.</b> 18-su-2020-ue	Course name Real-Time Systems				
<b>Instructor</b> Prof. Dr. rer. nat.	. Andreas Schürr, M.Sc. Hendrik Göttmann	<b>Type</b> Practice	<b>SWS</b> 1		

18.	<b>dule nr.</b> ·bu-1010	<b>Credit points</b> 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Winter term	е	
Laı	nguage rman	0.01	100 11	Module owner     Prof. Ph.D. Thomas Burg				
1	sensors and a mass produc scientific inst critical dimen sintering, 3D modifications	Precision engineering enables the repeatable integration of microelectronic and mechanical components with sensors and actuators to create dense and complex electromechanical systems. The applications range from mass products such as smartphones or cars to precision prototypes in medical technology, spaceflight, and scientific instrumentation. The course introduces the principles of design and manufacturing for precision with critical dimensions in the micrometer to millimeter range. Manufacturing methods including casting, molding, sintering, 3D printing, forming, cutting, etching, and joining will be explained. The properties, composition, and modifications of materials (metals and alloys, ceramics, polymers, composites) will be discussed in the context of key manufacturing processes.						
2	To be able to respective ad application. T	<b>Learning objectives</b> To be able to classify and explain the most important maufacturing technologies, and to critically assess their respective advantages and disadvantages. To select suitable manufacturing technologies and to design for their application. To make quantitative estimates of the limitations of a given process and to evaluate the potential of new developments based on your knowledge of physical principles and materials.						
3	-	ed prerequisites fo	<u> </u>	<u> </u>				
4	The examina less than 6 st	n: e exam (Technical e: tion takes place in f	orm of a written e ation will be an ora	xam (duration: 90	n, Duration: 90 Min. minutes). If enrollm ration: 30 min.). The	ent is expected		
5	Prerequisite	for the award of c nal module examin	redit points					
6	<b>Grading</b> Module exan • Module		xamination, Oral/	written examinatio	n, Weighting: 100 %	)		
	Usability of the module							
7	B.Sc. etit, M.	B.Sc. etit, M.Sc. iCE, M.Sc. MEC, M.Sc. MedTec, B.Sc. und M.Sc. iST, B.Sc. CE         Grade bonus compliant to §25 (2)						
8	Grade bonus References							
8 9	Grade bonus References Lecture notes urses	s compliant to §25 s, Moodle course	(2)					
8 9	Grade bonus References Lecture notes	s compliant to §25 s, Moodle course Course name	(2)	ion Engineering				

<b>Course nr.</b> 18-bu-1010-ue	<b>Course name</b> Foundations of Precision Engineering		
<b>Instructor</b> Prof. Ph.D. Thom	as Burg	<b>Type</b> Practice	<b>SWS</b> 1
<b>Course nr.</b> 18-bu-1010-pr	<b>Course name</b> Foundations of Precision Engineering Lab		
<b>Instructor</b> Prof. Ph.D. Thom	nas Burg	<b>Type</b> Lab	<b>SWS</b> 1

	o <b>dule nr.</b> -me-2040	Credit points 5 CP	Workload 150 h	Self-study 105 h	Module duration 1 Term	Module cycle Summer term		
	<b>nguage</b> glish			<b>Module owner</b> Prof. Dr. rer. nat.	Markus Meinert			
1	<ul><li>Fabric</li><li>Nanor</li><li>Quant</li></ul>	ontent gives an overview of ation of devices on th naterials: quantum d um Metrology Triang T transistors and othe	ne nanometer scale lots, nanowires, 21 gle (single-electron	e D materials (e.g. gr 1 transistor, quantu		nson effect)		
2	The student They can de current, volt students giv	<b>Learning objectives</b> The students will know the basics of fabrication and application of electronic devices on the nanometer scale. They can describe the operating principles of modern nano-devices and understand the precise measurement of current, voltage, and resistance via quantum mechanical effects and physical constants. Within the seminar, the students give a presentation on a nanoelectronic method or device of their choice. Thereby, they gain the ability to conduct self-directed literature research and to give technical presentations.						
3		ded prerequisites for edge of semiconductor						
4	The examina 10 students will be anno	m: le exam (Technical ex ation takes place in fo register, the examina punced in the beginni esentation about a sul	orm of a written ex tion will be an ora ing of the lecture.	am (duration: 90 n ll examination (du	ninutes). If one can es ration: 30 min.). The	timate that less than type of examination		
5		e for the award of c						
0	Passing the final module examination         Grading         Module exam:         • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)							
6	• Modu	Usability of the module						
	Usability of		c. WI-etit. B.Sc. ur	nd M.Sc. iST				
6	<b>Usability of</b> M.Sc. etit -	f <b>the module</b> SAE, M.Sc. iCE, M.Sc <b>is compliant to §25</b>		nd M.Sc. iST				

<b>Course nr.</b> 18-me-2040-vl	Course name Nanoelectronics		
<b>Instructor</b>	Markus Meinert	<b>Type</b>	SWS
Prof. Dr. rer. nat		Lecture	2
<b>Course nr.</b> 18-me-2040-se	Course name Nanoelectronics		
<b>Instructor</b>	Markus Meinert	<b>Type</b>	<b>SWS</b>
Prof. Dr. rer. nat		Seminar	1

	dule name ctromechanica	al Systems I						
Mo	<b>dule nr.</b> kn-1050	Credit points 5 CP	Workload 150 h	Self-study 90 h	Module duration	Module cy Winter terr		
Lan	nguage man	5.61	150 11	Module owner Prof. Dr. Mario Ki		Winter terr	11	
1	Teaching co Structure ar	ontent nd design methods o between mechanical		cal systems, mecha	anical, acoustical a			
2	Learning objectives The module provides the following competencies upon successful completion: Comprehension, description, cal- culation and application of the most relevant electromechanical transducers, comprising electrostatic transducer (e.g. microphone and accelerometer), piezoelectric transducers (e.g micro motors, micro sensors), electrody- namic transducer (loudspeaker, shaker), piezomagnetic transducer (e.g. ultrasonic source). Design of complex electromechanical systems like sensors and actuators and their applications by applying the discrete element network method.							
3		<b>led prerequisites fo</b> gineering and Inforr		r I				
4	Form of exa Module exa • Modul		xamination, Exam	ination, Duration:	120 Min., Default F			
5		e for the award of c						
6	Grading Module exar • Modul	n: e exam (Technical ex	xamination, Exam	ination, Weighting:	100 %)			
7	•	<b>the module</b> Sc. WI-etit, M.Sc. iC	E, M.Sc. MEC, B.5	Sc. und M.Sc. iST, I	3.Sc. CE			
8	Grade bonu	s compliant to §25	(2)					
9		omechanical Systems tems I, Workbook	in Microtechnic u	nd Mechatronic, Sp	pringer 2012, Script	for lecture Ele	ectrome-	
Coι	ırses							
	<b>Course nr.</b> 18-kn-1050-	vl Electromechar	nical Systems I					
		nn. Dr.h.c. Andreas F M.Sc. Laurenz Zieg		ario Kupnik, M.Sc.	Stephan Lecture		SWS 2	
	<b>Course nr.</b> 18-kn-1050-	ue Electromechar	nical Systems I					
		nn. Dr.h.c. Andreas F M.Sc. Laurenz Zieg		ario Kupnik, M.Sc.	Stephan Practice		SWS 2	

	<b>dule name</b> nputer System	ne II						
Мо	dule nr.	Credit points	Workload	Self-study	Module duration	Module cy		
	hb-2030	6 CP	180 h	120 h	1 Term	Summer te	rm	
	i <b>guage</b> man			Module owner Prof. DrIng. Chi	ristian Hochberger			
1	Teaching co	ntent						
	<ul><li>FPGA a</li><li>System</li></ul>	urable Technologies architectures and pro -On-Chip, HW comp grained reconfigura	oonents, SW toolc	·	odulo schedu-ling			
2	Learning objectives After completion of the module, students know reconfigurable technologies as well as chip architecture that employ them (e.g. FPGAs and CGRAs). They can select an ap-propriate technology for a given specific application. They know the components a system-on-chip (SoC) consists of. Students can configure and program an application specific SoC. They can map simple applications to a CGRA and know the limitations and pitfalls of this mapping.							
3	Thorough ba "Logischer Ei		igital circuits and		ture. as can be ob-t hould be able to writ			
4	Form of exa Module exan • Module	n:	xamination, Oral e	examination, Durat	ion: 30 Min., Defaul	t RS)		
5		e <b>for the award of c</b> inal module examina						
6	Grading Module exan • Module	n: e exam (Technical ex	xamination, Oral e	examination, Weigl	nting: 100 %)			
7	<b>Usability of</b> M.Sc. etit - I		M.Sc. iCE, M.Sc.	iST, M.Sc. MEC, M	.Sc. WI-etit, M.Sc. C	E		
8	Grade bonu	s compliant to §25	(2)					
9	<b>References</b> The slides (in	n German) of the lec	ture can be obtain	ned through moodl	e			
Co	ırses							
	<b>Course nr.</b> 18-hb-2030-	vl Course name Computer Syst	tems II					
	<b>Instructor</b> Prof. DrIng.	Christian Hochberg	ger, M.Sc. Christop	oh Flothow	<b>Type</b> Lecture		<b>SWS</b> 3	
	<b>Course nr.</b> 18-hb-2030-	ue Course name Computer Syst	tems II					
	Instructor Prof. DrIng.	Christian Hochberg	ger, M.Sc. Christor	oh Flothow	<b>Type</b> Practice		<b>SWS</b> 1	

10	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
	-jk-2020	6 CP	180 h	120 h	1 Term	Winter term
	<b>nguage</b> glish			Module owner Prof. DrIng. Roli	f Jakoby	
1	Fourier tran image theor directivity and of an antenn for beamforn equally space the most pre radiation fie applied for a coplanar-slo frequency de antennas an	ment most important ant sform for far-field pa y, determination of find gain. Antennas as ha, deriving the relat ning and smart anter ed linear arrays, mul valent of all antenna para perture antennas (ho t antennas) Some ba omain, physical optic d scattering problem adaptive beamformi	ttern calculations, ield regions of line key elements in po- tion between gain nna systems: fund ti-dimensional pla forms, relatively si ameters for differe orns, lenses or refl sic numerical calc cs and uniform the as. Smart antenna	, antenna modeling e sources, of the av ower budgets of rad and effective aper lamentals of phase unar arrays and mu mple in concept, ea ent types of antenna ector antennas) an ulation methods: in cory of diffraction a	g techniques, antenna erage radiated powe io links, introducing t ture. Array antennas d-scanning arrays, no tual coupling effects. sy to construct, very i as are derived from M d printed antennas (in ntegral equation methors)	a synthesis method r density and powe the effective apertur are a key hardwar on-uniformly excite Wire antennas: sti nexpensive. Antenn Maxwell 's equation microstrip-patch an hods in the time an ed and compared fo
2	efficiency an operating fre and the far- by using Fou analysis). T use fundam analysis, an incorporated antenna syst network etc able to deter applications	I know basic antenna d input impedance to equencies. The antenn field pattern of an ar- urier transformation of o assess in general p ental antenna theory tenna synthesis, ima l into the different ad tems that are assemb . for phased-scannin mine, analyze and ev	o compare, assess na field regions, rea- natenna can be dete or integral solution physical requirem y: impedance ma ge theory and fur laptive beamformina- bled of a certain nu g or smart antenn- valuate the most in	and evaluate differ active near-field, ne ermined from giver ns with distributed ents, constrains an tching techniques, ndamental limits of ng techniques, the a unber of separate of as in communicati	ent antennas for vari ar-field and far-field, n current distributior ideal dipoles as basi ad limitations of ant antenna modeling a f electrically small an array theory enables t elements, feeding ne- ions and sensing. Mo	ous applications an can be differentiate is along the antenn c elements (antenn ennas, students ca and far-field patter ntennas. After bein the student to desig
	reflector ant	, operating frequenc antennas (microstrip, ennas, lens antennas cy-independent anten	, dipole and slot a s, Cassegrain and	ntennas), (3.) aper Gregorian double-	reflector configuration	preover, students ar technology for man ire- dipole antenna antennas, parabol ons), (4.) broadban
3	reflector ant and frequen antennas). Recomment Fundamenta	antennas (microstrip, ennas, lens antennas cy-independent anter ded prerequisites fo alls of Communication	, dipole and slot a s, Cassegrain and nnas (V antennas, <b>pr participation</b>	ntennas), (3.) aper Gregorian double- biconical antennas	rture antennas (horn reflector configuratio	preover, students an technology for man ire- dipole antenna antennas, parabol ons), (4.) broadban
3	reflector ant and frequen antennas). Recommend Fundamenta Form of exa Module exam	antennas (microstrip, ennas, lens antennas cy-independent anten ded prerequisites fo ils of Communication	, dipole and slot a s, Cassegrain and nnas (V antennas, or participation ns, Microwave Eng	ntennas), (3.) aper Gregorian double- biconical antennas ineering 1	rture antennas (horn reflector configuratic , helical antennas, sp	preover, students ar technology for man ire- dipole antenna antennas, paraboli ons), (4.) broadban piral and log-period

	<ul><li>Module exam:</li><li>Module exam (Technical examination, Examination, Weighting: 100 %)</li></ul>						
7	Usability of the module						
	B.Sc. WI-etit, M.	Sc. etit - KTS, M.Sc. etit - SAE, M.Sc. iCE, M.Sc. WI-etit, B	S.Sc. und M.Sc. iST, M	.Sc. CE			
8	Grade bonus compliant to §25 (2)						
9 Co	<ul> <li>9 References</li> <li>Skriptum "Antennas and Adaptive Beamforming" will be provided electronically at the beginning of the</li> <li>Courses</li> </ul>						
	<b>Course nr.</b> 18-jk-2020-vl	<b>Course name</b> Antennas and Adaptive Beamforming					
	Instructor DrIng. Martin S	chüßler, DrIng. Alejandro Sáez, M.Sc. Jesús Pastor	<b>Type</b> Lecture	<b>SWS</b> 3			
	<b>Course nr.</b> 18-jk-2020-ue	<b>Course name</b> Antennas and Adaptive Beamforming		·			
	<b>Instructor</b> DrIng. Martin S	chüßler, DrIng. Alejandro Sáez, M.Sc. Jesús Pastor	<b>Type</b> Practice	<b>SWS</b> 1			

20	1.1					
	<b>dule name</b> rowave Engir	neering II				
	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
	jk-2130	6 CP	180 h	120 h	1 Term	Winter term
	<b>iguage</b> dish			Module owner Prof. DrIng. Roli	f Jakoby	
1	Teaching co	ontent		0		
	<ul> <li>Calcult lumpe</li> <li>Wave p</li> <li>Smith</li> <li>Design</li> </ul>	ve microwave comp ation of the two-port d elements) for MMI parameters and S-par chart and matching and equivalent circu- sistors)	parameters of sin Cs rameters circuits with line of	elements or lumped	l elements	ansmission lines and capacitors, inductors
	Part 2 Activ	e microwave compo				
		and equivalent circu		transistors (FET) a	nd heterostructure tr	ansistors (HEMTs)
		nd cut-off frequencie ky contacts: function		cs		
	Part 3 Activ	e microwave circuit	s (main part):			
		mplifiers: operation, ontor design	equivalent circuit,	gain, matching cir	cuit, stability and cir	cuit implementation
	<ul><li>Oscilla</li><li>Mixer</li></ul>					
	<ul> <li>Materi</li> </ul>	ial choice (compound				
		of these circuits rang -frequency sources up		cation systems such	as cell phones to sat	tellite transceivers as
				tal or ethical aspe	cts of product design	n, optimization, and
		are addressed in an a				
2						veguides, resonators,
3		<b>ded prerequisites fo</b> to Electrodynamics,		eering I		
4	Form of exa					
	Module exam	m: le exam (Technical ex	ramination Even	ination Duration	00 Min Dofault DO	
	- would	c chain (Technical e)	ammauon, Exam		50 mini., Derault KS)	
5		e for the award of c				
6	Grading	-				
	Module exa					
	• Modul	e exam (Technical ex	xamination, Exam	ination, Weighting:	: 100 %)	
7		<b>the module</b> KTS, M.Sc. iCE, M.Sc	WI atit D Sa	AMER ST MER	CE	
8		is compliant to §25	,	IU M.SC. 131, M.SC.	CE	
	State Dolla	is compliant to 325	(4)			
9	References	lidaa		11 ho	in the leature	
	-	lides will be handed	out. Literature wi	II de recommended	i in the lecture.	
L01	ırses					

<b>Course nr.</b> 18-jk-2130-vl	Course name Microwave Engineering II		
<b>Instructor</b>	tay Yilmazoglu	<b>Type</b>	<b>SWS</b>
PD DrIng. Ok		Lecture	3
<b>Course nr.</b> 18-jk-2130-ue	<b>Course name</b> Microwave Engineering II		
<b>Instructor</b>	ay Yilmazoglu	<b>Type</b>	<b>SWS</b>
PD DrIng. Ok		Practice	1

	<b>dule name</b> MO - Commur	nication and Space-Ti	me-Coding			
Мо	<b>dule nr.</b> ja-2010	Credit points 4 CP	Workload 120 h	Self-study 75 h	Module duration 1 Term	Module cycle Winter term
Lar	nguage glish		120 11	Module owner Prof. DrIng. Vah		whiter term
1	nications. Outline: Mot models, MIM space-time b decoders, di diversity, BE	course introduces the tivation and backgrou IO information theory lock code, orthogona ifferential space-time	nd; overview of sp , receive and trans al space-time bloc e block coding; N	bace-time and MIM smit diversity; chan k codes; linear disp MMO with limited	O communications; f nel estimation, MIMO persion codes; cohere feedback, Multianto	put (MIMO) commu- ading MIMO channel D detectors, Alamouti ent and non-coherent enna- and multiuser ulticell and multiuser
2	2 Learning objectives Students will understand modern MIMO communications and existing space-time coding techniques.					
3		<b>ded prerequisites fo</b> of basic communicati		ic information theo	ory.	
4	The examinates than 10	n: e exam (Technical ex ation takes place in	form of a written e examination w	n exam (duration: Il be an oral exam	120 minutes). If or	n., Default RS) ne can estimate that 0 min.). The type of
5	-	e <b>for the award of c</b> r final module examina	-			
6	Grading Module exar • Modul	n: e exam (Technical ex	amination, Oral/	written examinatio	n, Weighting: 100 %	))
7	-	the module KTS, M.Sc. etit - VAS	, M.Sc. iCE, M.Sc.	MEC, M.Sc. WI-et	it, B.Sc. und M.Sc. is	ST
8	Grade bonu	s compliant to §25	(2)	`		
9	and Sc • E.G.La Press, J • A.Paula sity Pr • Lin Ba • Howar Netwo	ons, 2005. rsson and P.Stoica, S 2003; raj, R.Nabar, and D.G ess, 2003. i and Jinho Choi, Lov	pace-Time Block Fore, Introduction W Complexity MIN	Coding for Wireless to Space-Time Wire AO detectors, Sprir	s Communications, C eless Communication nger, 2012.	mmunications, Wiley Cambridge University s, Cambridge Univer- unication for Cellular
C01	urses					

<b>Course nr.</b> 18-ja-2010-vl	<b>Course name</b> MIMO - Communication and Space-Time-Coding		
<b>Instructor</b>	hid Kooshkghazi	<b>Type</b>	<b>SWS</b>
Prof. DrIng. Va		Lecture	2
<b>Course nr.</b> 18-ja-2010-ue	<b>Course name</b> MIMO - Communication and Space-Time-Coding		
Instructor	hid Kooshkghazi	<b>Type</b>	<b>SWS</b>
Prof. DrIng. Va		Practice	1

	ech and Audi dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle			
18-zo-2070 6 CP 180			180 h	120 h	1 Term	Winter term			
	nguage man			Module owner Prof. DrIng. Abo	lelhak Zoubir				
1	and basic m Beamformin frequency er recognition.	of speech and audio ethods of audio sigr g for spatial filtering stimation. Mel-filter Classification metho en markov models).	al processing. Pr and noise reduct ind cepstral coeff ods based on GM	rocedures of codeb ion for spectral filt ficients (MFCCs) as M (Gaussian mixtu	the models of speec book based processin ering. Cepstral filterings basis for speaker d ire models) and spee sic signal processing,	g and audio coding ng and fundamenta etection and speecl ech recognition with			
2	help of the a processing, such as they (MMI). The and audio pu familiarize v	e module you acquir analysis of speech sig to range from the th are applied in mobile exercise will be orga cocessing. This will a	gnals. You learn a leory to practical e telephones, hear anized as a talk g llow you to acquir c and present you	bout different basi applications. You v ing aids, hands-free iven by each stude re the know-how to	audio signal process c and advanced met will acquire knowled e telephones, and mar ent with one self-sele read and understand as it will be certainly	hods of audio signa ge about algorithm n-machine-interface cted topic of speech l scientific literature			
3	Knowlegde a	<b>led prerequisites fo</b> about satistical signal adatory - is knowled;	l processing (lectu		Processing"). Desired	l			
4	Seminar pre (duration 10	n: e exam (Technical ex sentation: Scientific -15 min) or in group	talk about a topic	in the field of "Spe	on, Duration: 90 Min. eech and Audio Signa a group of 20 students	l Processing", singl			
		e for the award of c							
5		mai module examinit	ation						
5	Grading Module exan • Modul	n:		written examinatio	on, Weighting: 100 %	)			
	Module exame • Modul Usability of	n: e exam (Technical ex <b>the module</b>	kamination, Oral/ <sup>,</sup>		n, Weighting: 100 % I-etit, B.Sc. und M.Sc				
6	Module exar • Modul Usability of M.Sc. etit - I	n: e exam (Technical ex <b>the module</b>	amination, Oral/ , M.Sc. iCE, M.Sc.						

<b>Course nr.</b> 18-zo-2070-vl	<b>Course name</b> Speech and Audio Signal Processing		
Instructor	Ienning Puder	<b>Type</b>	SWS
Prof. DrIng.		Lecture	2
<b>Course nr.</b> 18-zo-2070-ue	<b>Course name</b> Speech and Audio Signal Processing		
<b>Instructor</b>	Ienning Puder	<b>Type</b>	<b>SWS</b>
Prof. DrIng.		Practice	1
<b>Course nr.</b> 18-zo-2070-se	<b>Course name</b> Sprach- und Audiosignalverareitung		
<b>Instructor</b>	Jenning Puder	<b>Type</b>	<b>SWS</b>
Prof. DrIng.		Seminar	1

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
18-	dg-1030	3 CP	90 h	60 h	1 Term	Summer term
	nguage			Module owner		
	rman			Prof. DrIng. Her	bert De Gersem	
1					equency simulations,	convergence stud
2	<b>Learning objectives</b> Students learn the basic concepts of the Finite Integration Technique (FIT) for the numerical solution of Maxwell's equations. Students are, furthermore, introduced to the practical application of the method for numerical field problems.					
3				commended: Basi	c knowledge in knov	vledge in "Techn
4		1:		examination, Durat	ion: 30 Min., Defaul	t RS)
	Passing the f	inal module examina	ation			
6	Grading Module exan • Module	n: e exam (Technical ex	xamination, Oral e	examination, Weigh	nting: 100 %)	
	Usability of the module B.Sc. etit, M.Sc. etit - CMEE, M.Sc. iCE, B.Sc. CE					
7	2.000 0000, 000	Grade bonus compliant to §25 (2)				
		s compliant to §25	(2)			
8	Grade bonus References	s compliant to §25	(2)			
8	Grade bonus References	-	(2)			
8 9	Grade bonus References Course notes	, lecture slides.				

М	dule nr.	Credit points	Workload	Colf study	Module duration	Modulo avalo	
	pr-1050	6 CP	180 h	Self-study 120 h	1 Term	Module cycle Summer term	
laı	n <b>guage</b> glish	1		<b>Module owner</b> Prof. Dr. rer. nat.	Sascha Preu	1	
	The lecture discusses the working principle of the most important devices and components of modern telecom- munication networks and optical data transmission systems. The starting point will be basic physical principles: The nature of light • Wave equation • Polarization • Absorption, transmission, reflection, refraction • Mirrors, HR-/AR coatings Waveguides • Fiber-optic waveguides • Attenuation, modes, dispersion • Fiber types • Connectors and splices • Dispersion and dispersion compensation • Kerr nonlinearity and self-phase modulation Components, e.g.: • Optical filters • Wavelength division multiplexers • Magneto-optical effect / optical isolator / circulator • Electro-optic modulator Lasers • Basics, concepts, types • Erbium-doped fiber lasers / amplifiers (EDFL / EDFA) • Optical semiconductor laser / amplifier (laser diode) Other selected components and devices						
2	Learning ol Students un	*	asics of physics, de			component specific	
3		ded prerequisites fo		-			
4	Form of exa Module exa • Modul		amination, Exam	ination, Duration:	90 Min., Default RS)		
5		e for the award of cr					
5							
7	-	the module			M.Sc. WI-etit, B.Sc.		

9	References				
	Lecture slides				
	Textbook (M. Cv	jetic, I. B. Djordjevic: "Advanced Optical Communication Sys	tems and Networks")		
Co	urses				
	Course nr. Course name				
	18-pr-1050-vl	Optical Communications - Components			
	Instructor		Туре	SWS	
	Prof. Dr. rer. nat.	Sascha Preu	Lecture	3	
	Course nr.	Course name			
	18-pr-1050-ue	Optical Communications - Components			
	Instructor		Туре	SWS	
	Prof. Dr. rer. nat.	Sascha Preu	Practice	1	

	Module name Technical Electrodynamics for iCE						
Мо	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle	
	dg-2150	5 CP	150 h	90 h	1 Term	Winter term	
	<b>iguage</b> dish			Module owner Prof. DrIng. Her	bert De Gersem		
1	Teaching co	ontent		0			
	<ol> <li>Fundamentals of electromagnetic field theory - Maxwell's equations in differential and integral form; Electromagnetic waves: propagation in free space, polarization, reflection/refraction.</li> <li>Numerical solution of electromagnetic field problems - Space discretization with surface and volume meshes; Main numerical algorithms for discrete local approximation of Maxwell's equations; Finite Integration Technique; Time and frequency domain solution methods; Stability, convergence.</li> <li>Practical aspects of electromagnetic simulation - Introduction to accuracy issues; Preprocessing: 3D geometry, computational domain, boundary conditions, electromagnetic field sources; Time vs frequency domain; Postprocessing; Network parameter extraction.</li> <li>Application to typical high-frequency devices: Waveguide / resonator structures, planar structures</li> </ol>						
2	be able to m	<b>bjectives</b> ll understand fundan odel microwave comp vare tools for electror	onents with simu				
3		ded prerequisites fo als of electrodynamic		r Elektrodynamik)			
4	Form of exa Module exa • Modul		amination, Exam	ination, Duration:	180 Min., Default RS	3)	
5		e for the award of cr final module examina					
6	Grading Module exa • Modul	m: le exam (Technical ex	amination, Exam	ination, Weighting	: 100 %)		
7	Usability of M.Sc. iCE, M	t <b>he module</b> A.Sc. CE					
8	Grade bonu	is compliant to §25	(2)				
9 Сот	References         Course manuscript         Additional References:         • D.K. Cheng: Field and Wave Electromagnetics. Addison-Wesley, New York, 1992         • C.A. Balanis: Advanced Engineering Electromagnetics. Wiley, New York, 1989         • Andrew F. Peterson et al. Computational Methods for Electromagnetics. Wiley-IEEE Press, 1997.						

<b>Course nr.</b>	Course name				
18-dg-2150-vl	Technical Electrodynamics for iCE				
<b>Instructor</b>	unteanu, Prof. Dr. Peter Thoma	<b>Type</b>	SWS		
Prof. Dr. Irina M		Lecture	2		
<b>Course nr.</b> 18-dg-2150-ue	<b>Course name</b> Technical Electrodynamics for iCE				
<b>Instructor</b>	unteanu, Prof. Dr. Peter Thoma	<b>Type</b>	<b>SWS</b>		
Prof. Dr. Irina M		Practice	2		

	Module name Advanced Digital Integrated Circuit Design							
Мо	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle		
	ho-2010 Iguage	6 CP	180 h	120 h Module owner	1 Term	Winter term		
	glish			Prof. DrIng. Kla	us Hofmann			
1	1 Teaching content MOS Transistor Models, CMOS Logic Gates, Chip Layout and Design Rules, Static and Dynamic Behavior of CMOS Circuits, Synchonous CMOS Circuits, Performance and Power Characterisation, Design Techniques and CAD Tools, FPGA and Gate Array Technologies, Memory Technologies, Data-Converters (A/D, D/A), Chip Test.							
2	<ul> <li>Learning objectives <ul> <li>A student is, after successful completion of this module, able to <ul> <li>understand the short-channel effects of modern CMOS transistors,</li> <li>derive and analyse the most important circuit concepts for digital logic gates,</li> <li>understand the design flow of digital ASICs based on standard cells (design, layout, simulation/verification),</li> <li>know the pros and cons of synchronous vs. asynchronous logic, multiclockphase systems,</li> <li>understand the differential design methods of integrated circuits (ASIC, ASIP, Full-custom/Semicustom, PLA, PLD, FPGA),</li> <li>understand the concepts of A/D and D/A-converters, and their fundamental technical properties and architectures,</li> <li>know the design principles and properties of integrated semiconductor memory (DRAM, SRAM, Flash. MRAM, FeRAM)</li> </ul> </li> </ul></li></ul>							
3	Recomment Lecture "Ele	<b>ded prerequisites fo</b> ctronics"	or participation					
4	Form of exa Module exa • Modul		xamination, Exam	ination, Duration:	90 Min., Default RS)			
5		e for the award of c final module examina						
6	Grading Module exan • Modul	m: le exam (Technical ex	amination, Exam	ination, Weighting:	100 %)			
7		<b>the module</b> DT, M.Sc. etit - SAE,	M.Sc. iCE, M.Sc.	iST, M.Sc. WI-etit				
8		<b>as compliant to §25</b> provement of up to 1,		s possible, which c	an be earned with te	sts.		
9 Coi		e Copies P. Uyemura: Fundame Jeste et al.: Principles			uits			
COL	41 303							

<b>Course nr.</b> 18-ho-2010-vl	Course name Advanced Digital Integrated Circuit Design		
Instructor	<b>Instructor</b>		<b>SWS</b>
Prof. DrIng. Kla	Prof. DrIng. Klaus Hofmann		3
<b>Course nr.</b> 18-ho-2010-ue	<b>Course name</b> Advanced Digital Integrated Circuit Design		
Instructor	us Hofmann	<b>Type</b>	<b>SWS</b>
Prof. DrIng. Kla		Practice	1

	<b>dule name</b> delling and S	imulation of Circuits				
	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
18-9	sc-2010	4 CP	120 h	75 h	1 Term	Summer term
<b>Language</b> German/English				Module owner Prof. Dr. rer. nat.	Sebastian Schöps	
1	Teaching content         The content of this course is the following:         • Circuit interpretation as directed graphs         • Modified nodal and loop analysis         • Flux and charge oriented formulations         • Differential algebraic equations         • Linear system solver         • Numerical solution of nonlinear systems         • Time-domain methods         • Frequency-domain solution         • Implementation of the numerical methods					
2	Learning objectives Students understand the theoretical and numerical fundamentals of circuit simulation and how the equations can be derived from Maxwell's equations. Circuit properties can be expressed in tems of graph theory. The sparse systems of equations such as the flux/charge oreinted modified nodal analysis can be assembled. In order to solve the obtained systems, different numerical methods for the simulation of circuits are relevant. This includes methods for the solution of linear systems (direct and iterative solvers), root-finding algorithms for nonlinear systems and implicit time integration methods. Mathematical concepts such as stability, convergence order or complexity are known and can be employed to judge the advantages and disadvantages of the various methods. Eventually, the students are able to programm their own circuit simulator, that can return both frequency as well as time domain solutions of electric networks.					
3	18-hs-1070	<b>ded prerequisites fo</b> Elektrotechnik und I Allgemeine Informati	nformationstechn			formationstechnik II, Scientific Computing
4	Form of exa Module exa	amination				
5		e for the award of c final module examina				
6	Grading Module exa • Modul	m: le exam (Technical ex	camination, Oral e	examination, Weigh	nting: 100 %)	
7		t <b>he module</b> .Sc. WI-etit, M.Sc. et	it - CMEE, M.Sc. i	CE, M.Sc. WI-etit,	B.Sc. und M.Sc. iST,	M.Sc. CE
8		<b>is compliant to §25</b> s of 0,4 if correctly in		ams are submitted		
9	References					

- L. W. Nagel, "SPICE2: A computer program to simulate semiconductor circuits", University of Berkeley, Tech. Rep., 1975.
- C.-W. Ho, A. E. Ruehli, and P. A. Brennan, "The modified nodal approach to network analysis", IEEE Trans. Circ. Syst., vol. 22, no. 6, pp. 504-509, Jun. 1975.
- J. Vlach, K. Singhal, Computer methods for circuit analysis and design. New York : Van Nostrand Reinold, 1983.

## Courses

G	ui ses			
	Course nr.Course name18-sc-2010-vlModelling and simulation of circuits			
	Instructor Prof. Dr. rer. nat. Sebastian Schöps		<b>Type</b> Lecture	<b>SWS</b> 2
	<b>Course nr.</b> 18-sc-2010-ue	<b>Course name</b> Modelling and simulation of circuits		
	Instructor Prof. Dr. rer. nat. Sebastian Schöps, M.Sc. Elias Paakkunainen		<b>Type</b> Practice	<b>SWS</b> 1

Module name Hardware for Neural Networks							
Мо	<b>dule nr.</b> zh-2010	<b>Credit points</b> 6 CP	Workload 180 h	Self-study 120 h	Module duration	Module cy Summer te	
Lar	<b>iguage</b> glish	0.01	100 11	Module owner Prof. DrIng. Li Z		builliner te	
1	I       Teaching content         • Training and inference of neural networks         • Challenges in accelerating neural networks         • Computation cost reduction in neural networks         • Neural networks acceleration with logic design and FPGAs         • Neural networks acceleration with in-memory-computing platforms						
2	Learning objectives Students that have completed this module know the development of neural networks and the challenges in accelerating neural networks with CPUs and GPUs. They can evaluate the computation cost of neural networks and select the corresponding methods to reduce the computation cost. They are also enabled to evaluate the performance of the different hardware acceleration platforms for neural networks.						
3		<b>led prerequisites fo</b> mming skills in Pyth					
4	Form of exa Module exar • Module	n:	xamination, Exam	ination, Duration:	90 Min., Default RS)		
5		e for the award of c					
6	Grading Module exar • Module	n: e exam (Technical ez	xamination, Exam	ination, Weighting	: 100 %)		
7	<b>Usability of</b> M.Sc. etit - A	<b>the module</b> AUT, M.Sc. etit - DT,	M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	M.Sc. iST		
8		s compliant to §25					
9	<b>References</b> Slides can be	e downloaded throug	gh Moodle platfor	m			
Coι	ırses						
	<b>Course nr.</b> 18-zh-2010-	Course namevlHardware for	Neural Networks				1
	Instructor Prof. DrIng	. Li Zhang			<b>Type</b> Lecture		<b>SWS</b> 2
	<b>Course nr.</b> 18-zh-2010-	pr Hardware for	Neural Networks				
	<b>Instructor</b> Prof. DrIng	. Li Zhang			<b>Type</b> Lab		<b>SWS</b> 2

10	dule nr. C	redit points 5 CP	Workload 150 h	Self-study 90 h	Module duration 1 Term	Module cycle Summer term			
	nguage	J GP	130 11	Module owner	1 101111	Summer term			
	glish			Prof. DrIng. Har	ald Klingbeil				
1	loaded with ma beam loading, particle tracking	ansmission lines gnetically perme basic terms and o	able materials, cav definitions of nonl ville's theorem, adi	vities based on clas inear dynamics, R	components, RF me sical resonators, cavi F acceleration, longi ns for special beam n	ty equivalent circui tudinal phase space			
2	Students know describe them n of different typ of RF manipula	Learning objectives Students know important RF components and sub-systems for particle accelerator cavities. They are able to describe them mathematically (e.g. by means of S-parameters), and they are familiar with the operating principle of different types of cavities for particle accelerators and their sub-systems and components. The description of RF manipulations in longitudinal phase space and related terms and definitions are known to them. The students are able to calculate different phenomena of accelerator technology quantitatively.							
3	Recommended	prerequisites fo	or participation						
4	Form of exami Module exam: • Module ex		xamination, Oral e	examination, Durat	ion: 30 Min., Defaul	t RS)			
5		<b>r the award of c</b> l module examin							
6	<b>Grading</b> Module exam: • Module ex	xam (Technical e:	xamination, Oral e	examination, Weigh	nting: 100 %)				
7	<b>Usability of the</b> M.Sc. etit - CM		TS, M.Sc. iCE, M.S	Sc. WI-etit, B.Sc. u	nd M.Sc. iST				
0	Grade bonus c	ompliant to §25	(2)						
8	<b>References</b> Lecture slides a	re offered for dov	wnload. Further re	ferences are given	in the lecture.				
	117000								
9	Course nr.     Course name								
9			ncy Systems for Pa	rticle Accelerators					
9	Course nr.	Radio Frequer	ncy Systems for Pa		<b>Type</b> Lecture	SWS 2			
9	Course nr. 18-kb-2040-vl Instructor	Radio Frequer arald Klingbeil Course name				SWS 2			

## 2.1.2 Communication Hardware - Labs and Projects

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cyc	
	hb-2040	6 CP	180 h	135 h	1 Term	Every Seme	ester
	nguage rman			Module owner Prof. DrIng. Chi	istian Hochberger		
1	be defined ir particularly architectures Usually, the	l work on their own adividually for each means the extensio as well as the protection course starts with a	group. In this co n, improvement, otypical implemen literature search	urse reconfigurable or adaptation of c ntation of applicati to get acquainted	urse. Topics and app e architectures will b components and tool ons on such reconfig with the underlying a written report and	be investigate ls for reconfig urable archite architecture.	d. Thi gurable ecture: This i
2	Successful st use tools to p They are cap	earning objectives Juccessful students will know how to use reconfigurable systems within a given application context. They can se tools to program these systems and know how to map an application onto a given reconfigurable architecture. They are capable to evaluate the performance critical parts of an application. They understand the implications of different coding styles for a particular task.					
3	<ul> <li>Recommended prerequisites for participation</li> <li>Knowledge of reconfigurable devices (cf. course computer systems II)</li> <li>Knowledge of computer architecture (cf. course computer systems I)</li> <li>Solid programming skills (either in C or Java depending on the application scenario).</li> </ul>						
	• Solid p	rogramming skills (				).	
4	Form of exa Module exan • Module	mination n: e exam (Study achie	either in C or Java	depending on the	application scenario) Default RS)		2.
4	Form of exam Module exam • Module Report and/o Prerequisite	mination n: e exam (Study achie	either in C or Java evement, Oral/writ e type of examinat redit points	depending on the	application scenario		2.
5	Form of exam Module exam • Module Report and/o Prerequisite Passing the find Grading Module exam	mination h: e exam (Study achie or Presentation. The for the award of c inal module examin	either in C or Java evement, Oral/writ e type of examinat redit points ation	depending on the	application scenario) Default RS) ced in the beginning		2.
5	Form of exame Module exame • Module Report and/or Prerequisite Passing the free Grading Module exame • Module Usability of	mination h: e exam (Study achie or Presentation. The for the award of c inal module examin h: e exam (Study achie	either in C or Java evement, Oral/writ e type of examinat redit points ation	depending on the tten examination, I ion will be announ	application scenario) Default RS) ced in the beginning		2
5 6 7	Form of exam Module exam Module exam Report and/or Prerequisite Passing the fit Grading Module exam Module exam Module Usability of M.Sc. etit - D	mination h: e exam (Study achie or Presentation. The for the award of c inal module examin h: e exam (Study achie the module	either in C or Java evement, Oral/writ type of examinat redit points ation evement, Oral/writ WI-etit, B.Sc. und	depending on the tten examination, I ion will be announ	application scenario) Default RS) ced in the beginning		2.
5 6 7	Form of exam Module exam Module exam Module exam Passing the fr Grading Module exam Module exam Module exam Module exam Module exam Grading Module exam Module exam Module exam Grading Module exam Module exam Mo	mination h: e exam (Study achie or Presentation. The for the award of c nal module examin h: e exam (Study achie the module T, M.Sc. iCE, M.Sc.	either in C or Java evement, Oral/writ e type of examinat redit points ation evement, Oral/writ WI-etit, B.Sc. und (2)	depending on the tten examination, I ion will be announ tten examination, V	application scenario) Default RS) ced in the beginning Weighting: 100 %)		2.
5 6 7 8 9	Form of exam Module exam Module exam Module exam Passing the fr Grading Module exam Module exam Module exam Module exam Module exam Grading Module exam Module exam Module exam Grading Module exam Module exam Mo	mination h: e exam (Study achie or Presentation. The for the award of c nal module examin h: e exam (Study achie the module or, M.Sc. iCE, M.Sc. s compliant to §25	either in C or Java evement, Oral/writ e type of examinat redit points ation evement, Oral/writ WI-etit, B.Sc. und (2)	depending on the tten examination, I ion will be announ tten examination, V	application scenario) Default RS) ced in the beginning Weighting: 100 %)		2.
5 6 7 8 9	Form of exam Module exam • Module Report and/o Prerequisite Passing the fi Grading Module exam • Module Usability of M.Sc. etit - E Grade bonus References Will be given	mination h: e exam (Study achie or Presentation. The for the award of c nal module examin h: e exam (Study achie the module or, M.Sc. iCE, M.Sc. s compliant to §25 to the students dur Course name	either in C or Java evement, Oral/writ type of examinat redit points ation evement, Oral/writ WI-etit, B.Sc. und (2)	tten examination, I ion will be announ tten examination, V d M.Sc. iST	application scenario) Default RS) ced in the beginning Weighting: 100 %)		2.

	dule name	ated Circuit Design I	.ab					
Mo	<b>dule nr.</b> ho-2120	Credit points 6 CP	Workload 180 h	Self-study 135 h	<b>Module d</b> 1 Term	duration	Module cy Summer te	
Lar	iguage	0.61	100 11	Module owner Prof. DrIng. Kla		n	Summer te.	1111
1	<b>Teaching co</b> Practical Des Tools	ontent sign Tasks in Full Cus	tom Design of Dig	ital or Analog Cirui	ts using St	ate-of-the-	Art Commerc	ial CAD
2	<ol> <li>develo</li> <li>simula</li> <li>draw,</li> <li>After succes</li> </ol>	p and verify transist te logic and analog overify and extract lay sful completion of that and to mutually	or circuitry using circuits (Pre- and ) yout his module the stu	Cadence Postlayout) dents are able to v				
3		<b>ded prerequisites fo</b> vanced Digital Integr		n" or "Electronic a	nd Integrat	ted Circuit	s"	
4	Report (inclu		programming code	) and/or Presentati	ion and/or	Oral exam		
5		e for the award of c final module examin						
6	Grading Module exa • Modul	n: e exam (Study achie	vement, Oral/wri	tten examination, V	Weighting:	100 %)		
7	Usability of M.Sc. etit - 1	<b>the module</b> DT, M.Sc. etit - SAE,	M.Sc. iCE, M.Sc.	MEC, M.Sc. WI-eti	t, B.Sc. und	d M.Sc. iS	Г, M.Sc. CE	
8		s compliant to §25						
9	• John F	e Slide Copies 2. Uyemura: Fundam /este et al.: Principle:			cuits			
Coι	urses							
	<b>Course nr.</b> 18-ho-2120-	pr Advanced Inte	grated Circuit De	sign Lab				
	Instructor Prof. DrIng	. Klaus Hofmann, M	.Sc. Markus Grabe	er, M.Sc. Jana Spätl	h	<b>Type</b> Lab		<b>SWS</b> 3

	ninar Integrate	d Electronic System	s Design A			1		
	o <b>dule nr.</b> ho-2160	Credit points 4 CP	Workload 120 h	Self-study 90 h	Module duration 1 Term	Module cycle Every Semeste		
	n <b>guage</b> glish			<b>Module owner</b> Prof. DrIng. Kla	us Hofmann			
1					electronics System D	esign; Creation	of	
2	A student is, a 1. gain a c	<ul> <li>Learning objectives</li> <li>A student is, after successful completion of this module, able to</li> <li>1. gain a deep understanding of the chosen research subject in the field of integrated electronic systems,</li> <li>2. write an essay on the chosen subject in a comprehesive form and present the outcome to an audience</li> </ul>						
3		<b>ed prerequisites fo</b> gital Integrated Circ		Aethods, Computer	Architectures, Progr	amming Know-I	Ho	
4	Advanced Digital Integrated Circuit Design, CAD Methods, Computer Architectures, Programming Know-How         Form of examination         Module exam:         • Module exam (Study achievement, Oral examination, Duration: 45 Min., Default RS)							
	• Would	exam (Study achie	vement, Oral exar	nination, Duration	: 45 Min., Default RS	5)		
5	Prerequisite	for the award of cr nal module examina	redit points	nination, Duration	: 45 Min., Default RS	5) 		
5	Prerequisite Passing the fi Grading Module exam	for the award of cr nal module examina	redit points ation			;)		
6	Prerequisite Passing the fi Grading Module exam • Module Usability of t	for the award of cr nal module examina :: exam (Study achie	redit points ation vement, Oral exar	nination, Weightin	g: 100 %)	;) 		
6 7	Prerequisite Passing the fi Grading Module exam • Module Usability of t M.Sc. etit - D	for the award of cr nal module examina :: exam (Study achie the module	redit points ation vement, Oral exar M.Sc. iCE, M.Sc.	nination, Weightin	g: 100 %)	;;) 		
6 7 8	Prerequisite Passing the fi Grading Module exam • Module Usability of t M.Sc. etit - D Grade bonus References	for the award of cr nal module examina :: exam (Study achie the module T, M.Sc. etit - SAE,	redit points ation vement, Oral exar M.Sc. iCE, M.Sc. 7 (2)	nination, Weightin	g: 100 %)	;;) 		
6 7 8 9	Prerequisite Passing the fi Grading Module exam • Module Usability of t M.Sc. etit - D Grade bonus References	for the award of cr nal module examina e: exam (Study achier the module T, M.Sc. etit - SAE, compliant to §25	redit points ation vement, Oral exar M.Sc. iCE, M.Sc. 7 (2)	nination, Weightin	g: 100 %)	;) 		
6 7 8 9	Prerequisite Passing the fi Grading Module exam • Module Usability of t M.Sc. etit - D Grade bonus References Topic-oriente	for the award of cr nal module examina exam (Study achie the module T, M.Sc. etit - SAE, compliant to §25 d Materials will be p Course name	redit points ation vement, Oral exar M.Sc. iCE, M.Sc. 7 (2)	nination, Weightin WI-etit, B.Sc. und 1	g: 100 %)	;;) 		

	dule name	Advanced - Martin C						
Mo	dule nr.	Advanced µWave Con Credit points	Workload	Self-study	Module o	duration	Module cy	
-	jk-2060	8 CP	240 h	180 h	1 Term		Every Seme	ester
	<b>iguage</b> man/English			Module owner Prof. DrIng. Rol	f Jakoby			
1	problem. Th group will b electronicall	3 students per proje ne projects will be ac e supervised individu y-steerable antennas e mixer and modulat	ctualized in each ually. The projects , RFIDs, RF sensor	cycle being offered comprises modern rs, adaptive tunable	l and intro antennas componer	oduced at t for multitu nts such as	the beginnin udinous appli s matching ne	g. Each ications,
	Research-ori will learn • how to • workin • how to • how to • to eval • to writ	ented Project Semin o solve scientific hard og out concepts o design, realize and o use commercial soft uate and discuss the re a brief scientific re- sent and discus their	lware-oriented pro characterize RF d tware and charact ir work in the con port about their w	oblems evices erization tools itext of the state-of- vork	art in this		upervision. S	tudents
3		<b>ded prerequisites fo</b> lls of Microwave Eng		tennas and Adaptiv	e Beamfor	ming		
4	Form of exa Module exa • Modul		vement, Oral exar	nination, Duration	: 30 Min., 1	Default RS	3)	
5		e for the award of c						
6	Grading Module exan • Modul	n: e exam (Study achie	vement, Oral exar	nination, Weightin	g: 100 %)			
7	•	<b>the module</b> KTS, M.Sc. iCE, M.Sc	2. WI-etit					
8	Grade bonu	s compliant to §25	(2)					
9	<b>References</b> Publications are available	will be hand out to t e.	hem. Software an	d characterization	tools as we	ell as tools	to realize RF	devices
<b>Co</b> ι	ırses							
	<b>Course nr.</b> 18-jk-2060-j	Course nameojProject Semina	ar Advanced µWay	ve Components & A	ntennas			1
	<b>Instructor</b> Prof. DrIng	. Rolf Jakoby, DrIng	g. Martin Schüßler	1		<b>Type</b> Project se	eminar	SWS

		Credit points	Workload	Self-study	Module duration	Module cycle	
	pe-2040	8 CP	240 h	180 h	1 Term	Winter term	
	<b>nguage</b> glish			Module owner Prof. DrIng. Ma	rius Pesavento		
1	tensor data re The specific th	eminar addresses n epresentations.	seminar will be a	dapted from year to	hannel processing wi o year according to th ell in advance.		
2		Learning objectives Students will understand theory, algorithms and applications of sensor array and multichannel system.					
3		<b>ed prerequisites fo</b> dge in linear algebra					
4	Form of exar Module exam • Module	:	vement, Oral exar	nination, Duration	: 40 Min., Default RS	)	
5		for the award of c nal module examina					
6	Grading Module exam • Module	ı: exam (Study achie	vement, Oral exar	nination, Weightin	g: 100 %)		
7	<b>Usability of t</b> M.Sc. etit - K	t <b>he module</b> TS, M.Sc. etit - VAS,	, M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	M.Sc. iST		
8	Grade bonus	compliant to §25	(2)				
9	Wiley & Sons				Estimation, and Mod	ulation Theory, Jo	
Co	urses						
	Course nr.	Course name					
	18-ре-2040-р	j Project Semina	ar Emerging Topic	s in Sensor Array a	and Multichannel Pro	cessing	

	<b>dule nr.</b> pe-2050	Credit points 8 CP	Workload 240 h	Self-study 180 h	Module duration 1 Term	Module cycle Summer term	
Laı	<b>nguage</b> glish	0.61	240 11	Module owner Prof. DrIng. Ma		Julinier term	
1	<b>Teaching co</b> This project communicati The specific	-seminar addresses ion systems. thematic focus of the	e seminar will be	IMO communicati adapted from year	ions for the next gen r to year according to e website well in adva	o the latest trends	
2	Students wil	<b>Learning objectives</b> Students will learn the fundamental concepts, procedures, theories, algorithms and applications of Massive MIMO systems and 5 G mobile communication networks by the latest scientific publications.					
3	Recommend	led prerequisites fo	r participation				
4	Form of exa Module exam • Module	n:	vement, Oral exar	nination, Duration	: 40 Min., Default RS	5)	
5		e for the award of cr inal module examina					
6	Grading Module exan • Module	n: e exam (Study achie	vement, Oral exar	nination, Weightin	g: 100 %)		
7	<b>Usability of</b> B.Sc. WI-etit	<b>the module</b> , M.Sc. etit - KTS, M	.Sc. etit - VAS, M.	Sc. iCE, M.Sc. WI-	etit, B.Ed. etit		
8	Grade bonu	s compliant to §25	(2)				
9	<b>References</b> References in	nclude the latest scie	ntific publications	, seminars and boo	oks.		
Co	urses						
	<b>Course nr.</b> 18-pe-2050-j	pj Project Semina	ar Emerging Topic	s in MIMO Comm	unication Networks		
	Instructor Prof. DrIng.				Туре	SV	

	<b>dule nr.</b> pr-2030	Credit points 8 CP	Workload 240 h	<b>Self-study</b> 180 h	Module duration	Module cycle
Lar	pi-2030 nguage man/English	o Cr	240 11	Module owner Prof. Dr. rer. nat.		Every Semester
1	of THz techn be defined l own, organi summarizin conclusions • Terahe • Optics • Spectr • Semice	g and solving specific nology as well as topi based on current rese zing and structuring g achieved results ar and defending them ertz Optics /photonics	ics of the area of C earch topics. The of a seminar task, ad conclusions by	Dptics and commun project seminar ir searching and ana means of a written	nent of Terahertz dev nication technology. Includes working on a alyzing of scientific re n report, presenting a ence. Topics include,	The specific task wil a given task by one's ference publications achieved results and
2	<ul> <li>the ab</li> <li>deep a</li> <li>the ski</li> <li>the cap</li> </ul>	etion of the course, st ility to apply theoreti nd special knowledg lls to find, analyze an	ical models to pra- e in a particular fi nd evaluate scient e the achieved scie	eld related to THz ific reference pape ntific findings in th	science, optics or ser rs for a particular top te form of a concise ro ont of an audience	bic
3		<b>ded prerequisites fo</b> wledge in at least one		lisciplines: Optics,	semiconductor physic	s, or THz technology
4	Form of exa Module exa • Modul	mination n: e exam (Study achie	vement, Oral/writ	ten examination, I		
	Prerequisit	e for the award of c				
5	Passing the	final module examina				
5	Grading Module exam		ation	ten examination, V	Weighting: 100 %)	
	Grading Module exam • Modul Usability of	n:	ation	ten examination, V	Weighting: 100 %)	
6	Grading Module exame • Modul Usability of M.Sc. etit - 1	n: e exam (Study achie <b>the module</b>	ation vement, Oral/writ	ten examination, V	Neighting: 100 %)	

<b>Course nr.</b> 18-pr-2030-pj	<b>Course name</b> Project Seminar Terahertz Technology, Communication and S	ensors	
<b>Instructor</b> Prof. Dr. rer. nat.	Sascha Preu	<b>Type</b> Project seminar	SWS 4

	<b>dule name</b> ninar Softwar	e System Technolog	V					
Mo	<b>dule nr.</b> su-2080	Credit points 4 CP	Workload 120 h	Self-study 90 h	Module of 1 Term	duration	Module cyc Every Seme	
	<b>iguage</b> man			Module owner Prof. Dr. rer. nat.	Andreas S	Schürr		
1		ntent e, the students produ ed to IT system devel						
2	sources and a literature r	<b>jectives</b> sful completion of t explore an unknown esearch and to analy rt as well as in an or	topic under scient ze the subject criti	tific aspects. The st	udents lear	n to suppo	rt the explora	ation by
3		<b>led prerequisites fo</b> edge in software eng		ramming language	es			
4							d in the begin	nning of
5		e for the award of c						
6	Grading Module exar • Module	n: e exam (Study achie	vement, Oral/wri	tten examination, V	Weighting:	100 %)		
7	<b>Usability of</b> M.Sc. etit - I	<b>the module</b> DT, M.Sc. iCE, M.Sc.	MEC, M.Sc. WI-e	tit, B.Sc. und M.Sc	. iST			
8	Grade bonu	s compliant to §25	(2)					
9	References https://www	v.es.tu-darmstadt.de	/lehre/aktuelle-ve	eranstaltungen/sst-	·S			
Coi	urses			0				
	<b>Course nr.</b> 18-su-2080-s	<b>Course name</b> See Seminar Softw	vare System Techr	nology				
	Instructor Prof. Dr. rer.	nat. Andreas Schür	r, M.Sc. Alexej An	dres		<b>Type</b> Seminar		<b>SWS</b> 2

	<b>dule nr.</b> -ho-1090	Credit points 6 CP	Workload 180 h	Self-study 135 h	Module duration 1 Term	Module cycle Summer term
	<b>nguage</b> glish			<b>Module owner</b> Prof. DrIng. Kla	us Hofmann	
1	Teaching con Realisation of		g-based VLSI Syste	em Design Project i	n a Team with indust	rial constraints
2	Learning ob A student is,	<b>jectives</b> after successful co <del>n</del>	npletion of this mo	odule, able to		
	Verilog 2. synthes After success	or VHDL, size the HDL descrip ful completion of th re able to mutually	otion using comme nis module the stu	ercial CAD software dents are able to v	pipelined CPU or sign e to a gate level descr vork constructively o rmediate results to p	ription n a feasible solutior
3	Lecture Com	<b>ed prerequisites fo</b> puter Aided Design high-level Programm	for System on Chi		ux/Unix, Computer A	architectures
4	Report (inclu and/or Collo	n: e exam (Study achie ding submission of p	programming code	) and/or Presentati	Default RS) ion and/or Oral exam type of examination v	
5		for the award of cannot nal module examination				
6	Grading Module exam • Module	n: e exam (Study achie	vement, Oral/writ	tten examination, V	Weighting: 100 %)	
7	Usability of B.Sc. MEC, M		. etit - SAE, M.Sc.	iCE, M.Sc. WI-etit	, B.Sc. und M.Sc. iST	
8	Grade bonus	s compliant to §25	(2)			
9	References Lecture slide	s "CAD4SoC"				
Co	urses					
	Course nr.	Coursements				
	18-ho-1090-j	or HDL Lab				

		Credit points	Workload	Self-study	Module duration	Module cycle	
18	ho-2161	6 CP	180 h	135 h	1 Term	Every Semester	
	<b>nguage</b> glish			<b>Module owner</b> Prof. DrIng. Kla	us Hofmann		
1					electronics System D	esign; Creation o	
2	<ul> <li>Learning objectives</li> <li>A student is, after successful completion of this module, able to</li> <li>1. gain a deep understanding of the chosen research subject in the field of integrated electronic systems,</li> <li>2. write an essay on the chosen subject in a comprehesive form and present the outcome to an audience</li> </ul>						
3	Recommende	ed prerequisites fo	r participation	-	Architectures, Progr		
4	Form of exam Module exam	nination :		· ·	: 45 Min., Default RS		
5		for the award of c nal module examina					
	Passing the final module examination         Grading         Module exam:         • Module exam (Study achievement, Oral examination, Weighting: 100 %)						
6	Module exam		vement, Oral exar	nination, Weightin	g: 100 %)		
	Module exam • Module Usability of t	exam (Study achie		nination, Weightin	g: 100 %)		
7	Module exam • Module Usability of t M.Sc. etit - S/	exam (Study achie he module	und M.Sc. iST	nination, Weightin	g: 100 %)		
7	Module exam • Module Usability of t M.Sc. etit - SA Grade bonus References	exam (Study achie <b>he module</b> AE, M.Sc. iCE, B.Sc.	und M.Sc. iST (2)	nination, Weightin	g: 100 %)		
7 8 9	Module exam • Module Usability of t M.Sc. etit - SA Grade bonus References	exam (Study achie <b>he module</b> AE, M.Sc. iCE, B.Sc. <b>compliant to §25</b>	und M.Sc. iST (2)	nination, Weightin	g: 100 %)		
6 7 8 9 Co	Module exam • Module Usability of t M.Sc. etit - SA Grade bonus References Topic-oriented	exam (Study achie the module AE, M.Sc. iCE, B.Sc. compliant to §25 d Materials will be p Course name	und M.Sc. iST (2)		g: 100 %)		

1	dule name		· · · · · 1					
	dule nr.	ms Hands-On 2: Des Credit points	Workload	Self-study	Module d	-	Module cy	cle
20-	00-0968	6 CP	180 h	120 h	1 Term		Every 2. Se	mester
	n <b>guage</b> man			Module owner Prof. DrIng. And	lreas Koch			
1	<b>Teaching co</b> These practi systems-on-o	cal labs are intende	d for students inte	erested in learning	how to des	sign hardv	vare accelera	tors for
	It covers a w	vide range of topics,	including					
	- OS drivers for accelerators							
	- design and interfacing of accelerators in Bluespec SystemVerilog							
	- Design flows and tool chains for hardware/software co-development							
	The actual accelerators covered are inspired by typical applications, e.g., image processing or stereovi- sion computations.							
2	<b>Learning objectives</b> Acquire skills in using the knowledge and techniques taught in prior classes to actually perform a complete hardware/software co-design of an application in an embedded systems context.							
3	<b>Recommended prerequisites for participation</b> Basic knowledge using Linux on embedded Systems (e.g., acquired in ESHO1). Knowledge of the Bluespec SystemVerilog hardware description language (e.g., as taught in Architecture and Design of Computing Systems).							
4	Form of exa Course relat • [20-00		hievement, Oral/v	vritten examinatio	n, Default I	RS)		
5	<b>Prerequisite</b> Pass exam (2	e for the award of c 100%)	redit points					
6	Grading Course relat • [20-00	ed exam: )-0968-pr] (Study ac	hievement, Oral/v	vritten examinatio	n, Weightir	ng: 100 %)	)	
7	Usability of	the module						
8	Grade bonu	s compliant to §25	(2)					
9	References							
Со	ırses							
	Course nr.	Course name						
	20-00-0968-			: Designing Hardw	are Accele	rators for	Systems-on-C	hip
	Instructor					Туре		SWS
	Prof. DrIng	. Andreas Koch				Lab		4

	dule name	in Emboddod Croton	a and Amplication					
Мо	<b>dule nr.</b> 00-1001	s in Embedded System Credit points 9 CP	Workload 270 h	<b>Self-study</b> 180 h	Module duration	<b>Module cycle</b> Every 2. Semester		
Lan	nguage man/English		270 11	Module owner Prof. DrIng. And		Every 2. Semester		
1	including fe determined technical as - Computing - Design of o	covers current topics ocused ones in the a by current research e well as introductory g systems architecture digital electronic circu	reas of embedde fforts in the ESA scientific skills, fo e at the processor tits and hardware	d and application- group and are inter r example, includir and systems-level	specific architecture nded to guide studen	s. The subjects are ts towards acquiring		
	Hardware/S - Operating Hardware/S Application - Design and	Use of Field-Programmable Gate Arrays Iardware/Software design and programming tools Operating systems and low-level programming Iardware/Software Co-Design pplication-specific architectures and techniques Design and/or programming of compute accelerators Debugging and analysis techniques for hardware/software-systems						
2	Participants then solve literature, s	<b>Learning objectives</b> Participants are intended to acquire the skills necessary to quickly become familiar with a new domain and then solve a complex practical problem within that domain. These skills can include studies of scientific literature, surveying existing code-bases from the hardware/software domains, and the practical implementation of hardware and/or software systems. The final talk should show proficiency with basic presentation techniques.						
3	An interest pre-requisit	<b>ded prerequisites fo</b> to develop high-quali es will be required. Th ng. Such skills can be	ty solutions in the nese can include d	igital design, comp	iler construction, syst	em-level and parallel		
4	Form of ex Course rela • [20-0		hievement, Oral/v	written examinatio	n, Default RS)			
5	<b>Prerequisit</b> Pass exam (	te for the award of cr (100%)	redit points					
6	Grading Course rela • [20-0	ted exam: 0-1001-pp] (Study ac	hievement, Oral/v	written examinatio	n, Weighting: 100 %	)		
7	B.Sc. Inform M.Sc Inform		grams.					
8	Grade bon	us compliant to §25	(2)					
9	References							
Coi	urses							

<b>Course nr.</b> 20-00-1001-pp	<b>Course name</b> Advanced Topics in Embedded Systems and Applications		
<b>Instructor</b> Prof. DrIng. And	dreas Koch	<b>Type</b> Project	<b>SWS</b> 6

	<b>dule name</b> ject Seminar I	Electromagnetic CAI	)				
Мо	<b>dule nr.</b> sc-1020	Credit points 8 CP	Workload 240 h	Self-study 180 h	Module durat	ion Module o Every Sen	•
	<b>nguage</b> rman/English			<b>Module owner</b> Prof. Dr. rer. nat.	Sebastian Schö	ps	
1	Topics of go	<b>ntent</b> roject in numerical f od scientific practic re addressed in an a	e, as well as socie	etal or ethical aspe	cts of product d	lesign, optimiza	tion, and
2	to estimate r	<b>jectives</b> l be able to simulate nodelling and nume Students are able to	rical errors. They	know how to prese			
3	<b>Recommended prerequisites for participation</b> Good understanding of electromagnetic fields, knowledge about numerical simulation methods.						
4	<ul> <li>Form of examination</li> <li>Module exam: <ul> <li>Module exam (Study achievement, Oral/written examination, Default RS)</li> <li>Report and/or Presentation. The type of examination will be announced in the beginning of the lecture.</li> </ul> </li> </ul>						
5		for the award of c					
6	Grading Module exan • Module	n: e exam (Study achie	vement, Oral/wri	tten examination, <sup>v</sup>	Weighting: 100	%)	
7	<b>Usability of</b> B.Sc. etit, M	<b>the module</b> Sc. etit - SAE, M.Sc	. iCE, M.Sc. MedT	ec, M.Sc. WI-etit, I	3.Sc. CE, M.Sc.	CE	
8	Grade bonu	s compliant to §25	(2)				
9	<b>References</b> Documents v	vill be made availab	le via Moodle if ne	ecessary.			
Coi	urses						
	<b>Course nr.</b> 18-sc-1020-p	j Course name Project Semin	ar Electromagneti	c CAD			
	InstructorTypeSWSProf. Dr. rer. nat. Sebastian SchöpsProject seminar4						

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle	
Lar	zo-2030 <b>1guage</b> glish	6 CP	180 h	135 h Module owner Prof. DrIng. Abo	1 Term	Every Semester	
1	Teaching co	ntent					
	<ol> <li>Discrete</li> <li>Frequere</li> <li>Digital</li> <li>IIR Filt</li> <li>Nonpare</li> </ol>	ction to MATLAB e-Time Signals and ncy-Domain Analysi FIR Filter Design er Design using Ana ametric Spectrum Estim	s using the DFT log Prototypes Estimation				
2	The students of digital FIF how MATLAI	arning objectives the students are able to apply skills acquired in the course Digital Signal Processing. These include the design digital FIR and IIR filters as well as non-parametric and parametric spectrum estimation. Students learn w MATLAB is used to apply theoretical concepts and to demonstrate signal processing techniques by using nds-on application examples.					
3	Recommended prerequisites for participation Fundamentals of Signal Processing						
4	Module exam • Module	<ul> <li>Form of examination</li> <li>Module exam: <ul> <li>Module exam (Study achievement, Written examination, Duration: 120 Min., Default RS)</li> <li>Exam (Duration: 120 min) and a Report (Lab Reports), Details will be announced at the beginning of the lecture.</li> </ul> </li> </ul>					
5	Prerequisite	for the award of c nal module examin	redit points				
6	<b>Grading</b> Module exam • Module	:: exam (Study achie	vement, Written e	examination, Weigh	nting: 100 %)		
7	<b>Usability of</b> M.Sc. etit - K		, M.Sc. iCE, M.Sc.	MedTec, M.Sc. W	I-etit, B.Sc. und M.Sc	. iST	
8	Grade bonus	compliant to §25	(2)				
9	<b>References</b> Lab manual						
Co	urses						
	<b>Course nr.</b> 18-zo-2030-p	r Digital Signal	Processing Lab				
	Instructor	Abdelhak Zoubir	~		<b>Type</b> Lab	SWS	

1 Q	odule nr. pr-2020	Credit points 4 CP	Workload 120 h	Self-study 90 h	Module duration 1 Term	Module cycle Summer term	
La	n <b>guage</b> glish	4 Gr	120 11	Module owner Prof. Dr. rer. nat.		Summer term	
1	Teaching con This summer	r school covers the			opments of microwa on the physical conc		
2	<ul><li>topics of</li><li>of relat</li><li>the infl</li></ul>	lerstand the present of microwave engine ed electronics	ering, THz engine t properties of ma	eering, and optical aterials and of wave	communications eguides on signal pro	cessing.	
3	Recommend	Recommended prerequisites for participation					
4	Prerequisite	n: e exam (Study achier for the award of cr	redit points	nination, Duration	: 30 Min., Default RS	3)	
		inal module examina	ation				
6	Grading Module exan • Module	n: e exam (Study achie	vement, Oral exar	nination, Weightin	g: 100 %)		
	<b>Usability of the module</b> M.Sc. etit - KTS, M.Sc. iCE, M.Sc. WI-etit, B.Sc. und M.Sc. iST						
7	•	15, M.SC. ICE, M.SC	,				
7	M.Sc. etit - K	s compliant to §25					
8	M.Sc. etit - K Grade bonus References		(2)	be downloaded.			
8 9	M.Sc. etit - K Grade bonus References	s compliant to §25	(2)	be downloaded.			
8 9	M.Sc. etit - K Grade bonus References A script (Eng	s compliant to §25 (lish) will be distributed Course name	(2) ted or slides can l	be downloaded. Aicrowaves and Lig	htwaves"		

	dule nr. zh-2020	Credit points 6 CP	Workload 180 h	Self-study 135 h	<b>Module dur</b> 1 Term	ation	Module cyc Every Seme	
	<b>1guage</b> glish			Module owner Prof. DrIng. Li Z	Lhang			
1	each student improvement tion of such h search to get	ntent work on their own . In this course har of software and har ardware with comm acquainted with the e presented in a wr	dware for neural dware methods fo ercial or open-sou hardware for neu	networks will be i r efficient hardward rce tools or FPGAs. ral networks. This	nvestigated. T e for neural ne Usually, the co	This par tworks ourse st	rticularly me and the imple arts with a lit	ans th ement teratur
2	They can use	ectives Idents will know how tools to train a neur o evaluate the perfo	ral network and ki	now how to realize				
3	• Knowle • Knowle	<ul> <li>Recommended prerequisites for participation</li> <li>Knowledge of neural network training and inference (cf. course hardware for neural network)</li> <li>Knowledge of digital or analog circuits (cf. course hardware for neural network)</li> <li>Solid programming skills (either in Python or VHDL depending on the application scenario)</li> </ul>						
4	Form of exam Module exam • Module		vement, Oral exar	nination, Duration	: 30 Min., Def	ault RS	;)	
5		for the award of c						
6	<b>Grading</b> Module exam • Module	:: exam (Study achie	vement, Oral exar	nination, Weightin	g: 100 %)			
7	<b>Usability of</b> M.Sc. etit - D	<b>he module</b> T, M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	ł M.Sc. iST				
8	Grade bonus	compliant to §25	(2)					
9	<b>References</b> Will be given	to the students dur	ing the individual	seminar kick-off n	neeting.			
Co	urses							
	<b>Course nr.</b> 18-zh-2020-p	j Course name project Semina	ar Hardware for N	leural Networks				
	<b>Instructor</b> Prof. DrIng.	Li Zhang			-	7 <b>pe</b> oject se	eminar	<b>SWS</b> 3

	<b>dule name</b> ject Seminar S	pintronic Devices						
	<b>dule nr.</b> me-2030	<b>Credit points</b> 6 CP	Workload 180 h	Self-study 135 h	<b>Module d</b> 1 Term	luration	Module cyc Every Seme	
	<b>iguage</b> man/English			<b>Module owner</b> Prof. Dr. rer. nat.	Markus M	einert		
1	range from t fabrication a sensor device fabrication fr	ntent t seminar, students the development of nd characterization s or memory cell (M rom the deposition or room conditions.	measurement sys. of functional thir RAM) prototypes.	stems for the chara n film systems, to t Students gain value	acterization he lithogra able insight	n of spint phic prepared s into the o	conic devices aration of spi entire chain o	, to the intronic f device
2	Individual pr the form of a	<b>jectives</b> n the basics of fabric ojects are carried ou project work and le o answer concrete q	it in small groups. earn and deepen tl	The students deep neir knowledge in t	oen the mat he applicat	terial learr	ned in the lect	tures in
3	<ul> <li>Recommended prerequisites for participation</li> <li>Introduction to Spintronics (desirable)</li> <li>Materials of Electrical Engineering (desirable)</li> </ul>							
4							of the lecture	e.
5		for the award of can an an an an arrive the award of can be a set of the set						
6	Grading Module exan • Module	n: e exam (Study achie	vement, Oral/wri	tten examination, V	Weighting:	100 %)		
7	<b>Usability of</b> M.Sc. etit - S	the module AE, M.Sc. iCE, B.Sc.	. und M.Sc. iST					
8	Grade bonus	s compliant to §25	(2)					
9	References Lecture notes	s Introduction to Spi	intronics (Meinert	), subject-specific l	iterature a	nd publica	tions.	
Coι	ırses							
	<b>Course nr.</b> 18-me-2030-	pj Project semina	ar Spintronic Devi	ces				1
	<b>Instructor</b> Prof Dr rer	nat. Markus Meiner	Ť			<b>Type</b> Project se	minar	SWS

Мо	in films and sp dule nr. me-2050	Credit points 5 CP	Workload 150 h	Self-study 105 h	Module duration	Module cy Every Seme	
Lar	nguage glish	5.01	150 11	Module owner Prof. Dr. rer. nat.			
1	cleanroom au Produc layer co Produc Measur	ocks, students have nd to measure their tion of metallic thin oupling (RKKY) tion of an AMR-base	properties: films using magne ed "barber pole" m ysteresis in thin fil	etron sputtering, g agnetic field senso ms, characterizatio	tic thin films and de iant magnetoresistan r using lift-off lithogr n of magnetization ar unnel junctions	ce (GMR), an aphy	nd inte
2	They carry of of the module	module, students lea It lithographic prepa	ration in the clear a basic understand	proom under the gu	production of thin m iidance of the instruct hnology, the associate	tor. Upon con	npletio
3		ecommended prerequisites for participation ntroduction to spintronics					
4	Report (inclu and/or Collo	1: e exam (Study achie ding submission of p	programming code	) and/or Presentat	Duration: 25 Min., De ion and/or Oral exam type of examination v	ination (25 n	
5	Prerequisite	<b>for the award of c</b> inal module examinat					
6	<b>Grading</b> Module exan • Module	n: e exam (Study achie	vement, Oral/writ	tten examination, V	Weighting: 100 %)		
7	<b>Usability of</b> M.Sc. etit - S	<b>the module</b> AE, M.Sc. iCE, B.Sc.	. und M.Sc. iST				
8	Grade bonu	s compliant to §25	(2)				
9	<b>References</b> Script and sl	ides for the internsh	ip Thin films and	spintronics lab			
Cot	urses						
	<b>Course nr.</b> 18-me-2050-	pr Thin films and	spintronics lab				
	Instructor				Туре		SWS

## 2.2 Communication Systems and Networking

## 2.2.1 Communication Systems and Networking - Lectures

	<b>dule nr.</b> jk-2040	Credit points 3 CP	Workload 90 h	Self-study 60 h	Module duration 1 Term	Module cycle Winter term	
Laı	nguage rman		7011	Module owner Prof. DrIng. Rol	L	Whiter term	
1	applications a will be dealt	vill be an introductio and the operating fre	equency ranges. In part, various prin	a historical survey	ribing their concepts ; the radar ranges and y radar techniques w nalysis.	d propagation effect	
2	and range of	l know about concep	n about the funct	ional principles of	well as to determine various radar system ects.		
3		Recommended prerequisites for participation Fundamentals of Communications, Microwave Engineering I					
4	<ul> <li>Form of examination</li> <li>Module exam:</li> <li>Module exam (Technical examination, Oral examination, Duration: 30 Min., Default RS)</li> </ul>						
5		e <b>for the award of c</b> inal module examina					
6	<b>Grading</b> Module exan • Module	n: e exam (Technical ex	amination, Oral e	examination, Weigh	nting: 100 %)		
7	<b>Usability of</b> B.Sc. WI-etit	<b>the module</b> , M.Sc. etit - KTS, M	.Sc. iCE, M.Sc. W	I-etit, B.Sc. und M	.Sc. iST, M.Sc. CE		
8	Grade bonu	s compliant to §25	(2)				
9	<b>References</b> Slides, Latest	t Publications and Bo	ooks				
Co	urses						
	<b>Course nr.</b> 18-jk-2040-v	Course name 1 Radar Techniq	ues				

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cyc	
	kp-1010	6 CP	180 h	120 h	1 Term	Winter term	L
	<b>1guage</b> glish			Module owner Prof. Dr. techn. H	leinz Köppl		
2	theory. Outline: information, u channels, bas channel codin bandwidth ef Access Chann Learning obj	uncertainty, entropy ics of source and ch ig theorem, capacity ficiency, capacity of el, Broadcast Chan ectives	, mutual information annel coding, line ty of Gaussian cha multiple parallel o nel, rate region.	on, capacity, differe ar block codes, Sha annels, capacity of channels and water	y, network informatic ential entropy, typical innon's source coding bandlimited channe filling, Gaussian vect	sequences, Ga theorem, Sha ls, Shannon's l tor channel, M	aussian innon' bounc lultiple
	theory.	· · · · · · · · · · · · · · · · · · ·					
3		Recommended prerequisites for participation Basic knowledge of probability theory					
4	Module exam • Module	<ul> <li>Form of examination</li> <li>Module exam:</li> <li>Module exam (Technical examination, Examination, Duration: 120 Min., Default RS)</li> </ul>					
5		for the award of canal module examination					
6	Grading Module exam • Module	: exam (Technical ex	xamination, Exam	ination, Weighting	: 100 %)		
7	Usability of t B.Sc. etit, B.S		it - CMEE, M.Sc. i	CE, B.Sc. und M.So	c. iST, B.Ed. etit, B.S	c. CE, M.Sc. C	E
8	Grade bonus	compliant to §25	(2)				
9	References         1. T.M. Cover and J.A. Thomas, Elements of Information Theory, Wiley & Sons, 1991.         2. R. W. Yeung, Information Theory and Network Coding, Springer, 2008.         3. Abbas El Gamal and Young-Han Kim, Network Information Theory, Cambrige, 2011.						
Соі	urses						
	<b>Course nr.</b> 18-kp-1010-v	Course name	heory I: Fundame	nts			
	Instructor		-		Туре		SWS

<b>Course nr.</b> 18-kp-1010-ue	<b>Course name</b> Information Theory I: Fundaments		
Instructor Prof. Dr. techn. H	Heinz Köppl, M.Sc. Anam Tahir	<b>Type</b> Practice	<b>SWS</b> 1

	<b>dule name</b> ormation Theor	y II: Networks					
Мо		Credit points 6 CP	Workload 180 h	Self-study 120 h	Module durat	ion Module cy Summer te	
Lar	<b>iguage</b> glish		l	Module owner Prof. DrIng. Mat	rius Pesavento		
1	outage and en regions of mu channel, relay MIMO multip paper coding,	ourse is devoted to godic capacity, ca ti-user channels, c channel, multiuse e-access and broad multi-user diversit	pacity of channels apacity regions of r bounds, graphic lcast channels, du	information theor with state, capaci multiple-access and al multi-hop netwo ality of MIMO mult el, secrecy rate and	ty of Gaussian d broadcast fad rks, routing, ne iple access and	vector channels, c ing channels, inter twork coding, cap broadcast channe	capacity rference pacity of
2	Learning obj Upon complet network infor	ion of the module,	students will have	an understanding o	of the advanced	concepts and strat	egies in
3		ed prerequisites for basic communication					
4	The examinat students regis	exam (Technical e ion takes place in f	form of a written e n will be an oral ex	written examinatio exam (duration: 12 camination (duratio	0 minutes). If a	pparent that less	than 10
5		f <b>or the award of c</b> al module examin					
6	Grading Module exam • Module		xamination, Oral/	written examinatio	n, Weighting: 1	00 %)	
7	<b>Usability of t</b> M.Sc. etit - Cl		TS, M.Sc. etit - VA	S, M.Sc. iCE, M.Sc.	WI-etit, B.Sc.	und M.Sc. iST, M.S	Sc. CE
8	Grade bonus	compliant to §25	(2)				
9	References						
	• T.M. Co	ver and J.A. Thoma	as, Elements of Inf	rk Information The ormation Theory, V Vireless Communic	Viley Sons, 1992	l.	s, 2005.
Co	ırses						
	<b>Course nr.</b> 18-pe-2010-v	Course name Information T	heory II: Network	S			1
	<b>Instructor</b> Prof. DrIng.	Marius Pesavento			<b>Typ</b> Lect		<b>SWS</b> 3

<b>Course nr.</b> 18-pe-2010-ue	<b>Course name</b> Information Theory II: Networks		
Instructor Prof. DrIng. Ma	rius Pesavento, M.Sc. Lukas Schynol	<b>Type</b> Practice	<b>SWS</b> 1

	<b>dule name</b> MO - Commur	nication and Space-Ti	ime-Coding			
Мо	<b>dule nr.</b> ja-2010	Credit points 4 CP	Workload 120 h	Self-study 75 h	Module duration 1 Term	Module cycle Winter term
Laı	nguage glish		120 11	Module owner Prof. DrIng. Vah	L	whiter term
1	nications. Outline: Mot models, MIN space-time b decoders, di diversity, BE	course introduces the tivation and backgrou IO information theory block code, orthogona ifferential space-time	ind; overview of sp y, receive and trans al space-time bloc e block coding; N	ce-time and multip pace-time and MIM smit diversity; chan k codes; linear disp MMO with limited	le-input multiple-out O communications; f nel estimation, MIMO persion codes; cohere feedback, Multianto	put (MIMO) commu- ading MIMO channel D detectors, Alamouti ent and non-coherent enna- and multiuser ulticell and multiuser
2	<b>Learning of</b> Students wil	<b>bjectives</b> ll understand moderr	n MIMO communi	ications and existin	ig space-time coding	techniques.
3		<b>ded prerequisites fo</b> of basic communication		sic information theo	ory.	
4	The examin less than 10	m: le exam (Technical ex ation takes place in	form of a written e examination w	n exam (duration: ill be an oral exam	120 minutes). If or	n., Default RS) ne can estimate that 0 min.). The type of
5		e for the award of cr final module examina				
6	Grading Module exar • Modul	m: le exam (Technical ex	amination, Oral/	written examinatio	n, Weighting: 100 %	5)
7	-	t <b>he module</b> KTS, M.Sc. etit - VAS,	, M.Sc. iCE, M.Sc.	MEC, M.Sc. WI-et	it, B.Sc. und M.Sc. is	ST
8	Grade bonu	is compliant to §25	(2)			
9	and So • E.G.La Press, • A.Pauli sity Pr • Lin Ba • Howar	ons, 2005. arsson and P.Stoica, S 2003; raj, R.Nabar, and D.G ress, 2003. i and Jinho Choi, Lov	pace-Time Block fore, Introduction w Complexity MIN	Coding for Wireless to Space-Time Wire MO detectors, Sprir	s Communications, C eless Communication 1ger, 2012.	mmunications, Wiley Cambridge University s, Cambridge Univer- unication for Cellular

<b>Course nr.</b> 18-ja-2010-vl	Course name MIMO - Communication and Space-Time-Coding		
<b>Instructor</b>	hid Kooshkghazi	<b>Type</b>	<b>SWS</b>
Prof. DrIng. Va		Lecture	2
<b>Course nr.</b> 18-ja-2010-ue	<b>Course name</b> MIMO - Communication and Space-Time-Coding		
<b>Instructor</b>	hid Kooshkghazi	<b>Type</b>	<b>SWS</b>
Prof. DrIng. Va		Practice	1

	<b>dule nr.</b> pe-2060	Credit points 4 CP	Workload 120 h	Self-study 75 h	Module duration 1 Term	Module cycle Summer term
	<b>nguage</b> glish			<b>Module owner</b> Prof. DrIng. Ma	rius Pesavento	
1	Outline: Mo Direction-of traditional r based meth mum Likeli processing, backward a sensing and Adaptive be Point-sourc (MVDR) be beamformin based beam	ontent e course introduces the otivation and backgrou f-arrival estimation (D nethods based on beau ods, MUSIC, ESPRIT, hood methods, Expect array interpolation, p averaging, redundance l sparse reconstruction e model, covariance amformer, Capon Bea ang, Hung-Turner proj former, non-stationar forming, multiuser be	und; applications, <u>boA):</u> mforming, super r MODE, root-MUS station Maximizat artly calibrated ar y averaging, corr n based DoA estim model, Wiener-H unformer, sample ection beamformer y environments, m	narrowband and esolution methods, IC, multidimensior ion (EM) algorithm rays, wideband DC elated sources, m nation, performance topf equation, Min matrix inversion, er, Generalized Sid	wideband signal mod Maximum-Likelihoo nal source localization m, partial relaxation OA estimation, spatial inimum redundancy e bounds himum Variance Dist signal self-nulling ef lelobe canceller bean	el d methods, Subspac n, approximate Max method, beamspac smoothing, forward arrays, compresse cortionless Respons fect, robust adaptiv nformer, Eigenspace
2	Learning o Upon comp			earned the applicat	ion of theory and algo	rithms for processin
3	Recommen	in linear algebra.	r participation			
4	The examination 10 The examination 10 The examination of the second seco		form of a writter e examination wi	exam (duration: ll be an oral exam	120 minutes). If or	ne can estimate tha
5	Prerequisit	e for the award of cr final module examination	redit points			
6	<b>Grading</b> Module exa • Modu	m: le exam (Technical ex	amination, Oral/	written examinatio	on, Weighting: 100 %	)
7		<b>f the module</b> it, M.Sc. etit - KTS, M.	Sc. etit - SAE, M.S	c. etit - VAS, M.Sc.	iCE, M.Sc. MEC, M.S	Sc. WI-etit, B.Sc. un
	Grade bon					

- 1. Academic Press Library in Signal Processing: Volume 3 Array and Statistical Signal Processing Edited by Rama Chellappa and Sergios Theodoridis, Section 2, Edited by Mats Viberg, Pages 457-967 (2014) a) Chapter 12 - Adaptive and Robust Beamforming, Sergiy A. Vorobyov, Pages 503-552
  - b) Chapter 14 DOA Estimation Methods and Algorithms, Pei-Jung Chung, Mats Viberg, Jia Yu, Pages
  - 599-650 c) Chapter 15 - Subspace Methods and Exploitation of Special Array Structures, Martin Haardt, Marius
  - Pesavento, Florian Roemer, Mohammed Nabil El Korso, Pages 651-717
- 2. Spectral Analysis of Signals, Petre Stoica, Randolph Moses, Prentice Hall, April 2005Optimum Array Processing: Part IV of Detection, Estimation, and Modulation Theory, Harry L. Van Trees, Wiley Online, 2002.

## C 11700

Course nr.	Course name		
18-pe-2060-vl	Sensor Array Processing and Adaptive Beamforming	1	
Instructor		Туре	SWS
Prof. DrIng. Ma	rius Pesavento	Lecture	2
Course nr.	Course name		
18-pe-2060-ue	Sensor Array Processing and Adaptive Beamforming		
Instructor	·	Туре	SWS
Prof. DrIng. Ma	rius Pesavento, M.Sc. Raphael Müller	Practice	1

The course covers the following topics:         • Motivation, Applications         • Fundamentals         • Adjecency matrix, Graph Laplacian, Graph shift operator         • Covariance matrix, conditional dependence, precision matrix         • Graph signal processing         • Consensus, Diffusion         • Graph spectral analysis, Graph Fourier Transform         • Total variational norm, Graph Frequencies         • Bandlimited graph signals, smoothness         • Graph filters, Graph sampling theorem         • Applications         • Network topology inference         • Link prediction         • Association network inference         • Pearson product-moment correlation         • Conditional independence graph         • Graph filters, Graph and/moment correlation         • Causality, Partial correlation         • Causality, Partial correlation         • Conditional independence graph         • Graphical LASSO, Graphical LASSO with Laplacian constraint         • Applications         • Subgraph identification         • Cliques identification         • Cliques identification         • Cliques identification         • Cliques identification         • Average consensus, diffusion, exact diffusion         • Graph neuronal (convolutional) network <th></th> <th>o<b>dule nr.</b> -pe-2080</th> <th>Credit points 6 CP</th> <th>Workload 180 h</th> <th>Self-study 120 h</th> <th>Module duration 1 Term</th> <th><b>Module cycle</b> Winter term</th>		o <b>dule nr.</b> -pe-2080	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	<b>Module cycle</b> Winter term
The course covers the following topics:         • Motivation, Applications         • Fundamentals         - definition of graphs, classes of graphs, properties of graphs, signals defined over graphs         - Adjecency matrix, Graph Laplacian, Graph shift operator         - Covariance matrix, conditional dependence, precision matrix         • Graph signal processing         - Consensus, Diffusion         - Graph spectral analysis, Graph Fourier Transform         - Total variational norm, Graph Frequencies         - Bandlimited graph signals, smoothness         - Graph filters, Graph sampling theorem         - Applications         • Network topology inference         - Tomographic network inference         - Pearson product-moment correlation         - Causality, Partial correlation         - Gaussian Markov Random Fields         - Graphical LASSO, Graphical LASSO with Laplacian constraint         - Applications         • Subgraph identification         - Cliques identification         • Craph neuronal (convolutional) network         • Applications         • Average consensus, diffusion, exact diffusion         - Graph analysis         • Subgraph identification         • Cliques identification         • Optimization over graphs         • Aver						rius Pesavento	
<ul> <li>Graph signal processing (i.e., the processing of signals defined over graphs) and network analysis form interdisciplinary research field with numerous and diverse applications. Upon completion of the module, studen will have gained systematic knowledge in graph signal processing theory, graph network analysis, graph topolo learning, optimization in graph networks, and learning using graph neural networks. They have learned essent concepts, algorithms and application areas of graph signal processing.</li> <li><b>Recommended prerequisites for participation</b></li> </ul>	1	The course • Motiv • Funda - 0 - 2 - 0 • Graph - 0 - 0 - 0 - 0 - 0 - 0 - 0 - 0	covers the following t ation, Applications amentals definition of graphs, c Adjecency matrix, Gra Covariance matrix, con a signal processing Consensus, Diffusion Graph spectral analysi Total variational norm Bandlimited graph sig Graph filters, Graph sa Applications ork topology inference Link prediction Association network in Comographic network in Comographic network in Conditional independe Gaussian Markov Rand Graphical LASSO, Grap Applications a analysis Subgraph identification Dization over graphs Average consensus, di Gradient tracking, pus Applications a neuronal (convolution	lasses of graphs, p ph Laplacian, Gra nditional depende s, Graph Fourier T a, Graph Frequenc nals, smoothness ampling theorem e nference topology inference ent correlation elation ence graph dom Fields phical LASSO with n	uph shift operator ence, precision mat Fransform ies the Laplacian constra	rix	r graphs
3 Recommended prerequisites for participation	2	Graph sign interdiscipl will have ga learning, op	al processing (i.e., th inary research field with ined systematic knowl otimization in graph ne	th numerous and c ledge in graph sigr etworks, and learn	liverse applications nal processing theo ing using graph net	. Upon completion of ry, graph network ana ural networks. They h	the module, studer lysis, graph topolo
	3	Recommer	ded prerequisites fo	r participation			

4 Form of examination

	In general, the ex register in semes	am (Technical examination, Oral/written examination, Duratio camination takes place in form of a written exam (duration: 12 ters in which the lecture does not take place, there will will be be of examination will be announced within one working weeks e.	0 minutes). If up to 20 an oral examination (	) students (duration:
5		<b>the award of credit points</b> module examination		
6	Grading Module exam: • Module exa	am (Technical examination, Oral/written examination, Weight	ing: 100 %)	
7	Usability of the M.Sc. etit - CME iST, M.Sc. CE	<b>module</b> E, M.Sc. etit - KTS, M.Sc. etit - VAS, M.Sc. iCE, M.Sc. MedTec,	, M.Sc. WI-etit, B.Sc. 1	und M.Sc.
8	Grade bonus co	mpliant to §25 (2)		
9	– www. – moodl • Further rea – Petar		cessing, Academic Pre	ess, 2018,
Co	urses			
	<b>Course nr.</b> 18-pe-2080-vl	<b>Course name</b> Graph signal processing, learning and optimization		
	<b>Instructor</b> Prof. DrIng. Ma	rius Pesavento	<b>Type</b> Lecture	<b>SWS</b> 3
	<b>Course nr.</b> 18-pe-2080-ue	<b>Course name</b> Graph signal processing, learning and optimization		
	Instructor Prof. DrIng. Mar Schynol	ius Pesavento, M.Sc. Yufan Fan, M.Sc. Tianyi Liu, M.Sc. Lukas	<b>Type</b> Practice	SWS 1

	<b>dule name</b> ahertz System	ns and Applications				
Mo	<b>dule nr.</b> pr-2010	Credit points 4 CP	Workload 120 h	Self-study 75 h	Module duration	Module cycle Summer term
Lan	nguage glish	4 CP	120 11	Module owner Prof. Dr. rer. nat.		Summer term
1	Teaching co The lecture and semicor in detail for photomixer discussed de	ontent will give an overview aductor-based devices two types of highly s (photo-diode based evices will be derived will be used for a la	s and Terahertz sy important device l and photocondu for experimental	stems. Terahertz d s: Schottky diodes ctive). The exercis ly relevant cases, w	etection and generat (mixers, multi-plier e, where performane vill help to deepen th	ion will be discussed s and rectifiers) and ce parameters of the e understanding.
2	systems, and • A gene • Workin • Workin	•	radiation, with d he state of the art and limits of cont	eepened knowledge in Terahertz techn inuous-wave photo	e in: ology mixer systems	generation, detection, ge
3	Bachelor in	<b>ded prerequisites fo</b> Electrical engineering sic knowledge in sem	g, Physics, or Mat		l	
4	The examina 20 students		rm of a written ex tion will be an ora	am (duration: 90 m	ninutes). If one can es	stimate that less than
5		e for the award of c ile final exam	redit points			
6	Grading Module exame • Module	m: e exam (Technical ex	amination, Oral/	written examinatio	n, Weighting: 100 %	))
7	•	<sup>e</sup> <b>the module</b> KTS, M.Sc. iCE, M.Sc	. WI-etit, M.Sc. C	E		
8	Grade bonu	is compliant to §25	(2)			
9 Cot	• G. Car	nik Lee, "Principles of pintero et al., "Semic tion," Wiley 2015, IS	conductor Terahe	rtz Technology: De		1 978-0-387-09540-0 t Room Temperature

<b>Course nr.</b> 18-pr-2010-vl	<b>Course name</b> Terahertz Systems and Applications		
Instructor	. Sascha Preu	<b>Type</b>	<b>SWS</b>
Prof. Dr. rer. nat		Lecture	2
<b>Course nr.</b> 18-pr-2010-ue	<b>Course name</b> Terahertz Systems and Applications		
Instructor	. Sascha Preu	<b>Type</b>	<b>SWS</b>
Prof. Dr. rer. nat		Practice	1

	<b>dule name</b> optive Filters					
	<b>dule nr.</b> zo-2010	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Summer term
Lar	iguage			Module owner Prof. DrIng. Abd		
1 Ger	man/English Teaching co	ontent		PIOL DL-IIIg. ADC		
	Theory:					
		tion of optimal filters e cost functions.	s for stochastic pro	ocesses, e.g. Wiene	r filter or linear pred	iction filter based on
	2. Elabor	ation of adaptive pr				nal solution for non-
	affine	projection, and the R	LS algorithm are	derived and extens	ively analysed.	as NLMS adaptation,
	proced	lure.		-	of adaptive filters	
					non-stationary input r the realization of c	t signals. Optimal filters in the
	freque Application	ncy domain, e.g. noi <b>s:</b>	se reduction proce	edures.		
					ple for the Weiner filt edback cancellation a	er, the acoustic noise regiven as examples
		filters. Furthermore				
		to offer an excursion				llows the students to
		with practical realiza			I III WAILAD WIIICH a	nows the students to
2		letion of the module				ters. The necessary
					h, audio and video p practical application	processing. Based on us.
					ain of adaptive filters ific literature, familia	chosen by you. This rize yourself with an
		pic and present your				in your professional
3		ded prerequisites fo	or participation			
4	Form of exa	mination				
		e exam (Technical ex			n, Duration: 90 Min.	
		1		-	-	timate that less than type of examination
_	will be anno	unced in the beginni	ng of the lecture.			
5		e for the award of c				
6	<b>Grading</b> Module exar	n:				
			kamination, Oral/	written examinatio	n, Weighting: 100 %	)
7	Usability of	the module				

	M.Sc. etit - KTS,	M.Sc. etit - VAS, M.Sc. iCE, M.Sc. WI-etit, B.Sc. und M.Sc. iST, N		
8	Grade bonus co	mpliant to §25 (2)		
9	References			
	Slides of the lect	ure.		
	Literature:			
	<ul> <li>E. Hänsler,</li> </ul>	G. Schmidt: Acoustic Echo and Noise Control, Wiley, 2004 (Text	tbook of this course)	;
	•	Adaptive Filter Theory, Prentice Hall, 2002;		
	<ul> <li>A. Sayed: I</li> </ul>	Fundamentals of Adaptive Filtering, Wiley, 2004;		
		unaumonitaio of fraup in o fraidening, fraid, j		
	• P. Vary, U.	Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 199	98 (in German)	
	• P. Vary, U.	1 0, 1,	98 (in German)	
Cou	• P. Vary, U.	1 0, 1,	98 (in German)	
Cou		1 0, 1,	98 (in German)	
Cou	ırses	Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 199	98 (in German)	
Cou	ırses Course nr.	Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 199 Course name Adaptive Filters	98 (in German)	SWS
Cou	irses Course nr. 18-zo-2010-vl	Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 199 Course name Adaptive Filters		SWS 3
Cou	irses Course nr. 18-zo-2010-vl Instructor	Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 199 Course name Adaptive Filters	Туре	
Cou	Irses Course nr. 18-zo-2010-vl Instructor Prof. DrIng. He	Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 199 Course name Adaptive Filters nning Puder I	Туре	
Cou	Irses Course nr. 18-zo-2010-vl Instructor Prof. DrIng. He Course nr.	Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 199          Course name         Adaptive Filters         nning Puder         Course name         Adaptive Filters	Туре	

	ech and Audi dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle			
	18-zo-20706 CP180 h120 h1 TermWinter term								
	<b>nguage</b> rman			Module owner Prof. DrIng. Abo	lelhak Zoubir				
1	and basic m Beamformin frequency e recognition.	of speech and audio nethods of audio sign ag for spatial filtering stimation. Mel-filter . Classification metho len markov models).	al processing. Pr and noise reduct ind cepstral coeff ods based on GM	cocedures of codeb ion for spectral filte ficients (MFCCs) as M (Gaussian mixtu	oook based processin ering. Cepstral filteri s basis for speaker d ure models) and spee	g and audio coding ng and fundamenta etection and speech ech recognition with			
2	Based on th help of the a processing, such as they (MMI). The and audio p familiarize v	<b>Learning objectives</b> Based on the module you acquire an advanced knowledge of digital audio signal processing mainly with the nelp of the analysis of speech signals. You learn about different basic and advanced methods of audio signal processing, to range from the theory to practical applications. You will acquire knowledge about algorithms such as they are applied in mobile telephones, hearing aids, hands-free telephones, and man-machine-interfaces MMI). The exercise will be organized as a talk given by each student with one self-selected topic of speech and audio processing. This will allow you to acquire the know-how to read and understand scientific literature, familiarize with an unknown topic and present your knowledge, such as it will be certainly required from you in your professional life as an engineer.							
3	Knowlegde	<b>ded prerequisites fo</b> about satistical signal ndatory - is knowled	processing (lectu		Processing"). Desired	l			
4	Seminar pre	m: le exam (Technical ex esentation: Scientific )-15 min) or in group	talk about a topic	in the field of "Spe	eech and Audio Signa	al Processing", single			
5	-	e for the award of cr final module examina	-						
6	Grading Module exa • Modul	m: le exam (Technical ex	amination, Oral/	written examinatio	n, Weighting: 100 %	)			
	<b>Usability of the module</b> M.Sc. etit - KTS, M.Sc. etit - SAE, M.Sc. iCE, M.Sc. MedTec, M.Sc. WI-etit, B.Sc. und M.Sc. iST, M.Sc. CE								
7	M.Sc. etit - 1		, M.Sc. iCE, M.Sc.	MedTec, M.Sc. W	I-etit, B.Sc. und M.So	e. iST, M.Sc. CE			
7 8				. MedTec, M.Sc. W	I-etit, B.Sc. und M.So	e. iST, M.Sc. CE			

<b>Course nr.</b> 18-zo-2070-vl	<b>Course name</b> Speech and Audio Signal Processing		
Instructor	Ienning Puder	<b>Type</b>	SWS
Prof. DrIng.		Lecture	2
<b>Course nr.</b> 18-zo-2070-ue	<b>Course name</b> Speech and Audio Signal Processing		
<b>Instructor</b>	Ienning Puder	<b>Type</b>	<b>SWS</b>
Prof. DrIng.		Practice	1
<b>Course nr.</b> 18-zo-2070-se	<b>Course name</b> Sprach- und Audiosignalverareitung		
<b>Instructor</b>	Jenning Puder	<b>Type</b>	<b>SWS</b>
Prof. DrIng.		Seminar	1

	dule name							
Sof	tware Defined	Networking		1			1	
	dule nr.	Credit points	Workload	Self-study	Module d	luration	Module cy	
	sm-2280	6 CP	180 h	120 h	1 Term		Winter tern	n
	LanguageModule ownerGerman/EnglishProf. DrIng. Ralf Steinmetz							
1	<ul> <li>The course deals with topics in the area of software defined networking:</li> <li>SDN Data Plane</li> <li>SDN Control Plane</li> <li>SDN Application Plane</li> <li>Network Function Virtualization</li> <li>Network Virtualization and Slicing</li> <li>QoS and QoE in Software Defined Networks</li> </ul>							
2		<b>jectives</b> etion of the module, sic technologies and		gained in-depth in	sights into	Software	Defined Netw	vorking,
3		<b>led prerequisites fo</b> s of the first 4 semes ed.		Knowledge of lectu	res Commı	inication N	Vetworks I an	d II are
4	The examina 15 students		orm of a written ex tion will be an ora	am (duration: 90 n	ninutes). If	one can es	stimate that le	ess than
5		e <b>for the award of c</b> inal module examin						
6	Grading Module exar • Module	n: e exam (Technical e:	xamination, Oral/	written examinatio	n, Weightii	ng: 100 %	)	
7	<b>Usability of</b> M.Sc. etit - I	<b>the module</b> DT, M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	ł M.Sc. iST				
8	Grade bonu	s compliant to §25	(2)					
9	<b>References</b> Textbooks as Slides and p	indicated. aper copies as neces	sary.					
Coι	ırses							
	<b>Course nr.</b> 18-sm-2280-	vl Software Defin	ned Networking					
	<b>Instructor</b> DrIng. Ralf	Kundel, M.Ed. Benj	amin Becker, M.So	. Chengbo Zhou		<b>Type</b> Lecture		<b>SWS</b> 2

<b>Course nr.</b> 18-sm-2280-ue	<b>Course name</b> Software Defined Networking		
Instructor	del, M.Ed. Benjamin Becker, M.Sc. Chengbo Zhou	<b>Type</b>	SWS
DrIng. Ralf Kur		Practice	2

	<b>dule name</b> work, Traffic	and Quality Manage	ment for Internet	Services		
	<b>dule nr.</b> 00-0056	Credit points 3 CP	Workload 90 h	Self-study 60 h	Module duration 1 Term	Module cycle Every 2. Semester
Lar	Language     Module owner       English     Prof. Dr. rer. nat. Eberhard Mühlhäuser					
1		ontent 1 into management of uality and traffic prof		provider (ISP-)netv	works for integrating	IP service platforms
2	<ul> <li>criteri</li> <li>QoS A</li> <li>QoS si social</li> <li>Quality Assi</li> <li>Netwo with p</li> <li>measu</li> <li>Quality assi</li> <li>Content</li> <li>transp</li> </ul>	tent: its and measures to en- a from the application rchitecture in IP Network apport & impact per a networking etc.) arance for Internet Seo ork and Transport Lay protection against error arement, monitoring, arance in service over	n & user perspection works: Differentian application in IP to ervices in ISP Network rer Impact: Routinn ors and failures. optimization of IH lays and at applic s (CDN), Clouds n, scalability	we (QoE: Quality o ted & Integrated S raffic mix (video str work Infrastructure g (OSPF, BGP), Mu P traffic regarding ( ation level and Peer-to-Peer N	ervices reaming, VoIP, web b s iltiprotocol Label Sw QoS Networks (P2P) incl.	prowsing, downloads, itching (MPLS), TCP . distributed caches,
3	Recommend Prerequisite		in computer scie	nce and Internet a	pplications is requir	red. The courses on
4	The form of two of the fo Written exa	ed exam: )-0056-vl] (Technical the examination will ollowing forms is pos	l be announced at sible.	the beginning of t	he course. One or a	combination of max. ninutes), homework
5	-	e for the award of c	redit points			
6	Grading Course relat		examination, Ora	al/written examina	tion, Weighting: 100	9%)
7	B.Sc. Inform M.Sc. Inform	natik				
8	-	in other degree prog is compliant to §25				
1	I					

9	References	laatura						
Con	Will be given in lecture.							
CO	urses	1						
	Course nr.	Course name						
	20-00-0056-vl	Network, traffic and quality management for Internet service	es					
	Instructor	·	Туре	SWS				
			Lecture	2				

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle			
	00-0512	6 CP	180 h		120 h   1 Term Every 2. Semeste				
	<b>nguage</b> glish			<b>Module owner</b> DrIng. Michael	Kreutzer				
1	network sec and cryptog the applicat	ted course Network S urity with particular e raphy to the networki ton layer, the course pr ll known mechanisms,	mphasis on Intern ng domain, we fo rovides a detailed	net security. After tr llow a top-down ap discussion of netwo	ansferring the fundar oproach to network se ork security principles	nentals of IT securit ecurity. Starting wit and protocols. In a			
	<ul> <li>Fundamer security thr</li> <li>Cryptograp crypto and i</li> <li>Application</li> <li>Transport i</li> <li>Network la</li> <li>Link layer</li> <li>Physical lat</li> <li>Operational</li> </ul>	ecurity: introduction, itals: a reference mo eats, attacks, services phic foundations for its use in networks, su a layer security layer security security yer security and phys al network security: fi opics in network securi	del for network s , and mechanisms networking secur ipport functions t ical security rewalls, intrusion	security, security s rity: symmetric cr o implement netwo	ypto and its use in r ork security				
2	cation netw important f are able to o thorough un layer, netwo and princip field. Addin peer-to-peer	bjectives sfully attending the co ork security with em undamentals from IT listinguish the most in nderstanding of secur rk layer, link layer, ph les in the area of netw ionally, students are security, mobile netw , which consist of liter	phasis on Interne security and cryp nportant basic tec ity mechanisms of ysical layer). As a vork security and able to describe york security, etc.)	t security. Student tography to the fie chniques for securi- on the different ne result, they are ab exhibit detailed th recent developme . The exercise deep	es are able to apply a eld of communication ng communication ne twork layers (applica- le to thoroughly discu- neoretical and practic nts in the area of ne pens the theoretical for	nd transfer the most networks. Student tworks. They have tion layer, transpor- ss the characteristic al knowledge in this etwork security (e., pundations by mean			
3		<b>ded prerequisites fo</b> in the area IT Securit		Cryptography and	Communication Net	works			
4	Form of exa Course relat	amination							
5	Prerequisit Pass exam (	e for the award of cr 100%)	edit points						
6	Grading Course relat		overningtion Or	l/witton overning	tion, Weighting: 100				

	B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik					
-		ther degree programs.				
8	In dieser Vorlesu	<b>mpliant to §25 (2)</b> ng findet eine Anrechnung von vorlesungsbegleitenden Leistu Ind den vom FB 20 am 30.3.2017 beschlossenen Anrechnungsreg Iren kann.	•			
9		, Radia Perlman, Mike Speciner: Network Security - Private Co htice Hall, 2002, ISBN: 978-0-14-046019-6; additional texts m		c World,		
Cot	urses					
	<b>Course nr.</b> 20-00-0512-iv	Course name Network Security				
	Instructor     Type       DrIng. Michael Kreutzer     Integrated course			SWS 4		

					Module cycle Every 2. Semester	
	<b>nguage</b> rman			<b>Module owner</b> DrIng. Michael	Kreutzer	
1	communicat underlying discussed. A exercises as deepen the Course conto - Properties - Fundament - Physical lay alignment, k - Practical as - Practical in	er security technique tion. This integrated theory is introduced ttacks against (practi well as the presenta understanding of the ents: of the physical layer tals of information the rer security technique agy extraction) spects of physical layer	d course discusse l and the applica cal) physical layer ation of selected re- subject matter. eoretic security an s (such as coopera er security techniq ysical layer securi	tion of these funct security technique ecent research res nd delineation from tive jamming, orth ues ty techniques using	ecurity on the physical practice of physical damentals towards p es are presented. The ults by seminar talks n cryptography ogonal blinding, zero g software-defined ra	layer security. The practical solutions is oretical and practica s of students furthe -forcing, interference
2	knowledge i theoretic ba practical phy practical rea	sfully attending the in the area of physic sics as well as theory ysical layer security t alization of physical fre the current state of	al layer security. and practice of p echniques and de layer security tec	They are able to d physical layer secu scribe their weakn hniques using soft	tical knowledge and lescribe the most im rity techniques. The esses. Students have ware-defined radios y and present the aqu	portant information are able to analyzed competencies in the . They can indeper
3	Recommen	<b>ded prerequisites fo</b> le Networking	r participation			
4	Form of exa Course relat	mination	examination, Ora	ıl/written examina	tion, Default RS)	
5	Prerequisite Pass exam (	e for the award of c 100%)	redit points			
6	Grading Course relat			17	tion, Weighting: 100	

	B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaft								
		B.Sc. Psychologie in IT							
	Joint B.A. Inform	atik							
	B.Sc. Sportwisse	ischaft und Informatik							
	Can be used in o	her degree programs.							
8	In dieser Vorlesu Novelle der APB ı	<b>Grade bonus compliant to §25 (2)</b> In dieser Vorlesung findet eine Anrechnung von vorlesungsbegleitenden Leistungen statt, die lt. 25 (2) der 5. Novelle der APB und den vom FB 20 am 30.3.2017 beschlossenen Anrechnungsregeln zu einer Notenverbesserung um bis zu 1.0 führen kann.							
9	References Selected literatur	e, will be given in lecture.							
Co	urses								
	<b>Course nr.</b> 20-00-0745-iv	<b>Course name</b> Physical Layer Security in Wireless Systems							
	Instructor DrIng. Michael	Kreutzer	<b>Type</b> Integrated course	<b>SWS</b> 3					

20.	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
La	00-0748 nguage glish	6 CP	180 h	120 h Module owner Prof. DrIng. The	1 Term	Winter term
1	The integra solutions ar communicat problems an will be deep Course cont - Introductio - Overview multiplexing - Medium ac PRMA, MAC - Wireless lo quality of se - Wireless m operation, m - Mobility at - Ad hoc ne routing para - Performan common mi	munications and wire ted course addresses e presented. Hereby tion systems. In addit ad learn about methoo ended by exercises.	s the characterist y our focus is on tion to describing dologies to approa eless communication ssion: frequencient spectrum, cellula vireless domain: e, polling) EEE 802.11 standa tagement tworks: Wireless to agement tworks: Wireless to agement to support m y, basics and application bile networks: Ovoid them, experim	tics/principles of r the network layer the state of the art ach such problems ons: Applications, l es & regulations, ar systems SDMA, FDMA, CD ard including phys mesh networks, IE ce and scheduling hobility on various lications, character verview of perform nental design and a	nobile networks in o , which is often rega in technology we dis systematically. The construction history, market vision signals, antennas, MA TDMA (fixed, A ical layer, MAC layer EEE 802.16 standard layers, Mobile IP distics of ad hoc com nance evaluation, sy analysis	detail, and practic arded as the glue scuss actual researce ontents of the cour signal propagatic loha, CSMA, DAM and access scheme including modes numunication, ad he stematic approach
2	Learning of After succes munication communication layers, with connections cal analysis and basic p the integrat calculation at	sfully attending the networks. They have tion and have a thore a focus on ad hoc and between the different of real communication rinciples of wireless red course deepen th as well as practical im	course, students is e gained insight ir ough understandi d mesh networks. t protocol layers ar on systems. The st and mobile com e theoretical four plementation/ap	have an in-deep kn nto media access co ing of mechanisms Moreover, the studend nd are able to apply tudents are therefor munications in the ndations by means	nowledge on the wor ontrol mechanisms of based on the netwo dents have acquired l w the acquired knowle ore be conversant wit cory and practice. T of exercises, which	rking of mobile con ledicated to wirele rk and the transpo knowledge about the edge on methodolo ch the characteristi The exercise-parts
3	Basic course	<b>ded prerequisites fo</b> es in Communication		ommended.		
1	Form of exa Course relat • [20-00		examination, Ora	al/written examina	tion, Default RS)	
5	Prerequisit	e for the award of cr	redit points			

	Course related ex • [20-00-074	kam: 8-iv] (Technical examination, Oral/written examination, Weig	;hting: 100 %)				
7	7 Usability of the module						
	B.Sc. Informatik						
	M.Sc. Informatik						
	M.Sc. Wirtschaft						
	B.Sc. Psychologie						
	Joint B.A. Inform						
		nschaft und Informatik					
	M.Sc. Sportwisse	enschaft und Informatik					
	Can be used in o	ther degree programs.					
8	In dieser Vorlesu	<b>mpliant to §25 (2)</b> ng findet eine Anrechnung von vorlesungsbegleitenden Leistu und den vom FB 20 am 30.3.2017 beschlossenen Anrechnungsreg nren kann.					
9	<b>References</b> Selected literatur	e, details are given in lecture.					
Co	urses						
	<b>Course nr.</b> 20-00-0748-iv	Course name Mobile Networking					
	Instructor Prof. DrIng. The	orsten Strufe	<b>Type</b> Integrated course	SWS 4			

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle		
20-00-0780 6 CP 180				135 h	1 Term	Every 2. Semester		
	<b>nguage</b> rman			Module owner Prof. Dr. rer. nat.	Eberhard Mühlhäus	er		
1	Teaching content The communication capabilities among the population is of utmost importance to respond to crises. This course will discuss how to build wireless communication systems from scratch, i.e. under the assumption that no communication infrastructure is left intact as a result of the crisis. The course introduces the theoretical basis from the fields of amateur radio as well as communication systems. It deepens these fields with the knowledge to design and build communication networks for times of crisis. The discussed technologies will span from local to global wireless communications without need of further infrastructure. Theoretical exercises as well as experimentation, the design and building of electrical circuits and the analysis of wireless technology under laboratory conditions deepen the understanding of the subject. Course contents: - Signals, signal propagation, antennas, basics of electrical engineering - Modulation schemes in analog and digital systems (OFDM, ATV/SSTV, Packet Radio, SSB,) - System aspects for communication in times of crisis							
2	and infrast and electro and practic	bjectives ssfully attending the co ructureless communic technical basics of wir e. They are able to bui npetences in the area	ation for emergen reless communicat Id a wireless comm	ncy response. They tions and know win munication system	understand the mos reless transmission m from scratch and ope	t important physica lechanisms in theory		
3	Recommen	nded prerequisites fo	r participation					
4	Form of ex Course rela • [20-0		examination, Ora	al/written examina	tion, Default RS)			
5	Prerequisi Pass exam	te for the award of cr (100%)	redit points					
6	Grading Course rela • [20-0	ited exam: 0-0780-iv] (Technical	examination, Ora	al/written examina	tion, Weighting: 100	%)		
7	B.Sc. Inform M.Sc. Inform M.Sc. Wirts B.Sc. Psych Joint B.A. I	matik schaftsinformatik .ologie in IT	rmatik					
	Can be used in other degree programs.							
	Call De use	a in other degree prog	grams.					

	In dieser Vorlesung findet eine Anrechnung von vorlesungsbegleitenden Leistungen statt, die lt. 25 (2) der 5. Novelle der APB und den vom FB 20 am 30.3.2017 beschlossenen Anrechnungsregeln zu einer Notenverbesserung um bis zu 1.0 führen kann.						
9	References Selected and giv	References Selected and given in lecture.					
Co	urses						
	<b>Course nr.</b> 20-00-0780-iv	Course name Wireless Network for Emergency Response: Fundamentals, Scratch	Design, and Build-up fr	rom			
	Instructor Prof. Dr. rer. nat	. Eberhard Mühlhäuser	<b>Type</b> Integrated course	SWS 3			

00	odule nr. 00-0120	Credit points 6 CP	<b>Workload</b> 180 h	Self-study	Module duration	Module cycle		
Language			Module owner					
Gei 1	man Prof. Dr. rer. nat. Eberhard Mühlhäuser Teaching content Objectives:							
2	<ul> <li>Knowledge</li> <li>Methodic k</li> <li>Course Cont</li> <li>Introductio</li> <li>Mobile Cor</li> <li>Internet of</li> <li>Service Dis</li> <li>Context- ar</li> <li>Human Co</li> <li>Privacy and</li> <li>Learning ol</li> <li>After success</li> </ul>	n to Ubiquitous Com nmunication Things: RFID and Sr covery & Cloudlets nd Location-aware Co mputer Interaction l Trust in Ubiquitous <b>ojectives</b> sfully attending the c	eges of the Ubiquir ent approaches to puting nart Items omputing Computing	tous Computing these challenges	technical basis of mo			
3	these challes	nges. They are able to ded prerequisites fo	o apply their know or participation		g. They know current quitous computing sy			
4	Form of exa Course relat			al/written examina	tion, Default RS)			
5	-	e for the award of c 100%)	redit points					
	Pass exam (100%)         Grading         Course related exam:         • [20-00-0120-iv] (Technical examination, Oral/written examination, Weighting: 100 %)							
6	• [20-00				, , ,	%)		
6	Usability of B.Sc. Inform M.Sc. Inform M.Sc. Wirts B.Sc. Psycho Joint B.A. In B.Sc. Sporty	natik chaftsinformatik ologie in IT				%)		

9	Novelle der APB und den vom FB 20 am 30.3.2017 beschlossenen Anrechnungsregeln zu einer Notenverbesserung um bis zu 1.0 führen kann.         References         Literature recommendations will be updated regularly, an example might be:         A Primary Literature:							
		Handbook of Research: Ubiquitous Computing Technology for Real Time Enterprises edited by Prof. Dr. Max Mühlhäuser, Dr. Iryna Gurevych, 2008, Information Science Reference, ISBN-10: 1599048329						
	B Secondary Literature:							
	<ol> <li>Stefan Poslad</li> <li>Kapitel Mobil</li> </ol>	. Gupta et al.: Fundamentals of Mobile & Pervasive Comput Ubiquitous Computing, Wiley 2009, ISBN 978-0-470-0356 communikation: M. Sauter: Grundkurs Mobile Kommunika und Wireless LAN; Vieweg-Teubner Studium 2010	0-3	DPA unc				
	4. J. Krumm (Ed	.): Ubiquitous Computing Fundamentals, CRC Press 2010 [Ed.): Smart Environments, Wiley 2005						
Со	4. J. Krumm (Ed							
Со	4. J. Krumm (Ed D. Cook, S. Das (							

10	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle	
	-jk-2020	6 CP	180 h	120 h	1 Term	Winter term	
	<b>nguage</b> glish			Module owner Prof. DrIng. Roli	f Jakoby		
1	<b>Teaching content</b> Overview of most important antenna parameters types as well as their applications. Fundamental theories: Fourier transform for far-field pattern calculations, antenna modeling techniques, antenna synthesis methods, image theory, determination of field regions of line sources, of the average radiated power density and power, directivity and gain. Antennas as key elements in power budgets of radio links, introducing the effective aperture of an antenna, deriving the relation between gain and effective aperture. Array antennas are a key hardware for beamforming and smart antenna systems: fundamentals of phased-scanning arrays, non-uniformly excited, equally spaced linear arrays, multi-dimensional planar arrays and mutual coupling effects. Wire antennas: still the most prevalent of all antenna forms, relatively simple in concept, easy to construct, very inexpensive. Antenna radiation fields and antenna parameters for different types of antennas are derived from Maxwell 's equations, applied for aperture antennas (horns, lenses or reflector antennas) and printed antennas (microstrip-patch and coplanar-slot antennas) Some basic numerical calculation methods: integral equation methods in the time and frequency domain, physical optics and uniform theory of diffraction are briefly summarized and compared for antennas and scattering problems. Smart antennas in communication and radar systems, with focus on beam						
2	<ul> <li>steering and adaptive beamforming.</li> <li>Learning objectives</li> <li>Students will know basic antenna parameters: pattern, gain, directivity, half-power beamwidth, side- lobe-level, efficiency and input impedance to compare, assess and evaluate different antennas for various applications and operating frequencies. The antenna field regions, reactive near-field, near-field and far-field, can be differentiated and the far-field pattern of an antenna can be determined from given current distributions along the antenna by using Fourier transformation or integral solutions with distributed ideal dipoles as basic elements (antenna analysis). To assess in general physical requirements, constrains and limitations of antennas, students can use fundamental antenna theory: impedance matching techniques, antenna modeling and far-field pattern analysis, antenna synthesis, image theory and fundamental limits of electrically small antennas. After being incorporated into the different adaptive beamforming techniques, the array theory enables the student to design antenna systems that are assembled of a certain number of separate elements, feeding network, beamforming network etc. for phased-scanning or smart antennas in communications and sensing. Moreover, students are able to determine, analyze and evaluate the most important classes of antennas in wireless technology for many applications, operating frequencies, desired requirements or practical constrains: (1.) wire- dipole antennas, (2.) planar antennas, lens antennas, Cassegrain and Gregorian double-reflector configurations), (4.) broadband</li> </ul>						
	reflector ant	antennas (microstrip,	, dipole and slot a s, Cassegrain and	ntennas), (3.) aper Gregorian double-	rture antennas (horn reflector configuratio	preover, students ar technology for man ire- dipole antenna antennas, parabol ons), (4.) broadban	
3	reflector ant and frequen antennas). Recomment Fundamenta	antennas (microstrip, ennas, lens antennas cy-independent anter ded prerequisites fo alls of Communication	, dipole and slot a s, Cassegrain and nnas (V antennas, <b>pr participation</b>	ntennas), (3.) aper Gregorian double- biconical antennas	rture antennas (horn reflector configuratio	preover, students an technology for man ire- dipole antenna antennas, parabol ons), (4.) broadban	
3	reflector ant and frequen antennas). Recommend Fundamenta Form of exa Module exam	antennas (microstrip, ennas, lens antennas cy-independent anten ded prerequisites fo ils of Communication	, dipole and slot a s, Cassegrain and nnas (V antennas, or participation ns, Microwave Eng	ntennas), (3.) aper Gregorian double- biconical antennas ineering 1	rture antennas (horn reflector configuratic , helical antennas, sp	preover, students ar technology for man ire- dipole antenna antennas, paraboli ons), (4.) broadban piral and log-period	

	Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)						
7	Usability of the module						
	B.Sc. WI-etit, M.	Sc. etit - KTS, M.Sc. etit - SAE, M.Sc. iCE, M.Sc. WI-etit, B	S.Sc. und M.Sc. iST, M	.Sc. CE			
8	Grade bonus co	mpliant to §25 (2)					
9 Co	References Skriptum "Antennas and Adaptive Beamforming" will be provided electronically at the beginning of the lecture.						
	<b>Course nr.</b> 18-jk-2020-vl	<b>Course name</b> Antennas and Adaptive Beamforming					
	<b>Instructor</b> DrIng. Martin Schüßler, DrIng. Alejandro Sáez, M.Sc. Jesús Pastor		<b>Type</b> Lecture	<b>SWS</b> 3			
	<b>Course nr.</b> 18-jk-2020-ue	<b>Course name</b> Antennas and Adaptive Beamforming		·			
	<b>Instructor</b> DrIng. Martin S	chüßler, DrIng. Alejandro Sáez, M.Sc. Jesús Pastor	<b>Type</b> Practice	<b>SWS</b> 1			

	Module name							
	<b>dule name</b> rowave Engir	neering II						
	<b>dule nr.</b> jk-2130	Credit points 6 CP	<b>Workload</b> 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Winter term		
	iguage	0 CP	100 11	Module owner				
	glish			Prof. DrIng. Rol	f Jakoby			
1	<ul> <li>Teaching content         Part 1 Passive microwave components:         <ul> <li>Calculation of the two-port parameters of simple passive components and circuits (transmission lines and lumped elements) for MMICs</li> <li>Wave parameters and S-parameters</li> <li>Smith chart and matching circuits with line elements or lumped elements</li> <li>Design and equivalent circuits of passive microwave components (transmission lines, capacitors, inductors and resistors)</li> </ul> </li> <li>Part 2 Active microwave components:         <ul> <li>Design and equivalent circuits of field effect transistors (FET) and heterostructure transistors (HEMTs)</li> <li>Gain and cut-off frequencies</li> <li>Schottky contacts: function and characteristics</li> </ul> </li> <li>Part 3 Active microwave circuits (main part):         <ul> <li>FET amplifiers: operation, equivalent circuit, gain, matching circuit, stability and circuit implementation</li> <li>Oscillator design</li> <li>Mixer design</li> <li>Material choice (compound semiconductor material systems: properties, fabrication and requirements)</li> </ul> </li> <li>Applications of these circuits range from communication systems such as cell phones to satellite transceivers as well as high-frequency sources up to Terahertz.</li> </ul>							
2						veguides, resonators,		
3		ded prerequisites fon to Electrodynamics,		eering I				
4	Form of exa Module exa • Modul		amination, Exam	ination, Duration:	90 Min., Default RS)			
5		e for the award of cr final module examina						
6	Grading Module exan • Modul	m: le exam (Technical ex	xamination, Exam	ination, Weighting	: 100 %)			
7		the module KTS, M.Sc. iCE, M.Sc	. WI-etit, B.Sc. ur	nd M.Sc. iST, M.Sc.	CE			
8	Grade bonu	is compliant to §25	(2)					
9	-	lides will be handed	out. Literature wi	ll be recommended	l in the lecture.			
<b>Co</b> ι	Courses							

<b>Course nr.</b> 18-jk-2130-vl	Course name Microwave Engineering II		
<b>Instructor</b>	<b>ructor</b>		<b>SWS</b>
PD DrIng. Okta	DrIng. Oktay Yilmazoglu		3
<b>Course nr.</b> 18-jk-2130-ue	Course name Microwave Engineering II		
<b>Instructor</b>	y Yilmazoglu	<b>Type</b>	<b>SWS</b>
PD DrIng. Okta		Practice	1

	Module name Matrix Analysis and Computations							
	<b>dule nr.</b> pe-2070	<b>Credit points</b> 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Summer term		
	i <b>guage</b> lish			<b>Module owner</b> Prof. DrIng. Ma	rius Pesavento			
1	1 Teaching content This graduate course is a foundation class on matrix analysis and computations, which are widely used in many different fields, e.g., machine learning, computer vision, systems and control, signal and image processing, communications, networks, optimization, and many more Apart from the theory this course will also cover the design of efficient algorithm and it considers many different examples from the aforementioned fields including examples from social media and big data analysis, image processing and medical imaging, communication network optimization, and written text classification. Specific topics: (i) basic matrix concepts, subspace, norms, (ii) linear least squares (iii) eigendecomposition, singular value decomposition, positive semidenite matrices, (iv) linear system of equations, LU decomposition, Cholesky decomposition (v) pseudo-inverse, QR decomposition (vi) advanced tensor decomposition, advanced matrix calculus, compressive sensing, structured matrix factorization							
2			ced topics in matr	ix analysis and rela	ated algorithms at an	advanced level upon		
3		<b>led prerequisites fo</b> edge in linear algebra						
4	The examinates the states that 10	n: e exam (Technical ex ation takes place in	form of a written e examination wi	n exam (duration: Il be an oral exam	on, Duration: 120 Mir 120 minutes). If or ination (duration: 20	ne can estimate that		
5	Prerequisite Pass module	e <b>for the award of c</b> final exam.	redit points					
6	Grading Module exar • Module		amination, Oral/	written examinatio	on, Weighting: 100 %	)		
7				etit - CMEE, M.Sc.	etit - KTS, M.Sc. iCI	E, M.Sc. MEC, M.Sc.		
8	Grade bonu	s compliant to §25	(2)					
9	References							

- Gene H. Golub and Charles F. van Loan, Matrix Computations (Fourth Edition), John Hopkins University Press, 2013.
- Roger A. Horn and Charles R. Johnson, Matrix Analysis (Second Edition), Cambridge University Press, 2012.
- Jan R. Magnus and Heinz Neudecker, Matrix Differential Calculus with Applications in Statistics and Econometrics (Third Edition), John Wiley and Sons, New York, 2007.
- Giuseppe Calaore and Laurent El Ghaoui, Optimization Models, Cambridge University Press, 2014.
- ECE 712 Course Notes by Prof. Jim Reilly, McMaster University, Canada (friendly notes for engineers) http://www.ece.mcmaster.ca/faculty/reilly/ece712/course\_notes.htm

## Courses

<b>Course nr.</b> 18-pe-2070-vl	<b>Course name</b> Matrix Analysis and Computations		
Instructor Prof. DrIng. Ma	· · ·	<b>Type</b> Lecture	<b>SW</b> 3
<b>Course nr.</b> 18-pe-2070-ue	<b>Course name</b> Matrix Analysis and Computations		
<b>Instructor</b> Prof. DrIng. Ma	rius Pesavento	<b>Type</b> Practice	<b>SW</b> 3

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
18-	8-mu-2010 6 CP 180 h		180 h	120 h	1 Term	Winter term
	Inguage     Module owner       nglish     Prof. DrIng. Michael Muma					
1	Teaching content Robust Data Science for Signal Processing • Basics on robust statistical learning • Robust regression models • Robust clustering and classification • Robust time-series and spectral analysis • High-dimensional robust data science Biomedical Applications • Body-worn and radar-based sensing of vital signs • Electrocardiogram (ECG) and Photoplethysmogram (PPG) • Biomarker selection • Eye research • Genomics • Intracranial Pressure (ICP) The lecture covers fundamental topics and recent developments in robust data science. Unlike classical statistical learning and signal processing, which relies strongly on the normal (Gaussian) distribution, robust methods can tolerate impulsive noise, outliers and artifacts that are frequently encountered in biomedical applications. Robust data science and biomedical application lectures alternate. Exercises revise the theory and apply robust machine learning and signal processing algorithms to real world data. Software toolboxes in Python, Matlab					
	and R that i	mplement the lecture				
2	<b>Learning ol</b> Students un variety of pr outliers and	mplement the lecture ojectives iderstand the basics coblems. They are fa impulsive noise. The	e contents are ava of robust signal p miliar with variou	ilable to the studer rocessing and data is biomedical appli	ts. science and are ablected and solutions and know th	es in Python, Matla e to apply them to e causes of artifact
2	Learning ol Students un variety of pr outliers and spectral ana Recommen	mplement the lecture ojectives iderstand the basics coblems. They are fa impulsive noise. The	e contents are ava of robust signal p miliar with variou y can apply algorit or participation	ilable to the studer rocessing and data is biomedical appli thms for robust reg	ts. science and are ablected and solutions and know th	es in Python, Matla e to apply them to e causes of artifacts
	Learning ol Students un variety of pr outliers and spectral ana Recommenta Fundamenta Form of exa Module exam	mplement the lecture ojectives Iderstand the basics coblems. They are fa impulsive noise. The lysis. ded prerequisites fo al knowledge of statis	e contents are ava of robust signal p miliar with variou y can apply algorit or participation stical signal proces	ilable to the studer rocessing and data is biomedical appli thms for robust reg	nts. I science and are able cations and know th ression, cluster analy	es in Python, Matla e to apply them to e causes of artifact sis, classification and
3	Learning ol Students un variety of pr outliers and spectral ana Recommenta Fundamenta Form of exa Module exan • Modul	mplement the lecture ojectives aderstand the basics coblems. They are fa impulsive noise. The lysis. ded prerequisites for al knowledge of statis amination m: le exam (Technical example e for the award of c	e contents are ava of robust signal p miliar with variou y can apply algorit or participation stical signal proces xamination, Exam	ilable to the studer rocessing and data is biomedical appli thms for robust reg	nts. I science and are able cations and know th ression, cluster analy	es in Python, Matla e to apply them to e causes of artifact sis, classification an
3 4 5	Learning of Students un variety of pro- outliers and spectral ana Recommenta Fundamenta Form of exa Module exan • Modul Prerequisite Pass module Grading Module exan	mplement the lecture ojectives aderstand the basics coblems. They are fa impulsive noise. The lysis. ded prerequisites fo al knowledge of statis amination m: e exam (Technical ex e for the award of cr final exam	e contents are ava of robust signal p miliar with variou y can apply algorit or participation stical signal proces kamination, Exam redit points	ilable to the studer rocessing and data is biomedical appli thms for robust reg ssing	nts. I science and are able cations and know th ression, cluster analy 180 Min., Default RS	es in Python, Matla e to apply them to e causes of artifact sis, classification an
3	Learning ol Students un variety of pro outliers and spectral ana Recomment Fundamenta Form of exa Module exan • Module Prerequisite Pass module Grading Module exan • Modul Usability of	mplement the lecture ojectives aderstand the basics coblems. They are fa impulsive noise. The lysis. ded prerequisites fo al knowledge of statis amination m: le exam (Technical exam e for the award of created final exam	e contents are ava of robust signal p miliar with variou y can apply algorit or participation stical signal proces kamination, Exam redit points	ilable to the studer rocessing and data is biomedical appli thms for robust reg ssing ination, Duration: ination, Weighting	nts. a science and are able a cations and know th ression, cluster analy 180 Min., Default RS : 100 %)	es in Python, Matla e to apply them to e causes of artifact sis, classification an

A manuscript and lecture slides can be downloaded via Moodle. Further reading

- Zoubir, A. M. and Koivunen, V. and Ollila, E. and Muma, M.: Robust Statistics for Signal Processing. Cambridge University Press, 2018.
- Zoubir, A. M. and Koivunen, V. and Chackchoukh J, and Muma, M. Robust Estimation in Signal Processing: A Tutorial-Style Treatment of Fundamental Concepts. IEEE Signal Proc. Mag. Vol. 29, No. 4, 2012, pp. 61-80.
- Huber, P. J. and Ronchetti, E. M.: Robust Statistics. Wiley Series in Probability and Statistics, 2009.
- Maronna, R. A. and Martin, R. D. and Yohai, V. J.: Robust Statistics: Theory and Methods. Wiley Series in Probability and Statistics, 2006.

## Courses

<b>Course nr.</b>	Course name				
18-mu-2010-vl	Robust Signal Processing With Biomedical Applications				
Instructor	chael Muma	<b>Type</b>	<b>SWS</b>		
Prof. DrIng. Mic		Lecture	3		
<b>Course nr.</b> 18-mu-2010-ue	<b>Course name</b> Robust Data Science With Biomedical Applications				
Instructor	chael Muma	<b>Type</b>	<b>SWS</b>		
Prof. DrIng. Mic		Practice	1		

Mo	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
-		90 h	60 h	1 Term	Summer term	
	<b>iguage</b> man			Module owner Prof. DrIng. Her	bort Do Corsom	
1	<b>Teaching co</b> Basics FIT, el			uasistatics, high fr	equency simulations,	convergence stud
2	<b>Learning objectives</b> Students learn the basic concepts of the Finite Integration Technique (FIT) for the numerical solution of Maxwell's equations. Students are, furthermore, introduced to the practical application of the method for numerical field problems.					
3	Basics of Ma	Recommended prerequisites for participation Basics of Maxwell's equations, linear algebra. Recommended: Basic knowledge in knowledge in "Technical Electrodynamics"				
4	Form of exam Module exam • Module	1:	κamination, Oral ε	examination, Durat	ion: 30 Min., Default	t RS)
5		for the award of c				
6	Grading Module exan • Module	n: e exam (Technical ex	xamination, Oral e	examination, Weigh	nting: 100 %)	
7	<b>Usability of</b> B.Sc. etit, M.	<b>the module</b> Sc. etit - CMEE, M.S	Sc. iCE, B.Sc. CE			
8	Grade bonus	s compliant to §25	(2)			
9	References Course notes	, lecture slides.				
Co	urses					
	Course nr.	Course name				
	18-dg-1030-v	vl Finite Integrat	ion Technique			

	<b>dule name</b> ivex Optimiza	ntion in Signal Proces	sing and Commu	nications		
Мо	<b>dule nr.</b> pe-2020	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Summer term
	iguage	0.61	100 11	Module owner		Summer term
	lish			Prof. DrIng. Mar	rius Pesavento	
1	This graduate course introduces the basic theory of convex optimization and illustrates its use with many recapplications in communication systems and signal processing. Outline: Introduction, convex sets and convex functions, convex problems and classes of convex problems (LP, SOCP, SDP, GP), Lagrange duality and KKT conditions, basics of numerical algorithms and interior point method optimization tools, convex inner and outer approximations for non convex problems, sparse optimization distributed optimization, discrete optimization, mixted integer linear and non-linear programming, Branch-a Bound method, Branch-and-Cut method, customized iterative optimization, Newton method, gradient project method, conjugate gradient method, block coordinate descent method, successive convex approximation method. BSUM method, Majorization Maximization, difference-of-convex procedure, ADMM, step size selection, opti step size compution, applications.					vex problems (LP, QP, terior point methods, sparse optimization, amming, Branch-and- l, gradient projection proximation method,
2	2 Learning objectives After completing the module, students will have become familiar with advanced topics in modern communication This includes in particular the basic theory of convex optimization and its application in digital signal processin and mobile communication systems.					
3		<b>ded prerequisites fo</b> in linear algebra and		s of signal processi	ng and communication	ons.
4	The examin less than 14	n: e exam (Technical ex ation takes place in	form of a written e examination wi	n exam (duration: Il be an oral exam	120 minutes). If or	n., Default RS) ne can estimate that 0 min.). The type of
5		e for the award of c				
6	Grading Module exar • Modul	m: e exam (Technical ex	amination, Oral/	written examinatio	n, Weighting: 100 %	)
7	•		M.Sc. etit - KTS, M	l.Sc. etit - VAS, M.S	c. iCE, M.Sc. WI-etit,	B.Sc. und M.Sc. iST,
8	Grade bonu	s compliant to §25	(2)			
9	References					
	http:// • D. P. B • Daniel	/www.stanford.edu/ ertsekas, Nonlinear I	boyd/cvxbook/) Programming, Ath na C. Eldar, Conv	ena Scientific, Belr	nont, Massachusetts,	4. (online Verfügbar: 2nd Ed., 1999. nd Communications,
Coi	ırses					

<b>Course nr.</b> 18-pe-2020-vl	<b>Course name</b> Convex Optimization in Signal Processing and C	Communications	
<b>Instructor</b>	arius Pesavento	<b>Type</b>	SWS
Prof. DrIng. M		Lecture	2
<b>Course nr.</b> 18-pe-2020-ue	<b>Course name</b> Convex Optimization in Signal Processing and C	Communications	
Instructor	arius Pesavento, M.Sc. Yufan Fan	<b>Type</b>	<b>SWS</b>
Prof. DrIng. M		Practice	1
<b>Course nr.</b> 18-pe-2020-pr	<b>Course name</b> Convex Optimization in Signal Processing and C	Communications Lab	
<b>Instructor</b>	arius Pesavento	<b>Type</b>	<b>SWS</b>
Prof. DrIng. M		Lab	1

	dule name					
	bile Commun		147	Calf at a lar		
	<b>dule nr.</b> kl-2020	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Summer term
	iguage			Module owner		
Eng	glish			Prof. DrIng. Anj	a Klein	
1	<ul> <li>Mobile</li> <li>Duple:</li> <li>Mobile</li> <li>Modul</li> <li>Code o</li> <li>Orthog</li> <li>Optim</li> <li>Cellula</li> <li>Divers</li> <li>Multip</li> <li>Power</li> </ul>	ontent covers aspects of mole e radio systems, servi x and multiple access e radio channel, dete lation schemes division multiple access gonal frequency divis um and suboptimum ar radio capacity and ity methods ole input multiple out control and handove ecture of mobile radi	ces, market, stand s techniques, cellu rministic and stoc ess (CDMA) ion multiplexing ( receiver techniqu spectrum efficien sput (MIMO) syste er	lardization lar concept hastic description (OFDM) es cy	rticular focus on the p	physical layer.
2	<ul> <li>a profemble</li> <li>schem</li> <li>a profe</li> <li>the ab</li> <li>the ab</li> </ul>	etion of the module, a bund understanding of communication system	of physical layer as ems, duplex schem of signal propagat nd solve problems lyse and evaluate	tes, multi carrier sch tion in mobile radio of the field of the different system co	hemes, receiver techr o systems (mobile rac physical layer oncepts	-
3	Determinist	<b>ded prerequisites fo</b> ic Signals and Syster ntific Computing		on Technology I, M	athematics I to III, S	Statistics/Probability
4	Form of exa Module exa • Modul		xamination, Exam	ination, Duration:	90 Min., Default RS)	
5	-	e for the award of c	-			
6	Grading Module exan • Modul	m: le exam (Technical ex	xamination, Exam	ination, Weighting	: 100 %)	
7	•	the module KTS, M.Sc. etit - VAS	, M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	M.Sc. iST	
8	Grade bonu	is compliant to §25	(2)			
9	References					

## | will be announced in the lecture

will be annound	ed in the lecture		
Courses			
<b>Course nr.</b> 18-kl-2020-vl	Course name Mobile Communications		
Instructor Prof. DrIng. Ar	Instructor Prof. DrIng. Anja Klein, DrIng. Lin Xiang		<b>SWS</b> 3
<b>Course nr.</b> 18-kl-2020-ue	Course name Mobile Communications		
<b>Instructor</b> Prof. DrIng. An Yilmaz	ja Klein, DrIng. Lin Xiang, M.Sc. Fengcheng Pei, M.Sc. Mustafa	<b>Type</b> Practice	<b>SWS</b> 1

Module nr.Credit pointsWorkload18-kl-20105 CP150 h				Self-studyModule duration90 h1 Term		Module cycle Winter term
Laı	<b>1guage</b> glish			Module owner Prof. DrIng. Ang		
1	<b>Teaching content</b> Linear and nonlinear digital modulation scheme channel capacity, channel models, channel estima schemes, OFDM					
2	<ul> <li>the ab means</li> <li>the ab</li> <li< td=""><th>bjectives etion of the lecture, s ility of comparing, ev s of signal space repre- bility to understand, d bility to understand and bility to understand, d bility to describe the in ultipath channel at the nowledge of equalizing as the ability to deri- ility to analyze and ev FDM-systems; bility to design and ev- ic wireless communic bility to mathematical</th><th>aluating, classifying esentations; lescribe and analy nd derive optimum lescribe and analy nfluence of a mult he receiver; g the received sig ive and design sever valuate the propert valuate the system cation scenarios;</th><td>vze the influence of n receivers in case vze the influence of ipath channel mat nal in order to und veral equalizer stru- ties and application n parameters of m</td><th>f AWGN on the signal of AWGN channels; f multipath propagati hematically (channel do the influence of mu ictures; areas of multicarrier sulticarrier schemes f</th><td>l; on on the signal; model) and estimate ultipath propagation transmission systems for the application in</td></li<></ul>	bjectives etion of the lecture, s ility of comparing, ev s of signal space repre- bility to understand, d bility to understand and bility to understand, d bility to describe the in ultipath channel at the nowledge of equalizing as the ability to deri- ility to analyze and ev FDM-systems; bility to design and ev- ic wireless communic bility to mathematical	aluating, classifying esentations; lescribe and analy nd derive optimum lescribe and analy nfluence of a mult he receiver; g the received sig ive and design sever valuate the propert valuate the system cation scenarios;	vze the influence of n receivers in case vze the influence of ipath channel mat nal in order to und veral equalizer stru- ties and application n parameters of m	f AWGN on the signal of AWGN channels; f multipath propagati hematically (channel do the influence of mu ictures; areas of multicarrier sulticarrier schemes f	l; on on the signal; model) and estimate ultipath propagation transmission systems for the application in
3	Determinist	<b>ded prerequisites fo</b> ische Signale und Syst istics/Probability The	teme, Communica		Basics of Telecommun	ication, Mathematic
4	Form of exa Module exa	amination			90 Min., Default RS)	
5		e for the award of cr final module examina				
6	<b>Grading</b> Module exa			ination, Weighting	: 100 %)	
7	<b>Usability of</b> M.Sc. etit -	f <b>the module</b> KTS, M.Sc. etit - VAS,	M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	M.Sc. iST, M.Sc. CE	

<b>Course nr.</b> 18-kl-2010-vl	Course name Communication Technology II		
<b>Instructor</b> Prof. DrIng. An	<b>Instructor</b> Prof. DrIng. Anja Klein		SWS 2
<b>Course nr.</b> 18-kl-2010-ue	Course name Communication Technology II		·
Instructor Prof. DrIng. An	ja Klein, M.Sc. Sumedh Dongare, M.Sc. Yi Wang	<b>Type</b> Practice	<b>SWS</b> 2

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle	
	zo-2060	6 CP	180 h	120 h	1 Term	Winter term	
	<b>nguage</b> glish			Module owner Prof. DrIng. Abc	lelhak Zoubir		
1	<ol> <li>2) Digital Filt</li> <li>Impulse Resp</li> <li>3) Digital Spectrum</li> </ol>	ime Signals and Lin er Design - Filter D onse Filters; Impler ectral Analysis - Ra imation; Applicatio	esign Principles; L mentations ndom Signals; No	inear Phase Filters	ruction of Analog Sig ; Finite Impulse Resp ods for Spectrum Est	oonse Filters; Infi	
2	Students und Furthermore, the basics of	<b>Learning objectives</b> Students understand basic principles of signal processing. They can design and analyze FIR and IIR filters. Furthermore, they are able to analyze statistical signals in the time and frequency domain. The students know the basics of spectral estimation and can design non-parametric as well as parametric spectral estimators and analyze them with respect to their performance.					
3		ed prerequisites for signals and system					
4	Form of exar Module exam • Module	:	xamination, Exam	ination, Duration:	180 Min., Default RS	5)	
5		for the award of c nal module examin					
6	<b>Grading</b> Module exam • Module	: exam (Technical e:	xamination, Exam	ination, Weighting	: 100 %)		
7	<b>Usability of t</b> M.Sc. etit - K und M.Sc. iS <sup>7</sup>	TS, M.Sc. etit - SAE	E, M.Sc. etit - VAS,	M.Sc. iCE, M.Sc.	MEC, M.Sc. MedTec	, M.Sc. WI-etit, I	
8	Grade bonus	compliant to §25	(2)				
0	References         Course manuscript         Additional References:         • A. Oppenheim, W. Schafer: Discrete-time Signal Processing, 2nd ed.         • J.F. Böhme: Stochastische Signale, Teubner Studienbücher, 1998						
9		me: Stochastische					
9 Co	• J.F. Böh	Course name					

<b>Course nr.</b> 18-zo-2060-ue	<b>Course name</b> Digital Signal Processing		
Instructor Prof. DrIng. Abc	lelhak Zoubir, M.Sc. Christian Eckrich, M.Sc. Christian Schroth	<b>Type</b> Practice	<b>SWS</b> 1

Mo	dule name					
		leling - Machine Lear	rning			
	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
-	kp-2110 Iguage	6 CP	180 h	120 h Module owner	1 Term	Summer term
	glish			Prof. Dr. techn. H	leinz Köppl	
1	Important m communicat Funda Taxono Regres Dimen and si Probal Funda Funda Funda Appro theory Hidde convol High-c data, l	provides an introduct nodels and learning m tion technology. mentals of probability omy of machine learn ssion and classification asionality reduction, of gnal processing bilistic graphical mod- mentals of Bayesian mentals of convex op ximate algorithms for (e.g. decoding of LE n Markov models (I lutional codes) limensional statistics learning causality rel	nethods are present ty theory and mul- ing problems and mon: theory, method clustering and big dels: categories, in inference, Monte ptimization: Solut r scalable Bayesian OPC codes) HMM): Theory, A ("large p small n" ations from obser- projections, comp	ited and exemplifie tivariate statistics models (supervised ls and ICT applicat data analytics: me ference and param Carlo methods, Bay ion methods and ap n inference; applicat lgorithms and ICT setting), learning ov vational data. ressive sensing: Th	d through problems f unsupervised, gener ions thods and application vesian non-parametri oplication in commun tion in signal process T applications (e.g. dependency structure eory and applications	nications sing and information Viterbi decoding of e in high-dimensional s in signal processing
2	machine lea They are al	e able to interpret ar rning problems.	problems to star			f domain in terms of d are able to deter-
		ble to implement al art libraries in mach		rithms from scrate	h, but they are als	o familiar with the
	•	ble to determine th on algorithms based	-	-	ity of a method an	d choose an appro-
		ble to apply the ac , analysis of social ne		to other domains	s, such as data ana	alysis in biomedical
3				from course 18-st-	2030 Matlab Grundk	urs) and engineering
4	The examin less than 10	m: le exam (Technical e: ation takes place in	form of a written ne examination w	n exam (duration: ill be an oral exam	120 minutes). If or	n., Default RS) ne can estimate that 0 min.). The type of

5		<b>the award of credit points</b> module examination			
6	Grading Module exam: • Module exa	am (Technical examination, Oral/written examination, Weight	ting: 100 %)		
7		<b>module</b> .Sc. etit - CMEE, M.Sc. etit - DT, M.Sc. etit - KTS, M.Sc. etit - iST, B.Sc. CE, M.Sc. CE	- VAS, M.Sc. iCE, M.Sc.	WI-etit,	
8	Grade bonus compliant to §25 (2)				
9 Co	<ul> <li>Christophe</li> </ul>	urphy. Machine Learning - A probabilistic perspective, MIT Pre r M. Bishop. Pattern recognition and Machine Learning, Sprin mann und Sara van de Geer. Statistics of high-dimensional dat nger, 2011	ger, 2006	applica-	
	<b>Course nr.</b> 18-kp-2110-vl	Course name Data-driven Modeling - Machine Learning			
	<b>Instructor</b> Prof. Dr. techn. H	leinz Köppl	<b>Type</b> Lecture	<b>SWS</b> 2	
	<b>Course nr.</b> 18-kp-2110-ue	<b>Course name</b> Data-driven Modeling - Machine Learning			
	<b>Instructor</b> Prof. Dr. techn. H	leinz Köppl	<b>Type</b> Practice	<b>SWS</b> 1	
	<b>Course nr.</b> 18-kp-2110-pr	<b>Course name</b> Data-driven Modeling - Machine Learning Lab			
	<b>Instructor</b> Prof. Dr. techn. H	leinz Köppl	<b>Type</b> Lab	<b>SWS</b> 1	

00	odule nr. 00-0120	Credit points 6 CP	Workload	Self-study	Module duration	Module cycle
Language			180 h	120 h Module owner	1 Term	Summer term
Gei 1	rman <b>Teaching co</b> Objectives:	ontent		Prof. Dr. rer. nat.	Eberhard Mühlhäuse	er
2	<ul> <li>Knowledge</li> <li>Methodic k</li> <li>Course Cont</li> <li>Introductio</li> <li>Mobile Cor</li> <li>Internet of</li> <li>Service Dis</li> <li>Context- ar</li> <li>Human Co</li> <li>Privacy and</li> <li>Learning ol</li> <li>After success</li> </ul>	n to Ubiquitous Com nmunication Things: RFID and Sr covery & Cloudlets nd Location-aware Co mputer Interaction l Trust in Ubiquitous <b>ojectives</b> sfully attending the c	eges of the Ubiquir ent approaches to puting nart Items omputing Computing	tous Computing these challenges	technical basis of mo	
3	these challes	nges. They are able to ded prerequisites fo	o apply their know or participation		g. They know current quitous computing sy	
4	Form of exa Course relat			al/written examina	tion, Default RS)	
5	-	e for the award of c 100%)	redit points			
	Pass exam (100%)         Grading         Course related exam:         • [20-00-0120-iv] (Technical examination, Oral/written examination, Weighting: 100 %)					
6	• [20-00				, , ,	%)
6	Usability of B.Sc. Inform M.Sc. Inform M.Sc. Wirts B.Sc. Psycho Joint B.A. In B.Sc. Sporty	natik chaftsinformatik ologie in IT				%)

9	um bis zu 1.0 fü References	mendations will be updated regularly, an example might be		esserung
		esearch: Ubiquitous Computing Technology for Real T user, Dr. Iryna Gurevych, 2008, Information Science Referen		
	B Secondary Lite	rature:		
	<ol> <li>Stefan Poslad</li> <li>Kapitel Mobil</li> </ol>	. Gupta et al.: Fundamentals of Mobile & Pervasive Comput Ubiquitous Computing, Wiley 2009, ISBN 978-0-470-0356 communikation: M. Sauter: Grundkurs Mobile Kommunika und Wireless LAN; Vieweg-Teubner Studium 2010	0-3	DPA unc
	4. J. Krumm (Ed	.): Ubiquitous Computing Fundamentals, CRC Press 2010 [Ed.): Smart Environments, Wiley 2005		
Со	4. J. Krumm (Ed			
Со	4. J. Krumm (Ed D. Cook, S. Das (			

	<b>dule nr.</b> sm-2340	Credit points	Workload	Self-study	Module duration	Module cycle
		4 CP	120 h	75 h	1 Term	Summer term
	<b>1guage</b> glish			Module owner Prof Dr rer pat	Björn Scheuermann	
1	<ul> <li>Resilie</li> <li>Resilie</li> <li>Import</li> <li>Requir</li> <li>Requir</li> <li>Methoto - W</li> <li>- W</li> <li>Resilie</li> </ul>	covers the following t nce in the different of nce in communicatio tance of resilience for ements for current of ds to increase resilien Vireless networks (e.g. Vired networks nt network managen nce through adaptivi	lisciplines on networks r communication n ommunication net nce in communiat g., mobile commun nent in software-c	tworks ion networks nications) lefined networks		
>	I comin o ol	•••••				
	communicat and diversit	e familiar with the id ion networks. They a y, and can apply thes	re familiar with v e methods to the	arious methods for	ious disciplines with increasing resilience, ication networks.	
2 3	Students are communicat and diversit	e familiar with the id ion networks. They a	re familiar with v e methods to the	arious methods for	increasing resilience,	
3	Students are communicat and diversit Recommend Form of exa Module exam • Modul The examina 10 students	e familiar with the id ion networks. They a y, and can apply thes ded prerequisites fo mination m: e exam (Technical ex ation takes place in fo	are familiar with v e methods to the or participation camination, Oral/ form of a written e tion will be an ora	arious methods for design of commun written examinatic exam (duration: 90	increasing resilience,	, such as redundan , Default RS) timate that less th
	Students are communicat and diversit Recommend Form of exa Module exam • Modul The examina 10 students will be anno Prerequisite	e familiar with the id ion networks. They a y, and can apply thes <b>ded prerequisites fo</b> mination m: e exam (Technical ex ation takes place in for register, the examina unced in the beginni e for the award of co	are familiar with v e methods to the or participation camination, Oral/ form of a written e tion will be an ora ng of the lecture. redit points	arious methods for design of commun written examinatic exam (duration: 90	increasing resilience, ication networks. on, Duration: 90 Min. o min.). If one can est	, such as redundan , Default RS) timate that less th
3 4 5	Students are communicat and diversit Recommend Form of exa Module exam • Modul The examina 10 students will be anno Prerequisite Passing the Grading Module exam	e familiar with the id ion networks. They a y, and can apply thes <b>ded prerequisites fo</b> mination m: e exam (Technical ex ation takes place in for register, the examina unced in the beginni e for the award of co final module examination m:	are familiar with v e methods to the or participation camination, Oral/ form of a written e tion will be an orang of the lecture. redit points ation	arious methods for design of communi written examinatio exam (duration: 90 al examination (du	increasing resilience, ication networks. on, Duration: 90 Min. o min.). If one can est	, such as redundar , Default RS) timate that less th type of examinati
3	Students are communicat and diversit Recommend Form of exa Module exam- Modul exam- 10 students will be anno Prerequisite Passing the Grading Module exam- Modul Usability of	e familiar with the id ion networks. They a y, and can apply thes <b>ded prerequisites fo</b> mination m: e exam (Technical ex ation takes place in for register, the examina unced in the beginni e for the award of cr final module examination m: e exam (Technical ex final module examination)	amination, Oral/ corm of a written e tion will be an orang of the lecture. redit points ation	arious methods for design of communi- written examinatio exam (duration: 90 al examination (du	increasing resilience, ication networks. on, Duration: 90 Min. 0 min.). If one can est ration: 30 min.) The	, such as redundan , Default RS) timate that less th type of examinati

A lecture notes or slides can be downloaded:

Moodle Platform

Advanced literature

- Smith, Paul, et al. "Network resilience: a systematic approach." IEEE Communications Magazine 49.7 (2011): 88-97
- Sterbenz, James PG, et al. "Resilience and survivability in communication networks: Strategies, principles, and survey of disciplines." Computer networks 54.8 (2010): 1245-1265
- Mauthe, Andreas, et. al. "Disaster-resilient communication networks: Principles and best practices." 2016 8th International Workshop on Resilient Networks Design and Modeling (RNDM). IEEE, 2016

### Courses

<b>Course nr.</b> 18-sm-2340-vl	Course name Resilient Communication Networks		
Instructor	. Björn Scheuermann, DrIng. Tobias Meuser	<b>Type</b> Lecture	<b>SWS</b> 2
<b>Course nr.</b> 18-sm-2340-ue	Course name Resilient Communication Networks		'
<b>Instructor</b> Prof. Dr. rer. nat	. Björn Scheuermann, DrIng. Tobias Meuser	<b>Type</b> Practice	<b>SWS</b> 1

	dule name	ılar Communication				
Mo	<b>dule nr.</b> ja-2020	Credit points 4 CP	Workload 120 h	Self-study 75 h	Module duration	Module cycle Summer term
Lar	<b>1guage</b> glish			Module owner Prof. DrIng. Vah		
1	Teaching co This lecture communicat Basic J Backg Mathe Design Chann Review	e course introduces the tion (MC) systems. The principles of synthetic round concepts from ematical modeling of the n of modulation and case the estimation and part	he course covers t c MC systems and biology and chem MC channels invo letection schemes rameter estimatio ntal MC systems,	s in modeling, des he following topics potential applicati histry needed to un lving advection-rea for synthetic MC s n for synthetic MC	sign, and analysis of the second seco	synthetic molecular esses ations, and the signal
2	<ul> <li>explai based</li> <li>explai comm</li> <li>apply equati</li> <li>name optima</li> <li>derive chann</li> <li>name tures/</li> </ul>	etion of this interdisc n the basic principles communications n basic related concep unication within and the relevant physications) to derive commu- several modulation sc al and suboptimal de- estimators for estim- el several state-of-t limitations/challenge s will deepen their kn	s of MCs and diffe ots from chemistry between cells, etc u/chemical laws unication-theoretic chemes for embed tection for recover nating the MC ch he-art impleme es of building MC nowledge of the fu	rentiate them with and biology such a c. (e.g., Fick's law or cal models for MC ding information ir ring information annel impulse resp ntations of syn systems, in practice indamentals of com	a respect to convention as chemical reactions of in general advection channels not the properties of a ponse or physical part thetic MCs and e nmunication systems	onal electromagnetic- , molecules, proteins, on-reaction-diffusion molecules and derive arameters of the MC explain the fea- by reflecting on and .) in the new context
3		<b>ded prerequisites fo</b> of basic communication		ital communication	n	
4	The examin less than 10	m: le exam (Technical ex lation takes place in	form of a written e examination w	n exam (duration: ill be an oral exam	120 minutes). If or	n., Default RS) ne can estimate that 0 min.). The type of
5	-	e for the award of cr final module examina	-			
6	Grading Module exa • Modul	m: le exam (Technical ex	kamination, Oral/	written examinatio	on, Weighting: 100 %	))
7	-	f <b>the module</b> DT, M.Sc. etit - KTS, I	M.Sc. etit - VAS, N	I.Sc. iCE, M.Sc. M	edTec, M.Sc. WI-etit,	B.Sc. und M.Sc. iST

8		<b>mpliant to §25 (2)</b> ents up to 0.4 according to APB 25(2) through bonus for re	egularly completed ar	nd submitted
9	Moodle Platform Supplementary a T. Nakano, A. Ec T. Nakano, A. Ec	r slides can be downloaded: and advanced literature: kford, and T. Haraguchi. Molecular Communications, Camb kford, and T. Haraguchi. Molecular Communications, Camb fical Physics - Energy, Information, Life, Freeman and Comp	ridge University Press	· .
0				
	<b>Course nr.</b> 18-ja-2020-vl	Course name Synthetic Molecular Communication		
	<b>Instructor</b> Prof. DrIng. Val	nid Kooshkghazi	<b>Type</b> Lecture	<b>SWS</b> 2
	<b>Course nr.</b> 18-ja-2020-ue	<b>Course name</b> Synthetic Molecular Communication		
	Instructor Prof. DrIng. Val	iid Kooshkghazi, Ph.D. Ladan Khaloopour	<b>Type</b> Practice	<b>SWS</b> 1

	<b>dule name</b> nical applicati	ons of brain imaging	. stimulation. and	modeling		
Мо	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
	kp-2130 I <b>guage</b>	6 CP	180 h	120 h Module owner	1 Term	Winter term
Eng	lish			Prof. Dr. techn. H	leinz Köppl	
1	<ul> <li>Overvi</li> <li>Physic</li> <li>Physic</li> <li>and el</li> <li>Findin</li> <li>Prepro</li> <li>A</li> <li>P</li> <li>A</li> <li>A</li> <li>C</li> <li>Compute</li> <li>Machi</li> </ul>	uction to basic neuro ew of neurological an logical basis and clin logical basis and clin ectrophysiological (M g neuronal correlates cessing and analysis rtefact removal, sour ower spectra and even nalysis of correlation pplication of graph the ritical dynamics of the itational models of h ne learning approach ew of brain stimulation	nd neuropsychiatr ical applications of nical applications of AEG, EEG, ECoG) s of neurological a of functional brai rce reconstruction ent-related potent is, phase synchrom heory to brain net ne brain lealthy and clinica nes in clinical neur	ic disorders of structural brain in of functional brain methods and neuropsychiatr n imaging data , and filtering ials ization, and cross- works l neuronal activity roscience	imaging with hemod	lynamic (fMRI, PET)
2	imaging, bra Students ha and how th physiologica brain stimul advanced m and disease. results, and Students ha cillatory mod	aims to provide stud aim stimulation, comp ave acquired an ove ese can be studied al origin of key obser- ation and their respect athematical concepts They have processed can formulate resear	erview of differe with brain imag vables and the pri- ctive advantages a such as graph the d and carried out s rch questions for c	ng, particularly the nt types of neuro ing and computat nciples of commor nd applications. Th ory and brain critic statistical analyses of linical neuroscience ational modelling	eir clinical application ological and neurop ional modelling. The aly used techniques in hey are acquainted w cality to studying bra of neuroimaging data e. in neuroscience ar	sychiatric disorders hey understand the
3		<b>ded prerequisites fo</b> Fundamentals of Sig				
4	The examin		form of a written	exam (duration: 9	0 minutes). If one ca	an estimate that less
5	-	e for the award of cr	-			
6	Grading					

	Module exam: • Module exa	am (Technical examination, Oral/written examination, Weight	ing: 100 %)	
7	Usability of the M.Sc. iCE, M.Sc.	<b>module</b> MedTec, B.Sc. und M.Sc. iST, M.Sc. CE		
8	Through comple subject and acqu	mpliant to §25 (2) tion of special assignments, students can demonstrate their a ire a bonus to improve the grade by a maximum of 1.0. The bo e exam grade must be sufficient to pass without the bonus.		
	fered over the co be handed in. Bo	pecial assignments (three practical exercises and three se urse of the module. For getting the maximum bonus points, th onus points from special assignments are converted linearly in ole bonus points results in a 0.1 improvement to the exam and rovement of 1.0.	ree special assignments to exam grades, so that	need to getting
9	2019. • Eric Kande	e Beeck & Chie Nakatani: Introduction to Human Neuroimagi l: Principles of Neural Science, sixth edition. McGraw Hill, Nev al: Functional Neuroanatomy and Clinical Neuroscience. Oxfor	w York, 2021.	
Coi	ırses			
	<b>Course nr.</b> 18-kp-2130-vl	<b>Course name</b> Clinical applications of brain imaging, stimulation, and mode	eling	
	Instructor		<b>Type</b> Lecture	<b>SWS</b> 3
	<b>Course nr.</b> 18-kp-2130-ue	<b>Course name</b> Clinical applications of brain imaging, stimulation, and mode	eling	
	Instructor		<b>Type</b> Practice	<b>SWS</b> 1

# 2.2.2 Communication Systems and Networking - Labs and Projects

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cyc	
	-kl-2040	8 CP	240 h	180 h	1 Term	Summer ter	rm
	<b>nguage</b> glish			Module owner Prof. DrIng. Anj	a Klein		
1	processing a research top: working on t organizing a dealing with practical wor scientific pre	ial problems concer	concerning the net (2-3 students); project; ns, reading up the x; ults (report/preser	twork are possible, theoretical backgr ntation);	lems concerning sign , topics will be define round of the task;		
2	<ul><li>the abi</li><li>the known</li><li>the cap</li></ul>	tion of the course, s lity to classify and a owledge to plan and	nalyze special pro l organize projects l test methodologi	with temporal lim ies for analysis and	simulation environn		
3		l <b>ed prerequisites f</b> o wledge in digital co		nal processing, wit	reless communication	1.	
4		n: e exam (Study achie			Default RS) ced in the beginning	of the lecture	2.
5	Prerequisite	for the award of c	redit points				
6	Grading Module exan • Module	n: e exam (Study achie	evement, Oral/writ	tten examination, V	Weighting: 100 %)		
7	<b>Usability of</b> M.Sc. etit - k	<b>the module</b> TS, M.Sc. etit - VAS	, M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	M.Sc. iST		
8	Grade bonu	s compliant to §25	(2)				
9	<b>References</b> Literature wi	ll be announced du	ring the course.				
Co	urses						
	<b>Course nr.</b> 18-kl-2040-p	i Project Semin	ar Wireless Comm	unications			
	Instructor	Anja Klein, M.Sc. S			<b>Type</b> Project se		SWS

		Credit points	Workload	Self-study	Module duration	Module cycle
	pe-2040	8 CP	240 h	180 h	1 Term	Winter term
	<b>nguage</b> glish			Module owner Prof. DrIng. Ma	rius Pesavento	
1	tensor data re The specific th	eminar addresses neepresentations.	seminar will be a	dapted from year to	hannel processing wi o year according to th ell in advance.	
2	<b>Learning obj</b> Students will		algorithms and a	pplications of sense	or array and multicha	nnel system.
3		<b>ed prerequisites fo</b> dge in linear algebra				
4	Form of exar Module exam • Module	:	vement, Oral exar	nination, Duration	: 40 Min., Default RS	)
5		for the award of c nal module examina				
6	Grading Module exam • Module	ı: exam (Study achie	vement, Oral exar	nination, Weightin	g: 100 %)	
7	<b>Usability of t</b> M.Sc. etit - K	t <b>he module</b> TS, M.Sc. etit - VAS,	, M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	M.Sc. iST	
8	Grade bonus	compliant to §25	(2)			
9	Wiley & Sons				Estimation, and Mod	ulation Theory, Jo
Co	urses					
	Course nr.	Course name				
	18-ре-2040-р	j Project Semina	ar Emerging Topic	s in Sensor Array a	and Multichannel Pro	cessing

	<b>dule nr.</b> pe-2050	Credit points 8 CP	Workload 240 h	Self-study 180 h	Module duration 1 Term	Module cycle Summer term
Laı	<b>nguage</b> glish	0.61	240 11	Module owner Prof. DrIng. Ma		Julinier term
1	<b>Teaching co</b> This project communicati The specific	-seminar addresses ion systems. thematic focus of the	e seminar will be	IMO communicati adapted from year	ions for the next gen r to year according to e website well in adva	o the latest trends
2		ll learn the fundame			, algorithms and app t scientific publication	
3	Recommend	led prerequisites fo	r participation			
4	Form of exa Module exam • Module	n:	vement, Oral exar	nination, Duration	: 40 Min., Default RS	5)
5		e for the award of cr inal module examina				
6	Grading Module exan • Module	n: e exam (Study achie	vement, Oral exar	nination, Weightin	g: 100 %)	
7	<b>Usability of</b> B.Sc. WI-etit	<b>the module</b> , M.Sc. etit - KTS, M	.Sc. etit - VAS, M.	Sc. iCE, M.Sc. WI-	etit, B.Ed. etit	
8	Grade bonu	s compliant to §25	(2)			
9	<b>References</b> References in	nclude the latest scie	ntific publications	, seminars and boo	oks.	
Co	urses					
	<b>Course nr.</b> 18-pe-2050-j	pj Project Semina	ar Emerging Topic	s in MIMO Comm	unication Networks	
	Instructor Prof. DrIng.				Туре	SV

10	<b>dule nr.</b> pr-2030	Credit points 8 CP	Workload 240 h	Self-study 180 h	Module duration 1 Term	Module cycle Every Semester
Lar	nguage rman/English	o Cr	240 11	Module owner Prof. Dr. rer. nat.	L	Every Semester
1	of THz techn be defined l own, organi summarizin conclusions • Terahe • Optics • Spectr • Semice	g and solving specifi nology as well as top pased on current res- zing and structuring g achieved results ar and defending them ertz Optics /photonics	ics of the area of ( earch topics. The of a seminar task, nd conclusions by	Dptics and commun project seminar in searching and ana means of a written	nent of Terahertz dev nication technology. T ncludes working on a alyzing of scientific re n report, presenting a ence. Topics include,	The specific task wil a given task by one's ference publications achieved results and
2	<ul><li>the ab</li><li>deep a</li></ul>	etion of the course, s ility to apply theoret and special knowledg	ical models to pra		science ontics or set	niconductor physics
	• the cap		e the achieved scie	ific reference pape ntific findings in th	rs for a particular top ne form of a concise re	pic
3	the cap and di     Recomment	pability to summarize scuss achieved result ded prerequisites for	e the achieved scie ts in the form of a or participation	ific reference pape entific findings in th presentation in fro	rs for a particular top the form of a concise re- ont of an audience	pic eport, and to presen
3	<ul> <li>the cap and di</li> <li>Recomment Previous known</li> <li>Form of exat Module exat Module exat</li> </ul>	ded prerequisites for whedge in at least on mination m: e exam (Study achie	e the achieved scie ts in the form of a <b>or participation</b> e of the following of vement, Oral/writ	ific reference pape entific findings in the presentation in fro disciplines: Optics, tten examination, I	rs for a particular top the form of a concise re- ont of an audience semiconductor physic Default RS)	bic eport, and to presen es, or THz technolog
	<ul> <li>the cap and di</li> <li>Recommender Previous known</li> <li>Form of exate Module exate</li> <li>Module exate</li> <li>Module Report and/</li> <li>Prerequisite</li> </ul>	ded prerequisites for whedge in at least on mination m: e exam (Study achie	e the achieved scie ts in the form of a or participation e of the following of vement, Oral/write type of examinat redit points	ific reference pape entific findings in the presentation in fro disciplines: Optics, tten examination, I	rs for a particular top the form of a concise re- ont of an audience semiconductor physic	bic eport, and to presen rs, or THz technolog
4	<ul> <li>the cap and di</li> <li>Recommender Previous known</li> <li>Form of exation</li> <li>Module exation</li> <li>Module Report and/</li> <li>Prerequisite</li> <li>Passing the statistic of the st</li></ul>	pability to summarize scuss achieved result ded prerequisites for weldge in at least on mination m: e exam (Study achie for Presentation. The e for the award of c final module examination	e the achieved scie ts in the form of a or participation e of the following of vement, Oral/write type of examinat redit points ation	ific reference pape entific findings in the presentation in froe disciplines: Optics, tten examination, I ion will be announ	rs for a particular top the form of a concise re- ont of an audience semiconductor physic Default RS) ced in the beginning	bic eport, and to presen es, or THz technolog
4	<ul> <li>the cap and di</li> <li>Recommender Previous known</li> <li>Form of exation</li> <li>Module exation</li> <li>Module exation</li> <li>Module exation</li> <li>Prerequisite</li> <li>Passing the state</li> <li>Grading</li> <li>Module exation</li> <li>Module</li> <li>Module</li> <li>Module</li> <li>Wodule</li> <li>Module</li> <li>Module</li> </ul>	pability to summarize scuss achieved result ded prerequisites for owledge in at least on mination m: e exam (Study achie or Presentation. The e for the award of c final module examina- m:	e the achieved scie ts in the form of a or participation e of the following of vement, Oral/write type of examinat redit points ation	ific reference pape entific findings in the presentation in froe disciplines: Optics, tten examination, I ion will be announ	rs for a particular top the form of a concise re- ont of an audience semiconductor physic Default RS) ced in the beginning	bic eport, and to presen es, or THz technolog
4 5 6	<ul> <li>the cap and di</li> <li>Recommender Previous known</li> <li>Form of exat Module exate</li> <li>Module exate</li> <li>Module exate</li> <li>Grading</li> <li>Module exate</li> <li>Module</li></ul>	pability to summarize scuss achieved result ded prerequisites for owledge in at least on mination m: e exam (Study achie or Presentation. The e for the award of c final module examina- m: e exam (Study achie final module examina-	e the achieved scie ts in the form of a or participation e of the following of vement, Oral/write type of examinat redit points ation vement, Oral/write	ific reference pape entific findings in the presentation in froe disciplines: Optics, tten examination, I ion will be announ	rs for a particular top the form of a concise re- ont of an audience semiconductor physic Default RS) ced in the beginning	bic eport, and to presen es, or THz technolog

<b>Course nr.</b> 18-pr-2030-pj	<b>Course name</b> Project Seminar Terahertz Technology, Communication and S	ensors	
<b>Instructor</b> Prof. Dr. rer. nat.	Sascha Preu	<b>Type</b> Project seminar	SWS 4

	<b>dule nr.</b> zo-2030	Credit pointsWorkloadSelf-studyModule6 CP180 h135 h1 Term				Module cycle
Lar	zo-2030 <b>1guage</b> glish	6 CP	180 h	135 h1 TermEvery SemesterModule ownerProf. DrIng. Abdelhak Zoubir		
1	Teaching co	itent		1100 20 1100 1100		
	<ol> <li>Discrete</li> <li>Frequere</li> <li>Digital</li> <li>IIR Filte</li> <li>Nonpare</li> </ol>	ction to MATLAB E-Time Signals and Icy-Domain Analysi FIR Filter Design er Design using Ana ametric Spectrum E tric Spectrum Estim	s using the DFT log Prototypes Estimation			
2	<b>Learning objectives</b> The students are able to apply skills acquired in the course Digital Signal Processing. These include the dest of digital FIR and IIR filters as well as non-parametric and parametric spectrum estimation. Students lea how MATLAB is used to apply theoretical concepts and to demonstrate signal processing techniques by use hands-on application examples.				tion. Students learn	
3		ed prerequisites for s of Signal Processi				
4		: exam (Study achie			ion: 120 Min., Defau announced at the beg	
5	Prerequisite	for the award of c	redit points		0	0
6	Grading Module exam • Module	: exam (Study achie	vement, Written e	xamination, Weigh	nting: 100 %)	
7	<b>Usability of</b> M.Sc. etit - K		, M.Sc. iCE, M.Sc.	MedTec, M.Sc. W	I-etit, B.Sc. und M.Sc	. iST
8	Grade bonus	compliant to §25	(2)			
9	<b>References</b> Lab manual					
Coi	urses	1				
	<b>Course nr.</b> 18-zo-2030-p	r Digital Signal	Processing Lab			
	Instructor	Abdelhak Zoubir			<b>Type</b> Lab	SWS

	dule name					
		munications Semina				
	<b>dule nr.</b> sm-2090	Credit points 4 CP	Workload 120 h	Self-study 90 h	Module duration 1 Term	Module cycle Every Semester
	iguage	1.01	120 11	Module owner		
	man/English				Björn Scheuermann	
1	communicat trends in dif of a report newspapers Some poten • Knowl • Self on • Mobile • Servic	ar deals with curren tion systems. The edu ferent areas. To this a	acational objective im, an extensive li n of selected, hig he web technologi Fechnologies Overlay Communi Ietworking g	e of this seminar is terature research w h-quality research ies research area.	to gain knowledge a vill be performed, as v	ment of multimedia bout future research well as the writing-up e leading magazines,
2	multimedia students wil • Search • Analys • Write	all acquire profound	ems and applicat ng competencies: vant scientific liter lex technical and fic abstracts and su	ions which will bu rature. scientific informati	ild the future Intern	rds and literature on net. In so doing, the
3				tworks. Lectures is	n Communication N	etworks I and II are
4		m: le exam (Study achie				d in the beginning of
5	-	e for the award of c	· ·			
6	Grading Module exan • Modul	m: le exam (Study achie	vement, Oral/writ	tten examination, V	Weighting: 100 %)	
7		<b>the module</b> DT, M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	l M.Sc. iST		
8	Grade bonu	is compliant to §25	(2)			
9	<b>References</b> Depending of	on specific topic (sele	ected articles of ion	urnals, magazines.	and conferences).	
Co	irses	1				

	Course nr. 8-sm-2090-se	<b>Course name</b> Multimedia Communications Seminar II		
P	<b>nstructor</b> Prof. Dr. rer. nat Altenhofen	. Björn Scheuermann, Dr. Ing. Julian Zobel, M.Sc. Konrad	<b>Type</b> Seminar	<b>SWS</b> 2

	<b>dule name</b> ltimedia Com	munications Project	II			
Мо	<b>dule nr.</b> sm-2130	Credit points 9 CP	Workload 270 h	Self-study 180 h	Module duration 1 Term	Module cycle Every Semester
Lar	<b>nguage</b> rman/English	,		Module owner	Björn Scheuermann	
1	Teaching co The course of systems. Be selected acc scientific con • Netwo • Perform • Discre • Protoc • Infrast • Conter • Peer-to • Conter • Multim • Web se	leals with cutting edg sides a general over	view it provides a fic working areas more of the follow fic analysis network application or network services c networks / sensec mobile communition and services rchitectures anagement system re-authoring tools	evelopment topics a deep insight into of the participatin ving topics: ons es or networks cation / mesh netw ns for multimedia /	in the area of multim a special scientific t g researchers and c	edia communication opic. The topics are onvey technical and
2	future multi acquired. Ac • Search • Desigr • Impler • Applic • Acquis • Systen • Writin	to solve and evaluate	on networks and a are: project relevant lite nication application of software compo- ted analysis and d agement technique analyzing of techni entation and proje	applications using s erature ns and protocols onents for distribute esign techniques es for small develop nical and scientific e ect reports	state of the art scient ed systems pment teams	and development of ific methods shall be
3	Keen interes nications sys Solid e Solid l Basic l Solid l	ded prerequisites for at to develop and explo- stems using scientific experience in program knowledge in object of knowledge of design knowledge in comput- res in "Communicatio	lore challenging so methods. Further mming Java and/o priented analysis a patterns, refactor ter communication	we expect: or $C#$ (C/C++). and design. ing and project man n networks is recom	nagement. nmended.	e multimedia commu-
4	Report (incl Colloquium	m: e exam (Study achie uding submission of	programming co	de) and/or Preser	ntation and/or Oral	examination and/or be announced in the

5	-	<b>the award of credit points</b> module examination		
6	Grading Module exam: • Module exa	m (Study achievement, Oral/written examination, Weighting	: 100 %)	
7	Usability of the M.Sc. iCE, B.Sc.			
8	Grade bonus con	npliant to §25 (2)		
9	chapters from fol Andrew Tan Raj Jain: " Measureme Joshua Bloo Erich Gami Software" ( Martin Fow	rered by a selection of papers and articles. In addition we re- lowing books: henbaum: "Computer Networks". Prentice Hall PTR (ISBN 013 The Art of Computer Systems Performance Analysis: Techni- ent, Simulation, and Modeling" (ISBN 0-471-50336-3) th: "Effective Java - Programming Language Guide" (ISBN-13: na, Richard Helm, Ralph E. Johnson: "Design Patterns: Object ISBN 0-201-63361-2) ler: "Refactorings - Improving the Design of Existing Code" (ISBN- "Extreme Programming Explained - Embrace Changes" (ISBN-	30384887) iques for Experimental 978-0201310054) ets of Reusable Object O SBN-13: 978-020148567	Design, riented
Coi	ırses			
	<b>Course nr.</b> 18-sm-2130-pr	<b>Course name</b> Multimedia Communications Project Lab		
	<b>Instructor</b> Prof. Dr. rer. nat Altenhofen	. Björn Scheuermann, Dr. Ing. Julian Zobel, M.Sc. Konrad	<b>Type</b> Lab	<b>SWS</b> 6

		Credit points	Workload	Self-study	Module duration	Module cycle
		4 CP	120 h			
	<b>nguage</b> rman/English			Module owner Prof. Dr. rer. nat.	Karsten Weihe	
1	that is consi explore the presenting s seminar pap The prospet the SEEMO Course cont - Indepenter (typically in - Own, enha - Interpretat	ed Seminar on Netwo dered highly relevant aforementioned rese selected first-rate rese per. active topics for the O group. ents: nt exploration of a top	t for the future de arch area by stud arch articles. Deli advanced semin pic in the area of r	velopment of the g ying, critically ana verables are a shor ar will be derive networking, securit	iven topic areas. Goa lyzing and discussing t presentation, a fina ed from the current ty, mobility, and wire	l of the seminar is t g, summarizing, and l presentation, and t research topics of
	<ul> <li>Presentation</li> <li>Technical of</li> <li>Feedback t</li> </ul>	on of both talks for a liscussion after the ta o the speakers and th ding the process of sc	heterogenous aud ılks ıe talks (including	ience (experts/nor presentation skills	i-experts)	ent
	After succes manner. The for the inve analysis of	ssfully attending the ey have aquired detai estigated topic area. scientific articles, and n defend their work a	led knowledge on Techniques such l the presentation	selected mechanis as thoroughly sur of the obtained r	ms, methodologies a veying literature, cr	s well as application itical discussion an
3		<b>ded prerequisites fo</b> participation of an lee				
ł	Form of exa Course relat • [20-00		hievement, Oral/v	vritten examinatio	n, Default RS)	
5	<b>Prerequisit</b> Pass exam (	e for the award of c	redit points			
_	<b>Grading</b> Course relat					

	B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaft B.Sc. Psychologie Joint B.A. Inform B.Sc. Sportwisse	sinformatik s in IT		
	-			
	Can be used in o	her degree programs.		
8	Grade bonus co	npliant to §25 (2)		
9	<b>References</b> Will be announce	d in seminar.		
Co	urses			
	<b>Course nr.</b> 20-00-0549-se	<b>Course name</b> Advanced Seminar on Networking, Security, Mobility, and W	ireless Communications	
	Instructor		Туре	SWS
	Prof. DrIng. Ma	thias Hollick	Seminar	3

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
			180 h	120 h	1 Term	Every 2. Semester
	<b>nguage</b> rman/English			Module owner Prof. Dr. rer. nat.	Karsten Weihe	
1	software de wireless co	ercise on Secure Mob evelopment. Topic ar mmunications as we ation in software or ha	eas covered are colling and the combination of the	ommunication net tion of these. Go	works, IT security, n	nobile networks and
	<ul> <li>Solving of communica</li> <li>Survey on</li> <li>Conception</li> <li>Software/2</li> <li>Prototypic</li> <li>Evaluation</li> </ul>	f a problem in the ar	and discussion of ecture or a combin he target platform arget platform espect to performa	pros and cons ned hardware-softw 1		tworks and wireles
2						
3		ded prerequisites fo participation in an lea				
4	Form of ex Course rela • [20-0		hievement, Oral/v	vritten examinatio	n, Default RS)	
5	<b>Prerequisit</b> Pass exam (	e for the award of cr (100%)	redit points			
5	Grading	tod ovom.				
	Course rela • [20-0	0-0552-pr] (Study ac	hievement, Oral/v	vritten examinatio	n, Weighting: 100 %)	)
6 7	• [20-0 Usability o B.Sc. Inforr M.Sc. Inforr M.Sc. Wirts B.Sc. Psych Joint B.A. In	0-0552-pr] (Study act f <b>the module</b> natik matik chaftsinformatik ologie in IT		vritten examinatio	n, Weighting: 100 %)	)
6	• [20-0 Usability o B.Sc. Inform M.Sc. Inform M.Sc. Wirts B.Sc. Psych Joint B.A. In B.Sc. Sport	0-0552-pr] (Study act f <b>the module</b> natik matik chaftsinformatik ologie in IT nformatik	ormatik	vritten examinatio	n, Weighting: 100 %)	)

9	<b>References</b> Will be given in	lah		
	will be given ill	iaD.		
Cot	urses			
	Course nr.	Course name		
	20-00-0552-pr	Secure Mobile Networking Lab		
	Instructor		Туре	SWS
	Prof. DrIng. Ma	tthias Hollick	Lab	4

Module nr. Credit points Workload		- 1		Self-study	Module duration	Module cycle	
	00-0582	3 CP	90 h	60 h	1 Term	Every 2. Semester	
	<b>iguage</b> man/English	l		Module owner Prof. DrIng. Ma	tthias Hollick		
1	given topic discussing, presentatio Course con - Indepente (typically ir - Own, enha - Interpreta - Preparatio - Presentati - Technical	ar on Networking, Sec areas. Under superv summarizing, and pre n, and a seminar pape tents: nt exploration of a top a english) anced literature study, tion and classification n of an introductory t on of both talks for a l discussion after the ta	rision of the tutor senting selected re- er. bic in the area of r gudided by tutor of the literature s alk as well as a fir heterogenous aud lks	s, the seminar ime esearch articles. De networking, securit study, gudided by t nal talk including p ience (experts/non	cludes studying, crit eliverables are a short ey, mobility, and wire utor presentation slides, gu -experts)	ically analyzing and presentation, a fina less communication idided by tutor	
2	<ul> <li>Feedback to the speakers and the talks (including presentation skills) and technical content</li> <li>Learning objectives         After successfully attending the course, students are able to work in a scientific manner under guidance. They have aquired intermediate knowledge on selected mechanisms, methodologies as well as application the investigated topic area. Students can present this aquired knowledge to a heterogeneous audience explain the technical details of the investigated topic.     </li> </ul>				nder guidance. The ll-defined topic area		
3	Recommer	ded prerequisites fo participation in a lect	r participation				
4	Form of ex Course rela • [20-0		hievement, Oral/v	vritten examination	n, Default RS)		
5	Prerequisit Pass exam	e for the award of cr (100%)	redit points				
6	Grading Course rela • [20-0	ted exam: 0-0582-se] (Study acł	hievement, Oral/v	vritten examination	n, Weighting: 100 %)	)	
7	B.Sc. Inform M.Sc. Inform M.Sc. Wirts B.Sc. Psych Joint B.A. In	matik schaftsinformatik ologie in IT	rmatik				
	Can be used	l in other degree prog	vrams.				
	Grade bonus compliant to §25 (2)						

9	References				
	Depending on to	pic.			
Cot	ırses				
	Course nr.	Course name			
	20-00-0582-se	Seminar on Networking, Security, Mobility, and Wireless Cor	nmunications		
	Instructor		Туре	SWS	
	Prof. DrIng. Ma	tthias Hollick	Seminar	2	

20-	odule nr. C	redit points 6 CP				Module cycle
Language German			180 h	h 120 h 1 Term Every 2. Semeste Module owner DrIng. Michael Kreutzer		
1	specifically targ - Design and im - Design and im - Modifications - System progra Learning object After successful	l course, the stud get the open-source plementation of se of the Android M mming in genera ctives lly completing th	te Android OS and selected software a ecure user apps iddleware and Ker l is lab students with	l comprise the follo attacks (ethical hac nel to build securit ill have gained kno	king) y architectures wledge and hands-o	on expercience wit
3	programming i Recommended - Basics operati	security mechanisms in modern smartphone operating systems. Futhermore they gain experience in system programming in general. Recommended prerequisites for participation - Basics operating systems				
4	Form of exami Course related	<ul> <li>Knowledge in C++ and Java</li> <li>Form of examination</li> <li>Course related exam:</li> <li>[20-00-0615-pr] (Study achievement, Oral/written examination, Default RS)</li> </ul>				
5	Prerequisite for Pass exam (100	or the award of c	redit points			
6	<b>Grading</b> Course related	exam:	hievement, Oral/v	vritten examinatio	n, Weighting: 100 %)	)
7	<ul> <li>[20-00-0615-pr] (Study achievement, Oral/written examination, Weighting: 100 %)</li> <li>Usability of the module         B.Sc. Informatik          </li> <li>M.Sc. Informatik         M.Sc. Wirtschaftsinformatik          </li> <li>B.Sc. Psychologie in IT          Joint B.A. Informatik          B.Sc. Sportwissenschaft und Informatik      </li> </ul>					
	Joint B.A. Infor	matik	ormatik			
	Joint B.A. Infor B.Sc. Sportwiss Can be used in	matik enschaft und Info other degree prog	grams.			
3	Joint B.A. Infor B.Sc. Sportwiss Can be used in	matik enschaft und Info	grams.			
	Joint B.A. Infor B.Sc. Sportwiss Can be used in	matik enschaft und Info other degree prog ompliant to §25	grams.			
9	Joint B.A. Infor B.Sc. Sportwiss Can be used in Grade bonus c References	matik enschaft und Info other degree prog ompliant to §25	grams.			
8 9 Co	Joint B.A. Infor B.Sc. Sportwiss Can be used in Grade bonus c References Will be given ir	matik enschaft und Info other degree prog ompliant to §25 a lab. Course name	grams. (2)	Security		

	<b>dule name</b> vacy-Preservi	ing Technologies				
<b>Module nr.</b> 20-00-0935		Credit points 3 CP	Workload 90 h	Self-study 60 h	Module duration 1 Term	Module cycle Every 2. Semester
Language English			<b>Module owner</b> DrIng. Michael	Kreutzer		
1	by compan In this sem encryption practical iss Small group a written re Possible top - Privacy-pr - Privacy-pr - Privacy-pr - Privacy-pr - Privacy-pr - Represent - Tools for p	oil of the 21st century ies like Facebook or G inar, we will look at without revealing the sues of such solutions. os of students choose a eport and present in a bics include: eserving biometric ide reserving mobile appli- reserving download of reserving finding of co reserving checking for ing functions as data privacy-preserving app	oogle, as well as b techniques for pro- e data itself. We a topic for which th talk. entification cations, e.g., for lo files, e.g., for mea mmon contacts or credit worthiness (Universal Circuits plications	by intelligence serv otecting privacy the will investigate boot hey get two or thre ocation-based serving dical or patent data customers (Private (Private Function (S)	ices. at allow to process a th the theoretical ba e publications that th ces abases (Private Inform e Set Intersection)	sensitive data under ckground as well as ey will summarize in nation Retrieval)
2	Learning o	ls: Weitere Details: ht b <b>jectives</b> arn state-of-the-art ar			z privacy.	
3	Recommen Basic know	nded prerequisites for ledge in applied crypto hy" and ideally also "(	or participation ography is required	l, e.g., by successfu	Illy completing the co	urse "Introduction to
4	Form of ex Course rela • [20-0		hievement, Oral/v	vritten examinatio	n, Default RS)	
5	Prerequisi Pass exam	te for the award of c (100%)	redit points			
6	Grading Course rela • [20-0	ited exam: 0-0935-se] (Study ac	hievement, Oral/v	vritten examinatio	n, Weighting: 100 %	)
7	B.Sc. Inform M.Sc. Inform		grams.			
8	Grade bon	us compliant to §25	(2)			
9	References	3				
	urses					

<b>Course nr.</b> 20-00-0935-se							
<b>Instructor</b>	Kreutzer	<b>Type</b>	SWS				
DrIng. Michael		Seminar	2				

Mo		rotocols in embedd Credit points	Workload	Self-study	Module duration	Module cycle
	00-1064	6 CP	180 h	120 h	1 Term	Every 2. Semester
Lar	guage			Module owner		
Ger	man			Prof. Dr. rer. nat.	Eberhard Mühlhäus	er
1 2	a project with The main focu on the selecte as well as labe <b>Learning obj</b> After success protocols and	internship, student embedded hardwa s is on Bluetooth LH d project topic, har pratory environmer ectives ully completing th	are. In addition, as E, Bluetooth Mesh, dware (microcont nt (logic analyzers ne module, studen	spects of IT securit LoRaWAN and com rollers, FPGAs, RF , RF analyzers, osc ts will be able to o	dio protocols and ind y are also taken into munication via OOB transceivers, softwar illoscopes, etc.) are p leal with complex sp ical handling of eml	account. channels. Dependin e defined radio, etc. provided. pecifications of radio
3	Previous know and Embedde the programm	d Systems (compuls ing language C ar	r networks (compu sory lectures Comp ad basic knowledge	outer Organization e of electrical engin	puter Networks and and / or Data Engine neering are helpful, a ed systems "such as T	eering) Knowledge o as well as knowledg
4	The form of the form	l exam: [064-pr] (Study ac ne examination wil	l be announced at ossible. Report (oj	the beginning of	n, Default RS) he course. One or a submission of sourc	
	Course related • [20-00- The form of the two of the for (optional: incl	l exam: 1064-pr] (Study ac ne examination wil lowing forms is po uding presentation for the award of c	ll be announced at ossible. Report (op 1).	the beginning of	the course. One or a	
5	Course related • [20-00- The form of the two of the for (optional: incl <b>Prerequisite</b> Pass exam (10) <b>Grading</b> Course related	l exam: 1064-pr] (Study ac ne examination wil lowing forms is po uding presentation for the award of c 10%)	ll be announced at ossible. Report (op 1). <b>redit points</b>	the beginning of t	the course. One or a	e code), colloquiun
4 5 6 7	Course related • [20-00- The form of the two of the form (optional: incl <b>Prerequisite</b> Pass exam (100 <b>Grading</b> Course related • [20-00- Usability of the B.Sc. Information M.Sc. Information	l exam: 1064-pr] (Study ac ne examination wil lowing forms is po- uding presentation for the award of c 10%) d exam: 1064-pr] (Study ac ne module tik	ll be announced at ossible. Report (oj 1). <b>redit points</b> hievement, Oral/v	the beginning of t	the course. One or a submission of sourc	e code), colloquiun
5 6 7	Course related • [20-00- The form of the two of the form (optional: incl Prerequisite Pass exam (10) Grading Course related • [20-00- Usability of the B.Sc. Information May be used interval and the B.Sc. Information May be used interval and the Course related • [20-00- • [20-00-	d exam: 1064-pr] (Study ac the examination will lowing forms is po- uding presentation for the award of c 10%) d exam: 1064-pr] (Study ac he module tik tik	l be announced at ossible. Report (op i). <b>redit points</b> hievement, Oral/v	the beginning of t	the course. One or a submission of sourc	e code), colloquiur
5 6 7 8	Course related • [20-00- The form of the two of the form (optional: incl Prerequisite Pass exam (10) Grading Course related • [20-00- Usability of the B.Sc. Information May be used interval and the B.Sc. Information May be used interval and the Course related • [20-00- • [20-00-	l exam: 1064-pr] (Study ac ne examination wil lowing forms is po- uding presentation for the award of c 1064-pr] (Study ac he module tik tik n other degree pro	l be announced at ossible. Report (op i). <b>redit points</b> hievement, Oral/v	the beginning of t	the course. One or a submission of sourc	e code), colloquiur
5 6 7 8 9	Course related • [20-00- The form of the two of the form (optional: incle Prerequisite Pass exam (10) Grading Course related • [20-00- Usability of the B.Sc. Information M.Sc. Information May be used in Grade bonus	l exam: 1064-pr] (Study ac ne examination wil lowing forms is po- uding presentation for the award of c 1064-pr] (Study ac he module tik tik n other degree pro	l be announced at ossible. Report (op i). <b>redit points</b> hievement, Oral/v	the beginning of t	the course. One or a submission of sourc	e code), colloquiur
5 6 7 8 9	Course related • [20-00- The form of the two of the form (optional: incle Prerequisite Pass exam (10) Grading Course related • [20-00- Usability of the B.Sc. Information M.Sc. Information May be used in Grade bonus References	d exam: 1064-pr] (Study ac the examination will lowing forms is po- uding presentation for the award of c 1064-pr] (Study ac the module tik tik n other degree pro- compliant to §25 Course name	l be announced at ossible. Report (op i). redit points hievement, Oral/v grams. (2)	the beginning of the ptional: including	the course. One or a submission of sourc	e code), colloquiun

<b>Module nr.</b> 18-zo-2040		in Statistical Signal Credit points 8 CP	Workload 240 h	Self-study 180 h	Module duration	Module cycle Winter term	
	<b>nguage</b> glish	I	I	<b>Module owner</b> Prof. DrIng. Abo	lelhak Zoubir	I	
1	topics in sta Applications Processing, f from semest The course i The main to • Estima • Detect • Robus • Semin	covers the fundame tistical signal proces ; Robust Estimation; Direction of Arrival E er to semester. ncludes a series of lec pics covered are: ation theory ion theory t estimation theory ar projects: e.g., m	sing. Applications Prediction, Filterir stimation, and Sou ctures followed by icrophone arrays/	s are typically from ng, and Tracking w urce Detection; Tim a supervised resear /beamforming, loc	heory. These are ext in the following areas ith the Kalman Filter; he-Frequency Analysis rch seminar over appr calization and tracking	Detection in Rada Sensor Array Signa Topics may chang roximately 2 months	
	imaging, acoustic source localization, estimation of number of sources         Learning objectives         After completing the module, students will be able to work independently on advanced topics in signal processing						
2	Learning ol After comple	<b>ojectives</b> eting the module, stud	lents will be able to	o work independen			
	Learning of After comple and reprodu Recommen	<b>ojectives</b> eting the module, stud	lents will be able to he students can p <b>or participation</b>	o work independen	tly on advanced topics		
2 3 4	Learning of After comple and reprodu Recommen DSP, genera Form of exa Module exat • Modul	ojectives eting the module, stud ace existing results. T ded prerequisites for l interest in signal pr mination m: e exam (Study achie	dents will be able to the students can p or participation occessing wement, Oral/writ	o work independen resent these result tten examination, I	tly on advanced topics s and discuss them so	ientifically.	
3	Learning of After comple and reprodu Recommen DSP, genera Form of exa Module exat • Modul Report and/ the lecture. Prerequisit	ojectives eting the module, stud ace existing results. T ded prerequisites for l interest in signal pr mination m: e exam (Study achie	dents will be able to the students can p or participation occessing evement, Oral/write or Colloquium. Th redit points	o work independen resent these result tten examination, I	tly on advanced topics s and discuss them so Default RS)	ientifically.	
3 4 5	Learning of After complete and reproduct Recomment DSP, generat Form of exat Module exat • Modul Report and/ the lecture. Prerequisite Passing the Grading Module exat	ojectives eting the module, stuc- ice existing results. T ded prerequisites for l interest in signal pr inination m: e exam (Study achie or Presentation and/ e for the award of c final module examina	dents will be able to the students can p or participation rocessing evement, Oral/write or Colloquium. Th redit points ation	o work independen resent these result tten examination, I te type of examinat	tly on advanced topics s and discuss them so Default RS) ion will be announced	ientifically.	
3	Learning of After complete and reprodut Recommen DSP, genera Form of exat Module exat • Modul Report and/ the lecture. Prerequisite Passing the Grading Module exat • Modul Usability of	ojectives eting the module, stud ice existing results. T ded prerequisites for l interest in signal pr imination m: e exam (Study achie or Presentation and/ e for the award of c final module examina- m: e exam (Study achie	lents will be able to the students can p or participation focessing evement, Oral/write or Colloquium. Th redit points ation	o work independen resent these result tten examination, I te type of examinat	tly on advanced topics s and discuss them so Default RS) ion will be announced	d in the beginning o	

- Lecture slides
- Jerry D. Gibson and James L. Melsa. Introduction to Nonparametric Detection with Applications. IEEE Press, 1996.
- S. Kassam. Signal Detection in Non-Gaussian Noise. Springer Verlag, 1988.
- S. Kay. Fundamentals of Statistical Signal Processing: Estimation Theory. Prentice Hall, 1993.
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  Louis L. Scharf. Statistical Signal Processing: Detection, Estimation, and Time Series Analysis. Pearson
- Education POD, 2002.Harry L. Van Trees. Detection, Estimation, and Modulation Theory, volume I,II,III,IV. John Wiley & Sons, 2003.
- A. M. Zoubir and D. R. Iskander. Bootstrap Techniques for Signal Processing. Cambridge University Press, May 2004.

#### Courses

00	uises			
	18-zo-2040-se	Advanced Topics in Statistical Signal Processing		
	Instructor		Туре	SWS
	Prof. DrIng. Ab	delhak Zoubir, M.Sc. Pertami Kunz	Seminar	4

18-zo-2050         8 CP         240 h           Language         M				Self-study 180 h	Module duration 1 Term	Module cycle Summer term
		Module owner Prof. DrIng. Abc	L	Summer term		
1	Teaching co Signal detect many comm estimation we estimation we estimation so These lecture • Funda • Hypot - B - R - U - M • Estimat - T - M - S - U - F	tion and parameter on engineering opera vill be presented, allo	tions under a varie wing a better und and Estimation T ver/Neyman-Pears aracteristics ful Tests d Estimators sher-Neyman/Fact imum variance d the CRB	ndamental signal ety of names. In the erstanding of how heory son Tests	processing tasks. In is course, the theory l (and why) to design	pehind detection ar
2	can design ł In addition,	<b>ojectives</b> sful completion of th aypothesis tests and e students will be able present the methods	estimators for exis to review existing	ting problems and g work on detectior	implement them in and estimation inde	Matlab on their ow pendently. They ca
3	Recommen	<b>ded prerequisites fo</b> l interest in signal pr	r participation	01		
4						d in the beginning
5		e for the award of cr				
5	Grading Module exa • Modul	n: e exam (Study achie	vement, Oral/writ	tten examination, V	Weighting: 100 %)	
7	•	<b>the module</b> KTS, M.Sc. etit - VAS,	M.Sc. iCE, M.Sc.	MedTec, M.Sc. W	I-etit, B.Sc. und M.Sc	. iST, M.Sc. CE
8	Crede here	s compliant to §25				

9	References						
	<ul> <li>Press, 1996</li> <li>S. Kassam.</li> <li>S. Kay. Fun 1993.</li> <li>S. Kay. Fun</li> <li>E. L. Lehma</li> <li>E. L. Lehma</li> <li>Leon-Garci 1994.</li> <li>P. Peebles.</li> <li>H. Vincent 1994.</li> <li>Louis L. Sc Education I</li> <li>Harry L. Va 2003.</li> </ul>	oson and James L. Melsa. Introduction to Nonparametric I Signal Detection in Non-Gaussian Noise. Springer Verlag, 1 damentals of Statistical Signal Processing: Estimation Theory damentals of Statistical Signal Processing: Detection Theory nn. Testing Statistical Hypotheses. Springer Verlag, 2nd ed nn and George Casella. Theory of Point Estimation. Spring a. Probability and Random Processes for Electrical Engineer Probability, Random Variables, and Random Signal Principle Poor. An Introduction to Signal Detection and Estimation. S narf. Statistical Signal Processing: Detection, Estimation, a	288. 79. Prentice Hall, 7. Prentice Hall, 1998. 197	999. 1 edition, on, 1993. on, Pearson y & Sons,			
Co	urses						
	<b>Course nr.</b> 18-zo-2050-se	<b>Course name</b> Signal Detection and Parameter Estimation					
	Instructor Prof. DrIng. Abo						

	dule name	· · · · · · · · · · · · · · · · · · ·				
	dule nr.	munications Lab II Credit points	Workload	Self-study	Module duration	Module cycle
18-	sm-2070	6 CP	180 h	135 h	1 Term	Every Semester
Lar	iguage			Module owner		
German/English Prof. Dr. rer. nat. Björn Scheuermann						
1	Besides a ge according to competencie • Netwo • Perform • Discre • Protoc • Infrast • Contex • Peer-to • Conter • Multim • Web se • Adapti • Natura	deals with cutting-e neral overview, it pro- the specific working es in one or more of t rk planning and traf- mance evaluation of te event simulation fe ols for mobile ad hoo ructure networks for tt-aware communica- o-peer systems and a nt distribution and m nedia authoring and ervice technologies a ve educational techn al language processir	ovides a deep insig areas of the particular the following topic fic analysis network application or network service c networks / sense c mobile communi- tion and services rchitectures anagement system re-authoring tools nd service-oriente aologies ng in education	ght into a special de cipating researchers cs: ons es or networks cation / mesh netw ns for multimedia/ d architectures	evelopment topic. Th s and convey technica vorks e-learning	munication systems. le topics are selected al and basic scientific
				ster on the corresp	onding teaching web	site of KOM.
2	nication net Design Impler Applic Acquis Writin		ns shall be acquir nication applicatio of software compo- ted analysis and d agement technique entation and proje	ed. Acquired composed. Acquired composed compo	etences are: ed systems	e multimedia commu-
3	Keen interes expect: • Solid e • Solid b • Solid b	ded prerequisites for st to explore challen experience in program knowledge in object of knowledge in compu- es in Communication	nging topics which mming Java and/o oriented analysis a ter communication	or C# (C/C++) and design n networks are reco	ommended	esearch. Further we
4	Report (inclu and/or Collo the beginnin	n: e exam (Study achie uding submission of p oquium (testate), but ng of the lecture.	programming code t never more than	) and/or Presentati	on and/or Oral exam	ination (25 minutes) will be announced in
5		e for the award of c				

6	<ul><li>Grading</li><li>Module exam:</li><li>Module exam (Study achievement, Oral/written examination, Weighting: 100 %)</li></ul>							
7	•	Usability of the module						
8	-	M.Sc. etit - DT, M.Sc. iCE, M.Sc. WI-etit, B.Sc. und M.Sc. iST Grade bonus compliant to §25 (2)						
9	chapters from fo Andrew Ta Christian U 6" (ISBN-1: Joshua Blo Erich Gam Software" (	rered by a selection of papers and articles. In addition we re- lowing books: nenbaum: "Computer Networks". Prentice Hall PTR (ISBN 013 llenboom: "Java ist auch eine Insel: Programmieren mit der Ja 3: 978-3898428385) ch: "Effective Java Programming Language Guide" (ISBN-13: 9 na, Richard Helm, Ralph E. Johnson: "Design Patterns: Object ISBN 0-201-63361-2) "Extreme Programming Explained - Embrace Changes" (ISBN	30384887) wa Standard Edition 978-0201310054) cts of Reusable Objec	Version 5 / ct Oriented				
Co	urses							
	<b>Course nr.</b> 18-sm-2070-pr	<b>Course name</b> Multimedia Communications Lab II						
	Instructor Prof. Dr. rer. na Altenhofen	<b>Type</b> Lab	<b>SWS</b> 3					

# 2.3 Communication Algorithms

# 2.3.1 Communication Algorithms - Lectures

<b>Module nr.</b> 18-kp-1010		Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Winter term
Language English			I	<b>Module owner</b> Prof. Dr. techn. H	leinz Köppl	1
1	theory. Outline: information channels, ba channel coo bandwidth	ontent course introduces the , uncertainty, entropy, asics of source and ch ling theorem, capacit efficiency, capacity of unel, Broadcast Cham	, mutual informati annel coding, line ty of Gaussian cha multiple parallel o	on, capacity, differe ar block codes, Sha annels, capacity of	ential entropy, typical annon's source coding bandlimited channe	sequences, Gaussian theorem, Shannon' ls, Shannon's bounc
2	Learning of Upon compl theory.	<b>bjectives</b> letion of the module, s	students will have	an understanding	of the fundamentals o	of classic information
3		<b>ded prerequisites fo</b> edge of probability th				
4	Form of exa Module exa • Modu		camination, Exam	ination, Duration:	120 Min., Default RS	3)
5		e for the award of c				
6	<b>Grading</b> Module exa			ination, Weighting	: 100 %)	
7	•	f <b>the module</b> .Sc. WI-etit, M.Sc. et	it - CMEE, M.Sc. i	CE, B.Sc. und M.S	c. iST, B.Ed. etit, B.S	c. CE, M.Sc. CE
7	B.Sc. etit, B.Sc. WI-etit, M.Sc. etit - CMEE, M.Sc. iCE, B.Sc. und M.Sc. iST, B.Ed. etit, B.Sc. CE, M.Sc. CEGrade bonus compliant to §25 (2)					
8						

<b>Course nr.</b> 18-kp-1010-vl					
Instructor	Heinz Köppl, M.Sc. Anam Tahir	<b>Type</b>	<b>SWS</b>		
Prof. Dr. techn.		Lecture	3		
<b>Course nr.</b> 18-kp-1010-ue	<b>Course name</b> Information Theory I: Fundaments				
Instructor	Heinz Köppl, M.Sc. Anam Tahir	<b>Type</b>	<b>SWS</b>		
Prof. Dr. techn.		Practice	1		

	<b>dule name</b> ormation Theor	y II: Networks					
Мо		Credit points 6 CP	Workload 180 h	Self-study 120 h	Module durat	ion Module cy Summer te	
Lar	<b>iguage</b> glish		l	Module owner Prof. DrIng. Mat	rius Pesavento		
1	ITeaching contentThis lecture course is devoted to topics in network information theory. Outline: overview of Shannon capacity, outage and ergodic capacity, capacity of channels with state, capacity of Gaussian vector channels, capacity regions of multi-user channels, capacity regions of multiple-access and broadcast fading channels, interference channel, relay channel, multiuser bounds, graphical multi-hop networks, routing, network coding, capacity of MIMO multiple-access and broadcast channels, duality of MIMO multiple access and broadcast channels, dirty paper coding, multi-user diversity, wiretap channel, secrecy rate and physical layer security.						
2	Learning obj Upon complet network infor	ion of the module,	students will have	an understanding o	of the advanced	concepts and strat	egies in
3		ed prerequisites for basic communication					
4	The examinat students regis	exam (Technical e ion takes place in f	form of a written e n will be an oral ex	written examinatio exam (duration: 12 camination (duratio	0 minutes). If a	pparent that less	than 10
5		f <b>or the award of c</b> al module examin					
6	Grading Module exam • Module		xamination, Oral/	written examinatio	n, Weighting: 1	00 %)	
7	<b>Usability of t</b> M.Sc. etit - Cl		TS, M.Sc. etit - VA	S, M.Sc. iCE, M.Sc.	WI-etit, B.Sc.	und M.Sc. iST, M.S	Sc. CE
8	Grade bonus	compliant to §25	(2)				
9	References						
	• T.M. Co	ver and J.A. Thoma	as, Elements of Inf	rk Information The ormation Theory, V Vireless Communic	Viley Sons, 1992	l.	s, 2005.
Co	ırses						
	<b>Course nr.</b> 18-pe-2010-v	Course name Information T	heory II: Network	S			1
	<b>Instructor</b> Prof. DrIng.	Marius Pesavento			<b>Typ</b> Lect		<b>SWS</b> 3

<b>Course nr.</b> 18-pe-2010-ue	<b>Course name</b> Information Theory II: Networks		
Instructor Prof. DrIng. Ma	rius Pesavento, M.Sc. Lukas Schynol	<b>Type</b> Practice	<b>SWS</b> 1

	<b>dule name</b>	nication and Space-Ti	ime-Coding			
Мо	<b>dule nr.</b> ja-2010	Credit points 4 CP	Workload 120 h	Self-study 75 h	Module duration 1 Term	Module cycle Winter term
Lar	Language English			Module owner Prof. DrIng. Vahid Kooshkghazi		
1	Teaching co This lecture nications. Outline: Mon models, MIM space-time b decoders, d diversity, BE	course introduces the tivation and backgrou IO information theory block code, orthogona ifferential space-time	ind; overview of sp y, receive and trans al space-time bloc e block coding; N	ce-time and multip pace-time and MIM smit diversity; chan k codes; linear disp IIMO with limited	le-input multiple-out O communications; f nel estimation, MIMO persion codes; cohere feedback, Multianto	put (MIMO) commu- ading MIMO channel D detectors, Alamouti ent and non-coherent enna- and multiuser ulticell and multiuser
2	Learning of Students wi	<b>ojectives</b> ll understand moderr	n MIMO communi	cations and existin	g space-time coding	techniques.
3		<b>ded prerequisites fo</b> of basic communication		ic information the	ory.	
4	The examin less than 10	m: e exam (Technical ex ation takes place in	form of a written e examination w	n exam (duration: ill be an oral exam	120 minutes). If or	n., Default RS) ne can estimate that 0 min.). The type of
5		e for the award of cr final module examina				
6	Grading Module exan • Modul	m: e exam (Technical ex	amination, Oral/	written examinatio	on, Weighting: 100 %	))
7	-	the module KTS, M.Sc. etit - VAS,	, M.Sc. iCE, M.Sc.	MEC, M.Sc. WI-et	it, B.Sc. und M.Sc. is	ST
8	Grade bonu	is compliant to §25	(2)			
9	and So • E.G.La Press, • A.Paul sity Pr • Lin Ba • Howar Netwo	ons, 2005. ursson and P.Stoica, S 2003; raj, R.Nabar, and D.G ress, 2003. i and Jinho Choi, Lov	pace-Time Block fore, Introduction w Complexity MIN	Coding for Wireless to Space-Time Wire MO detectors, Sprir	s Communications, C eless Communication 1ger, 2012.	mmunications, Wiley Cambridge University s, Cambridge Univer- unication for Cellular
C01	urses					

<b>Course nr.</b> 18-ja-2010-vl	<b>Course name</b> MIMO - Communication and Space-Time-Coding		
<b>Instructor</b> Prof. DrIng. Val	nid Kooshkghazi	<b>Type</b> Lecture	<b>SWS</b> 2
<b>Course nr.</b> 18-ja-2010-ue	<b>Course name</b> MIMO - Communication and Space-Time-Coding		
<b>Instructor</b> Prof. DrIng. Val	nid Kooshkghazi	<b>Type</b> Practice	<b>SWS</b> 1

	<b>dule nr.</b> pe-2060	Credit points 4 CP	Workload 120 h	Self-study 75 h	Module duration 1 Term	Module cycle Summer term
Language English			Module owner Prof. DrIng. Marius Pesavento			
1	Outline: Mo Direction-of traditional r based meth mum Likeli processing, backward a sensing and Adaptive be Point-sourc (MVDR) be beamformin based beam	ontent e course introduces the otivation and backgrou f-arrival estimation (D nethods based on beau ods, MUSIC, ESPRIT, hood methods, Expect array interpolation, p averaging, redundance l sparse reconstruction e model, covariance amformer, Capon Bea ang, Hung-Turner proj former, non-stationar forming, multiuser be	und; applications, <u>boA):</u> mforming, super r MODE, root-MUS station Maximizat artly calibrated ar y averaging, corr n based DoA estim model, Wiener-H umformer, sample ection beamformer y environments, m	narrowband and esolution methods, IC, multidimensior ion (EM) algorithm rays, wideband DC elated sources, m nation, performance topf equation, Min matrix inversion, er, Generalized Sid	wideband signal mod Maximum-Likelihoo nal source localization m, partial relaxation OA estimation, spatial inimum redundancy e bounds himum Variance Dist signal self-nulling ef lelobe canceller bean	el d methods, Subspac n, approximate Max method, beamspac smoothing, forward arrays, compresse cortionless Respons fect, robust adaptiv nformer, Eigenspace
2	Learning o Upon comp			earned the applicat	ion of theory and algo	rithms for processin
3	Recommen	in linear algebra.	r participation			
4	The examination 10 The examination 10 The examination of the second seco		form of a writter e examination wi	exam (duration: ll be an oral exam	120 minutes). If or	ne can estimate tha
5	Prerequisit	e for the award of cr final module examination	redit points			
6	<b>Grading</b> Module exa • Modu	m: le exam (Technical ex	amination, Oral/	written examinatio	on, Weighting: 100 %	)
7		<b>f the module</b> it, M.Sc. etit - KTS, M.	Sc. etit - SAE, M.S	c. etit - VAS, M.Sc.	iCE, M.Sc. MEC, M.S	Sc. WI-etit, B.Sc. un
	Grade bon					

- 1. Academic Press Library in Signal Processing: Volume 3 Array and Statistical Signal Processing Edited by Rama Chellappa and Sergios Theodoridis, Section 2, Edited by Mats Viberg, Pages 457-967 (2014) a) Chapter 12 - Adaptive and Robust Beamforming, Sergiy A. Vorobyov, Pages 503-552
  - b) Chapter 14 DOA Estimation Methods and Algorithms, Pei-Jung Chung, Mats Viberg, Jia Yu, Pages
  - 599-650 c) Chapter 15 - Subspace Methods and Exploitation of Special Array Structures, Martin Haardt, Marius
  - Pesavento, Florian Roemer, Mohammed Nabil El Korso, Pages 651-717
- 2. Spectral Analysis of Signals, Petre Stoica, Randolph Moses, Prentice Hall, April 2005Optimum Array Processing: Part IV of Detection, Estimation, and Modulation Theory, Harry L. Van Trees, Wiley Online, 2002.

## C

Course nr.	Course name		
18-pe-2060-vl   Sensor Array Processing and Adaptive Beamforming			1
Instructor		Туре	SWS
Prof. DrIng. Ma	rius Pesavento	Lecture	2
Course nr.	Course name		
18-pe-2060-ue	Sensor Array Processing and Adaptive Beamforming		
Instructor	·	Туре	SWS
Prof. DrIng. Ma	rius Pesavento, M.Sc. Raphael Müller	Practice	1

English       Prof. DrIng. Marius Pesavento         1       Teaching content         The course covers the following topics:       • Motivation, Applications         • Fundamentals       - definition of graphs, classes of graphs, properties of graphs, signals defined over graphs         • Adjecency matrix, Graph Laplacian, Graph shift operator       - Covariance matrix, conditional dependence, precision matrix         • Graph signal processing       - Consensus, Diffusion       - Graph spectral analysis, Graph Fourier Transform         • Total variational norm, Graph Frequencies       - Bandlimited graph signals, smoothness       - Graph filters, Graph sampling theorem         • Applications       • Network topology inference       - Link prediction         • Association network inference       - Tomographic network topology inference       - Paarson product-moment correlation         • Conditional independence graph       - Gaussian Markov Random Fields       - Graph analysis         • Graph analysis       - Subgraph identification       - Clayleus identification         • Optimization over graphs       - Average consensus, diffusion, exact diffusion         • Graph neuronal (convolutional) network       - Applications         • Subgraph identification       - Graph neuronal (convolutional) network         2       Learning objectives       - Applications         • Graph neuronal (convolutional) networ		o <b>dule nr.</b> -pe-2080	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	<b>Module cycle</b> Winter term
The course covers the following topics:         • Motivation, Applications         • Fundamentals         - definition of graphs, classes of graphs, properties of graphs, signals defined over graphs         - Adjecency matrix, Graph Laplacian, Graph shift operator         - Covariance matrix, conditional dependence, precision matrix         • Graph signal processing         - Consensus, Diffusion         - Graph spectral analysis, Graph Fourier Transform         - Total variational norm, Graph Frequencies         - Bandlimited graph signals, smoothness         - Graph filters, Graph sampling theorem         - Applications         • Network topology inference         - Tomographic network inference         - Pearson product-moment correlation         - Causality, Partial correlation         - Gaussian Markov Random Fields         - Graphical LASSO, Graphical LASSO with Laplacian constraint         - Applications         • Subgraph identification         - Cliques identification         • Craph neuronal (convolutional) network         • Applications         • Average consensus, diffusion, exact diffusion         - Graph analysis         • Subgraph identification         • Cliques identification         • Optimization over graphs         • Aver	<b>Language</b> English						
<ul> <li>Graph signal processing (i.e., the processing of signals defined over graphs) and network analysis form interdisciplinary research field with numerous and diverse applications. Upon completion of the module, studen will have gained systematic knowledge in graph signal processing theory, graph network analysis, graph topolo learning, optimization in graph networks, and learning using graph neural networks. They have learned essent concepts, algorithms and application areas of graph signal processing.</li> <li><b>Recommended prerequisites for participation</b></li> </ul>	1	The course • Motiv • Funda - 0 - 2 - 0 • Graph - 0 - 0 - 1 - 0 - 0 - 1 - 0 - 1 - 0 - 0 - 1 - 0 - 1 - 0 - 0 - 0 - 0 - 0 - 0 - 0 - 0	covers the following t ation, Applications amentals definition of graphs, c Adjecency matrix, Gra Covariance matrix, con a signal processing Consensus, Diffusion Graph spectral analysi Total variational norm Bandlimited graph sig Graph filters, Graph sa Applications ork topology inference Link prediction Association network in Comographic network in Comographic network in Conditional independe Gaussian Markov Rand Graphical LASSO, Grap Applications a analysis Subgraph identification Dization over graphs Average consensus, di Gradient tracking, pus Applications a neuronal (convolution	lasses of graphs, p ph Laplacian, Gra nditional depende s, Graph Fourier T a, Graph Frequenc nals, smoothness ampling theorem e nference topology inference ent correlation elation ence graph dom Fields phical LASSO with n ffusion, exact diffi sh-sum algorithm,	uph shift operator ence, precision mat Fransform ies the Laplacian constra	rix	r graphs
3 Recommended prerequisites for participation	2	Graph sign interdiscipl will have ga learning, op	al processing (i.e., th inary research field with ined systematic knowl otimization in graph ne	th numerous and c ledge in graph sigr etworks, and learn	liverse applications nal processing theo ing using graph net	. Upon completion of ry, graph network ana ural networks. They h	the module, studer lysis, graph topolo
	3	Recommer	ded prerequisites fo	r participation			

4 Form of examination

	<ul> <li>Module exam:</li> <li>Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS)</li> <li>In general, the examination takes place in form of a written exam (duration: 120 minutes). If up to 20 stu register in semesters in which the lecture does not take place, there will will be an oral examination (dura 20 min.). The type of examination will be announced within one working weeks after the end of the examination registration phase.</li> </ul>				
5	<b>Prerequisite for the award of credit points</b> Passing the final module examination				
6	Grading Module exam: • Module exa	am (Technical examination, Oral/written examination, Weight	ing: 100 %)		
7	Usability of the M.Sc. etit - CME iST, M.Sc. CE	<b>module</b> E, M.Sc. etit - KTS, M.Sc. etit - VAS, M.Sc. iCE, M.Sc. MedTec,	, M.Sc. WI-etit, B.Sc. 1	und M.Sc.	
8	Grade bonus co	mpliant to §25 (2)			
9	– www. – moodl • Further rea – Petar		cessing, Academic Pre	ess, 2018,	
Co	urses				
	<b>Course nr.</b> 18-pe-2080-vl	<b>Course name</b> Graph signal processing, learning and optimization			
	<b>Instructor</b> Prof. DrIng. Ma	rius Pesavento	<b>Type</b> Lecture	<b>SWS</b> 3	
	<b>Course nr.</b> 18-pe-2080-ue	<b>Course name</b> Graph signal processing, learning and optimization			
	Instructor Prof. DrIng. Mar Schynol	ius Pesavento, M.Sc. Yufan Fan, M.Sc. Tianyi Liu, M.Sc. Lukas	<b>Type</b> Practice	SWS 1	

	<b>dule name</b> aptive Filters					
	<b>dule nr.</b> zo-2010	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Summer term
Lar	<b>nguage</b> man/English			Module owner Prof. DrIng. Abdelhak Zoubir		
1	Teaching co	ontent		1101. Di. 1116. 1100		
	suitabl 2. Elabor station affine j 3. Analys proced 4. Deriva 5. Proced freque <b>Application</b> Parallel to th reduction pro- for adaptive It is planned	le cost functions. Tation of adaptive privary signals in non-stappojection, and the Rois of the adaptation lure. tion and analysis of the decomplete for the decomplete decomple	ocedures, which ationary environme LS algorithm are behaviour and o the Kalman filter a position of signals se reduction proce pplications are exp ed. Acoustic echo beamforming app n to Siemens Audi	allow to iteratively ents. Here, the adapt derived and extension control procedures as optimal filter for a into sub-bands for edures. lained. As an examplicancellation and fea- proaches are introdu- tiology Engineering	approach the optin ptive procedures such vively analysed. of adaptive filters l non-stationary input r the realization of c ple for the Weiner filt edback cancellation a uced. Group in Erlangen.	signals. Optimal filters in the er, the acoustic noise
2	Learning of Upon compl algorithms a the content For the admi will allow yo	letion of the module are derived, interpret of the lecture you are ission to the exam yo ou to acquire the know pic and present your	e, students were t ted and applied to e able to apply ada u give a talk about w-how to read and	aught the fundame examples of speec aptive filters to real t a topic in the dom l understand scient	h, audio and video p practical application ain of adaptive filters ific literature, familia	
3	Recomment Digital Signa	<b>ded prerequisites fo</b> al Processing	or participation			
4	The examination 21 students	n: e exam (Technical ex ation takes place in fo	orm of a written ex tion will be an ora	am (duration: 90 m		, Default RS) stimate that less than type of examination
5		e for the award of c				
6	<b>Grading</b> Module exar • Modul		xamination, Oral/	written examinatio	n, Weighting: 100 %	)
7	Usability of	the module				

	M.Sc. etit - KTS, M.Sc. etit - VAS, M.Sc. iCE, M.Sc. WI-etit, B.Sc. und M.Sc. iST, M.Sc. CE							
8	Grade bonus compliant to §25 (2)							
9	References							
	Slides of the lect	ure.						
	Literature:							
	<ul> <li>E. Hänsler,</li> </ul>	G. Schmidt: Acoustic Echo and Noise Control, Wiley, 2004 (Textbe	book of this course);					
	• S. Haykin:	Adaptive Filter Theory, Prentice Hall, 2002;						
	• A. Sayed: H	• A. Sayed: Fundamentals of Adaptive Filtering, Wiley, 2004;						
	<ul> <li>P. Vary, U. Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 1998 (in German)</li> </ul>							
	• P. Vary, U.	1 0. 1.	8 (in German)					
	• P. Vary, U.	1 0. 1.	8 (in German)					
Coι	• P. Vary, U.	1 0. 1.	3 (in German)					
Cot		1 0. 1.	3 (in German)					
Coι	ırses	Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 1998	3 (in German)					
Coι	ırses Course nr.	Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 1998 Course name Adaptive Filters	3 (in German)	SWS				
Coι	irses Course nr. 18-zo-2010-vl	Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 1998 Course name Adaptive Filters Ty		<b>SWS</b> 3				
Cou	irses Course nr. 18-zo-2010-vl Instructor	Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 1998 Course name Adaptive Filters Ty	уре					
Coι	Irses Course nr. 18-zo-2010-vl Instructor Prof. DrIng. Hei	Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 1998 Course name Adaptive Filters Ty nning Puder Le	уре					
Cou	Irses Course nr. 18-zo-2010-vl Instructor Prof. DrIng. Her Course nr.	Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 1998          Course name         Adaptive Filters         Ty         nning Puder         Course name         Adaptive Filters	уре					

	ech and Audi dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
	zo-2070	6 CP	180 h	120 h	1 Term	Winter term
	<b>nguage</b> rman			Module owner Prof. DrIng. Abo	lelhak Zoubir	
1	and basic m Beamformin frequency e recognition.	of speech and audio nethods of audio sign ag for spatial filtering stimation. Mel-filter . Classification metho len markov models).	al processing. Pr and noise reduct ind cepstral coeff ods based on GM	cocedures of codeb ion for spectral filte ficients (MFCCs) as M (Gaussian mixtu	oook based processin ering. Cepstral filteri s basis for speaker d ure models) and spee	g and audio coding ng and fundamenta etection and speech ech recognition with
2	help of the a processing, such as they (MMI). The and audio p familiarize v	bjectives e module you acquir analysis of speech sig to range from the th are applied in mobile exercise will be orga rocessing. This will a vith an unknown topi ional life as an engin	gnals. You learn a eory to practical e telephones, hear anized as a talk g llow you to acquir c and present you	bout different basi applications. You v ing aids, hands-free iven by each stude re the know-how to	c and advanced met will acquire knowled e telephones, and ma ent with one self-sele read and understand	hods of audio signal ge about algorithms n-machine-interfaces cted topic of speech d scientific literature
3	Knowlegde	<b>ded prerequisites fo</b> about satistical signal ndatory - is knowled	processing (lectu		Processing"). Desired	l
4	Seminar pre	m: le exam (Technical ex esentation: Scientific )-15 min) or in group	talk about a topic	in the field of "Spe	eech and Audio Signa	al Processing", single
5	-	e for the award of cr final module examina	-			
6	Grading Module exa • Modul	m: le exam (Technical ex	amination, Oral/	written examinatio	n, Weighting: 100 %	)
	<ul> <li>7 Usability of the module</li> <li>M.Sc. etit - KTS, M.Sc. etit - SAE, M.Sc. iCE, M.Sc. MedTec, M.Sc. WI-etit, B.Sc. und M.Sc. iST, M.Sc. CE</li> </ul>					
7	M.Sc. etit - 1		, M.Sc. iCE, M.Sc.	MedTec, M.Sc. W	I-etit, B.Sc. und M.So	e. iST, M.Sc. CE
7 8				. MedTec, M.Sc. W	I-etit, B.Sc. und M.So	e. iST, M.Sc. CE

<b>Course nr.</b> 18-zo-2070-vl	<b>Course name</b> Speech and Audio Signal Processing		
<b>Instructor</b>	enning Puder	<b>Type</b>	<b>SWS</b>
Prof. DrIng. H		Lecture	2
<b>Course nr.</b> 18-zo-2070-ue	<b>Course name</b> Speech and Audio Signal Processing		
<b>Instructor</b>	enning Puder	<b>Type</b>	<b>SWS</b>
Prof. DrIng. H		Practice	1
<b>Course nr.</b> 18-zo-2070-se	<b>Course name</b> Sprach- und Audiosignalverareitung		
<b>Instructor</b>	enning Puder	<b>Type</b>	<b>SWS</b>
Prof. DrIng. H		Seminar	1

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
		180 h	120 h Module owner	1 Term	Every 2. Semester	
<b>Language</b> German			DrIng. Michael	Kreutzer		
1	<ul> <li>Calcu</li> <li>Basic princi</li> <li>Symm</li> <li>Block</li> <li>Crypt</li> <li>Proba</li> <li>Public</li> <li>RSA,</li> <li>Factor</li> <li>Discrete</li> <li>Crypt</li> </ul>	cal basic principles: lations in congruence ples of encryption: netric vs. asymmetric and stream ciphers, <i>A</i> analysis bility and perfect sect c-key encryption Diffie-Hellman, ElGan ring large numbers ete logarithms ographic hash functio l signatures	cryptosystems AES, DES urity nal	rings		
2	<ul> <li>under class :</li> <li>under and e</li> </ul>	ssful completion of the stood the mathematic rings, factoring large stood the principles of fficiency rstood the principles	cal foundations of numbers, probabi f public and secret	cryptography such lity theory and per key encryption and	fect security 1 relevant schemes ind	cluding their securit
3	Recomment • Linea	<b>ided prerequisites fo</b> ded: r Algebra for Compute ionale und Objektorie	er Science	nierkonzepte		
4	The form of two of the f		l be announced at sible.	the beginning of t	the course. One or a	
5	Prerequisit	ncluding tests). The for the award of ca	redit points			
	Pass exam (	(100%)				
6	Grading Course rela	tod over				

7	Usability of the	module						
	B. Sc. Informatil							
	M. Sc. Informati	k						
	M. Sc. IT Sicher	neit						
	M.Sc. IT Securit	ý						
	May be used in o	other degree programs.						
8	In dieser Veranst Novelle der Allg	<b>Grade bonus compliant to §25 (2)</b> In dieser Veranstaltung findet eine Anrechnung von vorlesungsbegleitenden Leistungen statt, die lt. 25(2) der 6. Novelle der Allgemeinen Prüfungsbestimmungen der TU Darmstadt und den vom Fachbereich Informatik am 14.07.2022 beschlossenen Anrechnungsregeln zu einer Notenverbesserung um bis zu 1.0 führen kann.						
9	References							
	978-3-642 • Johannes I Signatures • Neal Kobli • Alfred J. M 1997 (erhä • Bruce Schr • Douglas R	Buchmann: Cryptographic Protocols. Vorlesungsskript (	u.a. Undeniable, Fail-Stop u er Verlag, 1994 k of Applied Cryptography, C 94 s, 1995	nd Blind RC Press				
Co	urses							
_	<b>Course nr.</b> 20-00-0085-iv	<b>Course name</b> Introduction to Cryptography						
	Instructor		<b>Type</b> Integrated course	SWS 4				

20-	<b>dule nr.</b> 00-0121	Credit points 3 CP	Workload 90 h	Self-study 60 h	Module duration 1 Term	Module cycle Every 2. Semester		
Language German/English				Module owner	Eberhard Mühlhäus	-		
1	<ul> <li>Learning h and in the c</li> <li>Identifying</li> <li>Understand</li> <li>Technologi</li> <li>(e.g., smart</li> <li>Demonstrate</li> <li>enterprise set</li> </ul>	<ul> <li>Teaching content <ul> <li>Learning how state-of-the-art ubiquitous computing technologies can be utilized in enterprise business processes and in the context of smart city services</li> <li>Identifying technologies' economic potential for business processes and in the context of smart cities</li> <li>Understanding underlying technologies, their benefits, challenges, and corresponding business cases</li> <li>Technologies considered will be RFID technology and its integration with business processes, other smart items (e.g., smart shelfs), etc.</li> <li>Demonstration of how integration works between the real world and the virtual world as it is represented in enterprise software systems today</li> <li>Hands-on experience and live demonstrations</li> </ul> </li> </ul>						
2	After partic	Learning objectives After participation in this course, students will have aquired knowledge about implications of ubiquitous computing on business to business processes and in the context of smart city services in conjunction with basic						
3	Recommen	ded prerequisites fo	or participation					
4	Course relat	<ul> <li>Form of examination</li> <li>Course related exam:</li> <li>[20-00-0121-vl] (Technical examination, Oral/written examination, Default RS)</li> </ul>						
5	Prerequisit Pass exam (	e for the award of cr 100%)	redit points					
6	Grading Course relat • [20-00	ed exam: )-0121-vl] (Technical	examination, Ora	al/written examina	ation, Weighting: 100	%)		
7	B.Sc. Inform M.Sc. Inform	natik chaftsinformatik ologie in IT						
		wissenschaft und Info wissenschaft und Info						

- Mühlhäuser, M.; Gurevych, I. (Eds.): Ubiquitous Computing Technology for Real Time Enterprises Information Science Reference, Dezember, 2007

- Finkenzeller, K: RFID-Handbuch. Grundlagen und praktische Anwendungen von Transpondern, kontaktlosen Chipkarten und NFC. Hanser Fachbuch; Auflage: 5., aktual. u. erw. Aufl. (1. Oktober 2008)

- Fleisch, E.; Mattern, F. (Hrsg.): Das Internet der Dinge: Ubiquitous Computing und RFID in der Praxis, Springer, Berlin, Heidelberg, New York 2005

- Österle, H.; Fleisch, E.; Alt, R.: Business Networking - Shaping Collaboration between Enterprises, Springer
- Callaway, E.H.: Wireless Sensor Networks: Architectures and Protocols, Auerbach Publications

#### Courses

Course nr.Course name20-00-0121-vlUbiquitous computing in business processes					
Instructor		<b>Type</b> Lecture	sws		

	-	ı I							
1			Workload 180 h	Self-study	Module duration	Module cycle			
Language English			100 11	h 120 h 1 Term Every 2. Semeste Module owner Prof. Dr. Bernt Schiele					
1	Teaching c - Basics of i - Linear and - Foundation - Camera ca - Foundation - Foundation - Template a - Object class - Object det	Teaching content- Basics of image formation- Linear and (simple) nonlinear image filtering- Foundations of multi-view geometry- Camera calibration and pose estimation- Foundations of 3D reconstruction- Foundations of motion estimation from video- Template and subspace methods for object recognition- Object classification with bag of words- Object detection- Basics of image segmentation							
2	After succes fundament formulation	Learning objectives After successfully attending the course, students are familiar with the basics of computer vision. They understand undamental techniques for the analysis of images and videos, can name their assumptions and mathematical ormulations, as well as describe the resulting algorithms. They are able to implement these techniques in order o solve basic image analysis tasks on realistic imagery.							
3		ded prerequisites fo of lecture Visual Com		nended.					
4	Form of ex Course rela • [20-0		examination, Ora	al/written examina	tion, Default RS)				
5	Prerequisit Pass exam (	te for the award of cr (100%)	redit points						
6	Grading Course rela • [20-0	ted exam: 0-0157-iv] (Technical	examination, Ora	al/written examina	tion, Weighting: 100	%)			
7	B.Sc. Inform M.Sc. Inform B.Sc. Comp M.Sc. Comp M.Sc. Wirts B.Sc. Psych Joint B.A. In B.Sc. Sport M.Sc. Sport	matik putational Engineering putational Engineerin pchaftsinformatik ologie in IT	g ormatik ormatik						
		us compliant to §25	-						
8	01000000		(=)						

- Literature recommendations will be updated regularly, an example might be: R. Szeliski, ""Computer Vision: Algorithms and Applications"", Springer 2011 D. Forsyth, J. Ponce, ""Computer Vision A Modern Approach"", Prentice Hall, 2002

# С

Co	urses		
	<b>Course nr.</b> 20-00-0157-iv	Course name Computer Vision	
	Instructor	<b>Type</b> Integrated course	SWS

Du	a Science I			1		1	
	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle	
18-zo-2110 5 CP 150		150 h	90 h	1 Term	Summer term		
Language English				Module owner Prof. DrIng. Abc	lelhak Zoubir		
1	Teaching content         The course covers the following topics:         Python programming basics         Data science introduction         Data storage and formats         Data exploration and visualization         Statistical methods and inference         Descriptive statistics (uni & bivariate)         Inferential statistics         Feature extraction         Time Series Data         Image data         Audio data         Statistical learning         Cross-validation, overfitting, annotation         Regression         Classification						
2		offers an introduction bout all parts of a Da			strong practical orien /data acquisition over		
3	Recomment	led prerequisites fo	r participation				
4	The examina 16 students	n: e exam (Technical ex ition takes place in fo	rm of a written ex tion will be an ora	am (duration: 90 m	n, Duration: 90 Min. ninutes). If one can es ration: 45 min.). The	stimate that less tha	
5		e for the award of cr					
6	Grading Module exan • Modul		amination, Oral/	written examinatio	n, Weighting: 100 %	)	
7		<b>the module</b> (TS, M.Sc. etit - SAE)	, M.Sc. etit - VAS,	M.Sc. iCE, M.Sc. V	VI-etit, B.Sc. und M.S	Sc. iST, M.Sc. CE	
8		s compliant to §25	(2)				
	Yes						

- Lecture notes and slides can be downloaded here:
  - http://www.spg.tu-darmstadt.demoodle
- Further reading:
  - Wes McKinney: Python for Data Analysis, O'Reilly, 2017
  - Christopher M. Bishop: Pattern Recognition and Machine Learning, 2011
  - James, Witten, Hastie and Tibshirani, Introduction to Statistical Learning, Springer, 2017

### Courses

Courses nr. 18-zo-2110-vl	<b>Course name</b> Data Science I		
<b>Instructor</b> DrIng. Christian	n Debes	<b>Type</b> Lecture	<b>SWS</b> 2
<b>Course nr.</b> 18-zo-2110-ue	Course name Data Science I		
<b>Instructor</b> DrIng. Christia	n Debes	<b>Type</b> Practice	<b>SWS</b> 2

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle			
20-00-0629 6 CP 180				120 h	1 Term	Every 2. Semester			
	<b>iguage</b> glish			Module owner					
1	<ul> <li>Learning of</li> <li>Representa</li> <li>Imitation le</li> <li>Optimal co</li> <li>Reinforcem</li> </ul>	<ul> <li>Foundations from robotics and machine learning for robot learning</li> <li>Learning of forward models</li> <li>Representation of a policy, hierarchical abstraction with movement primitives</li> <li>Imitation learning</li> <li>Optimal control with learned forward models</li> <li>Reinforcement learning and policy search</li> <li>Inverse reinforcement learning</li> </ul>							
2	Upon succes learning and tasks. They apply reinfo will understa	<b>Learning objectives</b> Upon successful completion of this course, students are able to understand the relevant foundations of machine learning and robotics. They will be able to use machine learning approaches to empower robots to learn new tasks. They will understand the foundations of optimal decision making and reinforcement learning and can apply reinforcement learning algorithms to let a robot learn from interaction with its environment. Students will understand the difference between Imitation Learning, Reinforcement Learning, Policy Search and Inverse Reinforcement Learning and can apply each of this approaches in the appropriate scenario.							
3	<b>Recommended prerequisites for participation</b> Good programming in Matlab Lecture Machine Learning 1 - Statistical Approaches is helpful but not mandatory.								
4	Form of exa Course relat • [20-00		examination, Ora	al/written examina	tion, Default RS)				
5	Prerequisite Pass exam (1	e for the award of c	redit points						
6	Grading Course relat • [20-00		examination, Ora	al/written examina	tion, Weighting: 100	%)			
7	M.Sc. Comp M.Sc. Wirtso B.Sc. Psycho Joint B.A. In B.Sc. Sportv	atik natik national Engineering utational Engineerin chaftsinformatik logie in IT	g rmatik						
	Can be used	in other degree prog	vrams						
			Si anno.						

	Novelle der APB	dieser Vorlesung findet eine Anrechnung von vorlesungsbegleitenden Leistungen statt, die lt. 25 (2) der 5. ovelle der APB und den vom FB 20 am 30.3.2017 beschlossenen Anrechnungsregeln zu einer Notenverbesserung n bis zu 1.0 führen kann.						
9	References							
	Deisenroth, M. I	; Neumann, G.; Peters, J. (2013). A Survey on Policy Search	n for Robotics, Foundati	ions and				
	Trends in Roboti	CS						
	Kober, J; Bagnell	, D.; Peters, J. (2013). Reinforcement Learning in Robotics: A	Survey, International Jo	ournal of				
	Robotics Researc	h						
	• ·	ern Recognition and Machine Learning (2006),						
		to. Reinforcement Learning - an Introduction						
	Nguyen-Tuong, l	.; Peters, J. (2011). Model Learning in Robotics: a Survey						
Co	urses							
	Course nr.	Course name						
	20-00-0629-vl	Robot Learning						
	Instructor		Туре	SWS				
			Lecture	4				

	<b>dule name</b> nbinatorial Oj	otimization							
	dule nr.	Credit points	Workload	Self-study	Module du	uration	Module cyc	cle	
04-	10-0588	5 CP	150 h	150 h	1 Term		Every 9. Se		
	<b>iguage</b> Jlish			<b>Module owner</b> Prof. Dr. Yann Di	sser				
1	1 Teaching content shortest paths (advanced), maximum flows (advanced), min-cost maximum flows, maximum matchings, com- plexity								
2	2 Learning objectives The students know and understand the concepts and methods taught in the course and can apply them. They have a thorough understanding of the formal foundations of combinatorial optimization. They are able to independently expand their knowledge of the field and pursue supervised research projects.								
3		led prerequisites for ed: Introduction to (		Л					
4	<ul> <li>Form of examination Module exam:</li> <li>Module exam (Technical examination, Oral/written examination, Default RS) Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated by the instructor during the first lecture. during the first two weeks of the lecture, based on the prospective number of students taking the exam.</li> </ul>								
5		e <b>for the award of c</b> inal module examinat							
6	Grading Module exar • Module	n: e exam (Technical e:	kamination, Oral/	written examinatio	n, Weighting	g: 100 %	)		
7	<b>Usability of</b> M. Sc. Mathe	<b>the module</b> ematik and Mathem	atics, B Sc. Mathe	matik (3rd year)					
8	Grade bonu	s compliant to §25	(2)						
9	<b>References</b> Korte, Vyger	. Combinatorial Opt	imization. Spring	er, 2012.					
Coi	ırses								
	Course nr.	Course name							
	04-10-0588- Instructor	vu Combinatorial	Optimization			<b>Type</b> Lecture a	nd practice	<b>SWS</b> 0	

	<b>dule name</b> tistical Relatio	onal Artificial Intellig	ence: Logic, Proba	ability, and Compu	tation		
Mo	<b>dule nr.</b> 00-1011	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Every 2. Semester	
	Language English			<b>Module owner</b> Prof. Dr. techn. J	ohannes Fürnkranz		
1	<ul> <li>Teaching content         <ul> <li>Logic programming</li> <li>Inductive logic programming, i.e., learning logical programs from data</li> <li>Probabilistic graphical models: Inference and Learning</li> <li>Statistical relational models such as ProbLog and Markov logic networks</li> <li>Inference within statistical relational models</li> <li>Learning statistical relational models from data</li> <li>Relational linear and quadratic programs</li> </ul> </li> </ul>						
2	and AI: the where there properties in the same in understand posed by re	provides a systematic study and design of i e can be complex relandividuals have, what dividual, and the dyn	ntelligent agents ations among the at relations are tr namics of the wor nd methods of sta d know the curren	that act in worlds of individuals, where ue, what individua dd. After the succo ttistical relational A	composed of individu the agents can be u als exist, whether dif essful completion of AI. They understand	the course, students the basic challenges	
3	The success	<b>ded prerequisites fo</b> ful completion of "St not required.		Learning" and of "	Probabilistic Graphic	al Models" is recom-	
4	Form of exa Course relat • [20-00		examination, Ora	al/written examina	tion, Default RS)		
5	Prerequisite Pass exam (	e for the award of c 100%)	redit points				
6	Grading Course relat • [20-00	ed exam: )-1011-iv] (Technical	examination, Ora	al/written examina	tion, Weighting: 100	%)	
7	B.Sc. Inform M.Sc. Inform		grams.				
8	Grade bonu	is compliant to §25	(2)				
9	<b>References</b> Pointers to l	iterature will be upd	ated regularly and	l include:			
	cial Intellige		ty, and Computati	on. Synthesis Lectu		al Relational Artifi- ligence and Machine	
Coi	ırses						

<b>Course nr.</b> 20-00-1011-iv	<b>Course name</b> Statistical Relational Artificial Intelligence: Logic, Probability	, and Computation	
<b>Instructor</b> Prof. Dr. techn. J	ohannes Fürnkranz	<b>Type</b> Integrated course	SWS 4

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle		
	00-1017	6 CP	180 h	120 h	1 Term	Every 2. Semester		
	n <b>guage</b> glish			Module owner Prof. Dr. techn. J	ohannes Fürnkranz			
1	systems. Th updating, q Topics inclu Database A Parallel and Data Wareh MapReduce Spark and i	introduces the funda ne focus of this course uerying, and analyzin de: rchitectures l Distributed Database iousing and Hadoop ts Ecosystem	e is on the systems ng large datasets. es	s-oriented aspects	and internals of such	n systems for storing		
2	Learning o After the co of scalable o	Optional: NoSQL Databases, Stream Processing, Graph Databases, Scalable Machine Learning Learning objectives After the course the student will have a good overview of the different concepts, algorithms, and systems aspects of scalable data management. The main goal is that the students will know how to design and implement such systems including hands-on experience with state-of-the-art systems such as Spark.						
3	Recommended prerequisites for participation Programming in C++ and Java Informationsmanagement (20-00-0015-iv) Optional: Foundations of Distributed Systems (20-00-0998-iv)							
4	Form of ex Course rela • [20-0		examination, Ora	al/written examina	tion, Default RS)			
5	<b>Prerequisit</b> Pass exam (	e for the award of c (100%)	redit points					
6	Grading Course rela • [20-0	ted exam: 0-1017-iv] (Technical	examination, Ora	al/written examina	tion, Weighting: 100	9%)		
7	B.Sc. Inform M.Sc. Inform		grams.					
_	Grade bon	us compliant to §25	(2)					
8								

<b>Course nr.</b> 20-00-1017-iv	<b>Course name</b> Scalable Data Management Systems		
<b>Instructor</b>		ype	SWS
Prof. Dr. techn. J		ntegrated course	4

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
20-00-1058         5 CP         150 h         105 h         1 Term         Every 2. Sem						Every 2. Semester
Language German				Module owner Prof. Dr. techn. J	ohannes Fürnkranz	
1	to require in has since de lecture we v focus on the be considered Found Introd Introd Search Uninfo Heuris Local Constr Games Planni Planni Decisi Uncerr Bayesi Decisi Machi Neura Reinfo	elligence (AI) is conce itelligence. While rese eveloped towards solve vill give a brief survey topics search, planni ed. ations uction, History of AI gent Agents (RN chap ormed Search (RN chap to Search (RN chapter 4 aint Satisfaction Prol s: Adversarial Search ing in State Space (RI ons under Uncertaint tainty and Probabiliti an Networks (RN chap ne Learning l Networks (RN chap orcement Learning (R ophical Foundations	earch in the early utions that try to y over key topics of ing, learning, and (RN chapter 1) pter 2) apters 3.1 - 3.4) ters 3.5, 3.6) apters (RN chapter (RN chapter 10) V chapter 10) V chapter 11) ty ies (RN chapter 13) apter 14) ter 16) ters 18.1,18.2,18.	days was oriented of exploit the strengt of this core discipli reasoning. Historic r 6)	on results about hum ths of the computer. ne of computer scien	an thinking, the fiel In the course of thi ce, with a particula
2	<ul><li>under</li><li>partici</li></ul>	bjectives essful completion of t stand and explain fur pate in a discussion a lly judge new develop	ndemental technic about the possibili	ques of artificial int ty of an artificial in	telligence	founded argument
3	Recommen	ded prerequisites fo	or participation			
4	Form of exa Course relat • [20-00 Written Exa	ed exam: )-1058-iv] (Technical	examination, Ora	al/written examina	ition, Default RS)	
5	Prerequisit	e for the award of c	redit points			

		Course related exam: • [20-00-1058-iv] (Technical examination, Oral/written examination, Weighting: 100 %)					
7	Usability of the module B.Sc. Informatik M.Sc. Informatik M.Sc. Autonome Systeme und Robotik M.Sc. Artificial Intelligence and Machine Learning May be used in other degree programs.						
8		mpliant to §25 (2)					
9	References						
Co	urses						
	<b>Course nr.</b> 20-00-1058-iv	<b>Course name</b> Introduction to Artificial Intelligence					
	Instructor Prof. Dr. techn. 2	Johannes Fürnkranz		<b>Type</b> Integrated course	<b>SWS</b> 3		

	<b>dule name</b> trix Analysis a	and Computations								
	<b>dule nr.</b> pe-2070	Credit points 6 CP	Workload 180 h	Self-study 120 h	· · · · ·					
	<b>iguage</b> dish			<b>Module owner</b> Prof. DrIng. Ma						
1	1 Teaching content This graduate course is a foundation class on matrix analysis and computations, which are widely used in many different fields, e.g., machine learning, computer vision, systems and control, signal and image processing, communications, networks, optimization, and many more Apart from the theory this course will also cover the design of efficient algorithm and it considers many different examples from the aforementioned fields including examples from social media and big data analysis, image processing and medical imaging, communication network optimization, and written text classification. Specific topics: (i) basic matrix concepts, subspace, norms, (ii) linear least squares (iii) eigendecomposition, singular value decomposition, positive semidenite matrices, (iv) linear system of equations, LU decomposition, Cholesky decomposition (v) pseudo-inverse, QR decomposition (vi) advanced tensor decomposition, advanced matrix calculus, compressive sensing, structured matrix factorization									
2			ced topics in matr	ix analysis and rela	ated algorithms at an	advanced level upon				
3		<b>ded prerequisites fo</b> edge in linear algebra								
4	The examin less than 10	n: e exam (Technical ez ation takes place in	form of a written the examination with	n exam (duration: Il be an oral exam	n, Duration: 120 Mir 120 minutes). If or ination (duration: 20	ne can estimate that				
5	Prerequisite Pass module	e for the award of c final exam.	redit points							
6	<b>Grading</b> Module exar • Modul		kamination, Oral/	written examinatio	n, Weighting: 100 %	)				
7	B.Sc. etit, B	the module .Sc. WI-etit, M.Sc. e . und M.Sc. iST, B.E		etit - CMEE, M.Sc.	etit - KTS, M.Sc. iCI	E, M.Sc. MEC, M.Sc.				
8	Grade bonu	s compliant to §25	(2)							
9	References									

- Gene H. Golub and Charles F. van Loan, Matrix Computations (Fourth Edition), John Hopkins University Press, 2013.
- Roger A. Horn and Charles R. Johnson, Matrix Analysis (Second Edition), Cambridge University Press, 2012.
- Jan R. Magnus and Heinz Neudecker, Matrix Differential Calculus with Applications in Statistics and Econometrics (Third Edition), John Wiley and Sons, New York, 2007.
- Giuseppe Calaore and Laurent El Ghaoui, Optimization Models, Cambridge University Press, 2014.
- ECE 712 Course Notes by Prof. Jim Reilly, McMaster University, Canada (friendly notes for engineers) http://www.ece.mcmaster.ca/faculty/reilly/ece712/course\_notes.htm

#### Courses

<b>Course nr.</b> 18-pe-2070-vl	<b>Course name</b> Matrix Analysis and Computations		
Instructor Prof. DrIng. Ma	· · ·	<b>Type</b> Lecture	<b>SW</b> 3
<b>Course nr.</b> 18-pe-2070-ue	<b>Course name</b> Matrix Analysis and Computations		
<b>Instructor</b> Prof. DrIng. Ma	rius Pesavento	<b>Type</b> Practice	<b>SW</b> 3

Mo	dule name					
		leling - Machine Lea	rning			
	dule nr.	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle
	18-kp-2110         6 CP         180 h         120 h         1 Term         Summer ter           Language         Module owner					Summer term
English Prof. Dr. techn. Heinz Köppl						
1						
2	machine lea They are a	e able to interpret ar rning problems.	problems to star			T domain in terms of d are able to deter-
		ble to implement al art libraries in mach		rithms from scrate	h, but they are als	o familiar with the
		ble to determine th ion algorithms based			ity of a method an	d choose an appro-
		ble to apply the ac , analysis of social ne		to other domains	s, such as data and	alysis in biomedical
3				from course 18-st-	2030 Matlab Grundk	urs) and engineering
4	The examin less than 10	m: le exam (Technical e: lation takes place in	form of a written ne examination w	n exam (duration: ill be an oral exam	120 minutes). If or	n., Default RS) ne can estimate that 0 min.). The type of

5		<b>the award of credit points</b> module examination					
6	Grading Module exam: • Module exa	am (Technical examination, Oral/written examination, Weight	ting: 100 %)				
7		<b>module</b> .Sc. etit - CMEE, M.Sc. etit - DT, M.Sc. etit - KTS, M.Sc. etit - iST, B.Sc. CE, M.Sc. CE	- VAS, M.Sc. iCE, M.Sc.	WI-etit,			
8	Grade bonus co	mpliant to §25 (2)					
9 Co	<ul><li>Christophe</li><li>Peter Bühlt</li></ul>	<ul> <li>References</li> <li>Kevin P. Murphy. Machine Learning - A probabilistic perspective, MIT Press, 2012</li> <li>Christopher M. Bishop. Pattern recognition and Machine Learning, Springer, 2006</li> <li>Peter Bühlmann und Sara van de Geer. Statistics of high-dimensional data - Methods, theory and applications, Springer, 2011</li> </ul>					
	<b>Course nr.</b> 18-kp-2110-vl	Course name Data-driven Modeling - Machine Learning					
	<b>Instructor</b> Prof. Dr. techn. H	leinz Köppl	<b>Type</b> Lecture	<b>SWS</b> 2			
	<b>Course nr.</b> 18-kp-2110-ue	<b>Course name</b> Data-driven Modeling - Machine Learning					
	<b>Instructor</b> Prof. Dr. techn. H	leinz Köppl	<b>Type</b> Practice	<b>SWS</b> 1			
	<b>Course nr.</b> 18-kp-2110-pr	<b>Course name</b> Data-driven Modeling - Machine Learning Lab					
	<b>Instructor</b> Prof. Dr. techn. H	leinz Köppl	<b>Type</b> Lab	<b>SWS</b> 1			

Mod	ule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
18-ac	1-2090	3 CP	90 h	60 h	1 Term	Winter term
Language German			Module owner Prof. DrIng. Jürg	gen Adamy		
	<ul> <li>Image <ul> <li>G</li> <li>Object</li> <li>Discre</li> <li>S</li> <li>T</li> <li>C</li> <li>D</li> </ul> </li> <li>Basics of I</li> <li>Filterin</li> <li>B</li> <li>Filterin</li> <li>B</li> <li>L</li> <li>N</li> <li>Image</li> <li>M</li> <li>P</li> <li>F</li> <li>Image</li> <li>S</li> </ul>	Representation 2D an Acquisition Geometric Projections ive and Illumination te 2D signals eparability, Sampling ransformation, Interp convolution, Correlati Discrete Fourier Trans mage Analysis	Camera Calibrati polation on formation	on		
	the field of e range from driver assist The students two-dimensi to infer know	sful completion, the m engineering. The focus visual quality inspect	s is on methods th tion, visual roboti d understanding f the image plane o l given image data	at are relevant for cs, photogrammetr or the relations bet of a camera. They a a. They should deve	measuring and contro ry, visual odometry u ween the three-dime lso should learn abou elop some feeling for	ol tasks. Application up to visually guiden nsional world and it ut methods that exist the different kinds of
3 ]	Recommen	ded prerequisites fo	r participation			
]	The examina 10 students		rm of a written ex tion will be an ora	am (duration: 90 m	ninutes). If one can es	stimate that less that
5	Prerequisit	e for the award of ci	odit noints			

I	Module exam:				
		am (Technical examination, Oral/written exami	ination, Weight	ing: 100 %)	
7	Usability of the M.Sc. etit - AUT,	<b>module</b> M.Sc. iCE, M.Sc. MEC, M.Sc. MedTec, M.Sc. W	VI-etit, B.Sc. un	d M.Sc. iST, M.Sc.	. CE
8	Grade bonus co	mpliant to §25 (2)			
9					
Co	urses	1			
	<b>Course nr.</b> 18-ad-2090-vl	<b>Course name</b> Computer Vision in Engineering			
	<b>Instructor</b> DrIng. Thomas	Guthier, M.Sc. Frank Ziegler		<b>Type</b> Lecture	<b>SWS</b> 2

	<b>dule name</b> ivex Optimiza	ntion in Signal Proces	sing and Commu	nications		
Mo	Module nr.Credit pointsWorkloadSelf-studyModule durationModule cycle18-pe-20206 CP180 h120 h1 TermSummer term					
	Language Module owner					Summer term
Eng	glish			Prof. DrIng. Mai	rius Pesavento	
1	<ul> <li>Teaching content         This graduate course introduces the basic theory of convex optimization and illustrates its use with many recent applications in communication systems and signal processing.         Outline: Introduction, convex sets and convex functions, convex problems and classes of convex problems (LP, QP, SOCP, SDP, GP), Lagrange duality and KKT conditions, basics of numerical algorithms and interior point methods, optimization tools, convex inner and outer approximations for non convex problems, sparse optimization, distributed optimization, discrete optimization, mixted integer linear and non-linear programming, Branch-and-Bound method, Branch-and-Cut method, customized iterative optimization, Newton method, gradient projection method, conjugate gradient method, block coordinate descent method, successive convex approximation method, BSUM method, Majorization Maximization, difference-of-convex procedure, ADMM, step size selection, optimal step size compution, applications.     </li> </ul>					
2	This include:	eting the module, stud	sic theory of conve			dern communication. ital signal processing
3		<b>ded prerequisites fo</b> in linear algebra and		s of signal processi	ng and communication	ons.
4	The examin less than 14	n: e exam (Technical ex ation takes place in	form of a written e examination wi	n exam (duration: Il be an oral exam	120 minutes). If or	n., Default RS) ne can estimate that 0 min.). The type of
5		e for the award of c				
6	Grading Module exar • Modul	n: e exam (Technical ex	kamination, Oral/	written examinatio	n, Weighting: 100 %	)
7			M.Sc. etit - KTS, M	l.Sc. etit - VAS, M.S	c. iCE, M.Sc. WI-etit,	B.Sc. und M.Sc. iST,
8	Grade bonu	is compliant to §25	(2)			
9	<ul> <li>S. Boyd and L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004. (online Verfügbar: http://www.stanford.edu/ boyd/cvxbook/)</li> <li>D. P. Bertsekas, Nonlinear Programming, Athena Scientific, Belmont, Massachusetts, 2nd Ed., 1999.</li> <li>Daniel P. Palomar and Yonina C. Eldar, Convex Optimization in Signal Processing and Communications, Cambridge University Press, 2009.</li> </ul>					
Co	urses					

<b>Course nr.</b> 18-pe-2020-vl	<b>Course name</b> Convex Optimization in Signal Processing and C	Communications	
<b>Instructor</b>	arius Pesavento	<b>Type</b>	SWS
Prof. DrIng. M		Lecture	2
<b>Course nr.</b> 18-pe-2020-ue	<b>Course name</b> Convex Optimization in Signal Processing and C	Communications	
Instructor	arius Pesavento, M.Sc. Yufan Fan	<b>Type</b>	<b>SWS</b>
Prof. DrIng. M		Practice	1
<b>Course nr.</b> 18-pe-2020-pr	<b>Course name</b> Convex Optimization in Signal Processing and C	Communications Lab	
<b>Instructor</b>	Instructor		<b>SWS</b>
Prof. DrIng. M	Prof. DrIng. Marius Pesavento		1

Мо	dule name						
Mo	bile Commun	ications	I	1		1	
	<b>dule nr.</b> kl-2020	Credit points 6 CP	Workload 180 h	Self-study 120 h	<b>Module duration</b> 1 Term	Module cycle Summer term	
Language Module owner							
English Prof. DrIng. Anja Klein							
1	<ul> <li>Teaching content <ul> <li>The lecture covers aspects of mobile communication systems with particular focus on the physical layer.</li> <li>Mobile radio systems, services, market, standardization</li> <li>Duplex and multiple access techniques, cellular concept</li> <li>Mobile radio channel, deterministic and stochastic description</li> <li>Modulation schemes</li> <li>Code division multiple access (CDMA)</li> <li>Orthogonal frequency division multiplexing (OFDM)</li> <li>Optimum and suboptimum receiver techniques</li> <li>Cellular radio capacity and spectrum efficiency</li> <li>Diversity methods</li> <li>Multiple input multiple output (MIMO) systems</li> <li>Power control and handover</li> <li>Architecture of mobile radio systems</li> </ul> </li> </ul>						
2	<ul> <li>a profemolie</li> <li>schem</li> <li>a profe</li> <li>the ab</li> <li>the ab</li> </ul>	etion of the module, so ound understanding of communication syste	of physical layer as ems, duplex schem of signal propagat nd solve problems lyse and evaluate	ies, multi carrier scl ion in mobile radic of the field of the different system co	nemes, receiver techr o systems (mobile rac physical layer oncepts	ple access schemes of iques, multi antenna lio channel)	
3	Determinist	ded prerequisites for ic Signals and Syster ntific Computing		on Technology I, M	athematics I to III, S	Statistics/Probability	
4	Form of exa Module exa • Modul		xamination, Exam	ination, Duration:	90 Min., Default RS)		
5		e for the award of c					
6	<ul> <li>Grading</li> <li>Module exam:</li> <li>Module exam (Technical examination, Examination, Weighting: 100 %)</li> </ul>						
7	•	the module KTS, M.Sc. etit - VAS	, M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	M.Sc. iST		
8	Grade bonu	is compliant to §25	(2)				
9	References						

## will be announced in the lecture

	will be announc	ed in the lecture					
Со	urses						
	Course nr.Course name18-kl-2020-vlMobile Communications						
	Instructor Prof. DrIng. Ar	ija Klein, DrIng. Lin Xiang	<b>Type</b> Lecture	<b>SWS</b> 3			
	<b>Course nr.</b> 18-kl-2020-ue	Course name Mobile Communications					
	<b>Instructor</b> Prof. DrIng. An Yilmaz	Instructor Prof. DrIng. Anja Klein, DrIng. Lin Xiang, M.Sc. Fengcheng Pei, M.Sc. Mustafa		<b>SWS</b> 1			

	<b>dule name</b> work, Traffic	and Quality Manage	ment for Internet	Services					
	<b>dule nr.</b> 00-0056	Credit points 3 CP	<b>Workload</b> 90 h	Self-study 60 h	Module duration	Module cycle			
Lar	<b>nguage</b> glish	5 CP	90 11	Module owner	5				
1	Teaching co	ontent 1 into management o 1 uality and traffic prof		provider (ISP-)netv	works for integrating	IP service platforms			
2	<ul> <li>criteri</li> <li>QoS A</li> <li>QoS si social</li> <li>Quality Assi</li> <li>Netwo with p</li> <li>measu</li> <li>Quality assi</li> <li>Content</li> <li>transp</li> </ul>	tent: ts and measures to en- a from the application rchitecture in IP Network apport & impact per a networking etc.) arance for Internet Se ork and Transport Lay rotection against error arement, monitoring, arance in service over	n & user perspecti works: Differentia application in IP tr ervices in ISP Netw rer Impact: Routin ors and failures. optimization of IF lays and at applica s (CDN), Clouds n, scalability	ve (QoE: Quality o ted & Integrated S caffic mix (video str work Infrastructure g (OSPF, BGP), Mu P traffic regarding ( ation level and Peer-to-Peer N	ervices reaming, VoIP, web b s ıltiprotocol Label Sw QoS Networks (P2P) incl.	rowsing, downloads, itching (MPLS), TCP distributed caches,			
3	Recommend Prerequisite	<b>ded prerequisites fo</b> led: s: Basic knowledge tionsnetze I and II ar	in computer scie	nce and Internet a	pplications is requir	red. The courses on			
4	The form of two of the fo Written exa	ed exam: )-0056-vl] (Technical the examination will pllowing forms is pos	l be announced at sible.	the beginning of t	he course. One or a	combination of max. ninutes), homework			
5	-	e for the award of c	redit points						
6	Grading Course relat		examination, Ora	ıl/written examina	tion, Weighting: 100	%)			
7	B.Sc. Inform M.Sc. Inform	natik							
8	-	in other degree prog is compliant to §25							
0		is compliant to \$25							

9	References	laatura				
Con	Will be given in lecture.					
CO	urses	1				
	Course nr.	Course name				
	20-00-0056-vl	Network, traffic and quality management for Internet service	es			
	Instructor	·	Туре	SWS		
			Lecture	2		

Mo	dule name							
	tware Defined	Networking						
	<b>dule nr.</b> sm-2280	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module of 1 Term	duration	Module cyc Winter tern	
	nguage	0 CP	100 11	Module owner	1 IeIIII		willer tern	
	man/English			Prof. DrIng. Ral	f Steinmetz	Z		
1	<ul> <li>Teaching content</li> <li>The course deals with topics in the area of software defined networking: <ul> <li>SDN Data Plane</li> <li>SDN Control Plane</li> <li>SDN Application Plane</li> <li>Network Function Virtualization</li> <li>Network Virtualization and Slicing</li> <li>QoS and QoE in Software Defined Networks</li> </ul> </li> </ul>							
2		<b>jectives</b> etion of the module, sic technologies and		e gained in-depth in	sights into	Software	Defined Netw	vorking,
3		<b>led prerequisites fo</b> s of the first 4 semes ed.		Knowledge of lectu	res Comm	unication N	Vetworks I an	d II are
4	The examina 15 students		orm of a written ex tion will be an ora	am (duration: 90 n	ninutes). If	one can es	stimate that le	ess than
5		e <b>for the award of c</b> inal module examin						
6	Grading Module exar • Module	n: e exam (Technical e:	xamination, Oral/	written examinatio	on, Weighti	ng: 100 %	)	
7	<b>Usability of</b> M.Sc. etit - I	<b>the module</b> DT, M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	d M.Sc. iST				
8	Grade bonu	s compliant to §25	(2)					
9	<b>References</b> Textbooks as Slides and p	indicated. aper copies as neces	sary.					
<b>Co</b> ι	urses							
	<b>Course nr.</b> 18-sm-2280-	vl Software Defin	ned Networking					
	<b>Instructor</b> DrIng. Ralf	Kundel, M.Ed. Benj	amin Becker, M.So	c. Chengbo Zhou		<b>Type</b> Lecture		<b>SWS</b> 2

<b>Course nr.</b> 18-sm-2280	)-ue	<b>Course name</b> Software Defined Networking		
<b>Instructor</b> DrIng. Ral	f Kun	del, M.Ed. Benjamin Becker, M.Sc. Chengbo Zhou	<b>Type</b> Practice	<b>SWS</b> 2

Мо	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
18-	-sm-2010	6 CP	180 h	120 h	1 Term	Winter term
	nguage			Module owner		
English     Prof. DrIng. Ralf Steinmetz       1     Teaching content						
_	The course of munications aspects of co recent devel Computing a to Communi Topics are: • Basics • Transp …) • Transp • Interace • Electro • World • Distrib • SOA ( • Cloud • Overla • Video	Communication Netw with emphasis on the ommunication networ opments in the area of and Service-oriented A ication Networks I. and History of Comm ort Layer (Addressing ort Protocols (TCP, S ctive Pr	Internet. Starting iks. In addition to of multimedia com Architectures) will nunication Netwo g, Flow Control, Co SCTP) et, SSH, FTP,) P3, IMAP, MIME, RPC, Web Service JDDI,) naS, IaaS, Virtualis tured P2P, DHT S reaming, Flash Stu	with the history, th the basics includin imunication (e.g., V be examined thoro rks (Telegraphy vs. onnection Manager ) s, Event-based Con zation,) ystems, Application	e course discusses par g well known protoc /ideo Streaming, P2P ughly. The course is o Telephony, Reference nent, Error Detection nmunication)	st, current and futur ols and technologie , IP-Telephony, Clou lesigned as follow-u e Models,) , Congestion Contro
2	of computer course discu well known Video Stream	ojectives sful completion, the networking and tele sses past, current and protocols and techno ming, P2P, IP-Telepho The course is designed	communications v l future aspects of ologies, recent de ony, Cloud Compu	with emphasis on the communication net velopments in the uting and Service-c	he Internet. Starting tworks. In addition to area of multimedia o priented Architecture	with the history, the basics includir communication (e.g
3	Recomment Basic course Networks I i	ded prerequisites fo s of first 4 semesters s recommended. The d in practical program	<b>r participation</b> are required. Kno oretical knowledg	owledge in the topi e obtained in the c	cs covered by the cor ourse Communication	n Networks II will l
4	Form of exa Module exa	mination				
5		e for the award of cr final module examina				
6	Grading         Module exam:         • Module exam (Technical examination, Examination, Weighting: 100 %)					

## M.Sc. etit - DT, M.Sc. iCE, M.Sc. iST, M.Sc. WI-etit, B.Ed. etit 8 Grade bonus compliant to §25 (2) The maximum grade improvement is 1.0. For a grade improvement to be awarded, a minimum number of points (50% of the maximum achievable points) must be reached. From this minimum number, the grade improvement increases proportionally (from 0.0 grade improvement at the minimum number to a maximum of 1.0 grade improvement from 95% of the maximum achievable points). Above 95% of the maximum achievable points, the bonus is 1.0. 9 References Selected chapters from following books: Andrew S. Tanenbaum: Computer Networks, Fourth 5th Edition, Prentice Hall, 2010

- James F. Kurose, Keith Ross: Computer Networking: A Top-Down Approach, 6th Edition, Addison-Wesley, 2009
- Larry Peterson, Bruce Davie: Computer Networks, 5th Edition, Elsevier Science, 2011

<b>Course nr.</b> 18-sm-2010-vl							
<b>Instructor</b> Prof. DrIng. Ral M.Sc. Christoph	<b>Type</b> Lecture	<b>SWS</b> 3					
<b>Course nr.</b> 18-sm-2010-ue	Course name Communication Networks II						
<b>Instructor</b> Prof. DrIng. Ralf Steinmetz, DrIng. Tobias Meuser, M.Sc. Pratyush Agnih M.Sc. Christoph Gärtner		<b>Type</b> Practice	<b>SWS</b> 1				

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle		
	zo-2060	6 CP	180 h	120 h	1 Term	Winter term		
	<b>nguage</b> glish			Module owner Prof. DrIng. Abc	lelhak Zoubir			
1	<ol> <li>2) Digital Filt</li> <li>Impulse Resp</li> <li>3) Digital Spectrum</li> </ol>	ime Signals and Lin er Design - Filter D onse Filters; Impler ectral Analysis - Ra imation; Applicatio	esign Principles; L mentations ndom Signals; No	inear Phase Filters	ruction of Analog Sig ; Finite Impulse Resp ods for Spectrum Est	oonse Filters; Infi		
2	Students und Furthermore, the basics of	<b>Jearning objectives</b> Students understand basic principles of signal processing. They can design and analyze FIR and IIR filters. Surthermore, they are able to analyze statistical signals in the time and frequency domain. The students know the basics of spectral estimation and can design non-parametric as well as parametric spectral estimators and nalyze them with respect to their performance.						
3		ed prerequisites for signals and system						
4	Form of exar Module exam • Module	:	xamination, Exam	ination, Duration:	180 Min., Default RS	5)		
5		for the award of c nal module examin						
6	<b>Grading</b> Module exam • Module	: exam (Technical e:	xamination, Exam	ination, Weighting	: 100 %)			
7	<b>Usability of t</b> M.Sc. etit - K und M.Sc. iS <sup>7</sup>	TS, M.Sc. etit - SAE	E, M.Sc. etit - VAS,	M.Sc. iCE, M.Sc.	MEC, M.Sc. MedTec	, M.Sc. WI-etit, I		
8	Grade bonus	compliant to §25	(2)					
0	References Course manu Additional Re	ferences: enheim, W. Schafer		mal Processing, 2n Studienbücher, 199				
9		me: Stochastische						
9 Co	• J.F. Böh	Course name						

<b>Course nr.</b> 18-zo-2060-ue	<b>Course name</b> Digital Signal Processing		
Instructor Prof. DrIng. Abc	lelhak Zoubir, M.Sc. Christian Eckrich, M.Sc. Christian Schroth	<b>Type</b> Practice	<b>SWS</b> 1

	<b>dule name</b> adamentals of	Reinforcement Learn	ning			
	<b>dule nr.</b> kl-2070	Credit points 5 CP	Workload 150 h	Self-study 90 h	Module duration 1 Term	Module cycle Summer term
Lan Eng	<b>iguage</b> dish			<b>Module owner</b> Prof. DrIng. Anj		I
1	<ul> <li>Marko</li> <li>The M</li> <li>Taxono</li> <li>Algori SoftMa</li> <li>Funda</li> <li>Taxono Policy</li> <li>Algori Actor-0</li> <li>Linear</li> </ul>	v of Probability Theo v Property and Mark ulti-Armed Bandit Pr omy of Multi-Armed thms for Multi-Arme ax, LinUCB) and thei mentals of Dynamic omy of Approaches for Gradient and Actor-O	ov Decision Proce oblem vs. the Full Bandit Problems ( ed Bandit Problem r Application to C Programming and r the Full Reinforc Critic) einforcement Leas lication to Cyber-H ation	l Reinforcement Le e.g., Stochastic vs. ns (e.g., Upper Cor yber-Physical Netw Bellman Equation ement Learning Pro	Adversarial Rewards offidence Interval (UG orking s oblem (e.g., Temporal g., Q-Learning, SAR	, Contextual MAB) CB), Epsilon-Greedy, -Difference Learning, SA, Policy Gradient,
2	be able determ teristic determ makin differe choose formul determ explain differe identif explain choose apply	s are able to the Markov property e to use these concep- nine the characteristic s of the Full Reinforce nine under which con- g problems. ntiate the main MAB e appropriate MAB st late and solve Contex- nine under which con- n the difference betwe- ntiate between Temp y the limitations of M n the need for genera	ts to model decisi cs of the Multi-Arr cement Learning ( nditions the MAB strategies, e.g., Up rategies for the so ctual-MAB probler ditions Dynamic Fo poral-Difference, F MAB and full RL p alization in MAB a mation techniques es to solve MAB a	on-making problem ned Bandit (MAB) (RL) Problem. or the full RL form oper Confidence Int lution of MAB prob ns. Programming can be gramming and RL is Policy Gradient and roblems. nd full RL problem and use them in con nd full RL problem	ns in Cyber-Physical I Problem and compare sulation should be us erval (UCB), Epsilon- olems. e used to solve decisi methods. Actor-Critic RL tech us. mbination with MAB a s and obtain valid so	Networking. e them to the charac- sed to solve decision- Greedy and Softmax. on-making problems. niques.
3	• Pythor	<b>ded prerequisites fo</b> n or Matlab: basic kno eering mathematics a	owledge	eorv		
4	Form of exa		1			

	<ul> <li>Module exam:</li> <li>Module exam (Technical examination, Oral/written examination, Duration: 60 Min., Default RS)</li> <li>The examination takes place in form of a written exam (duration: 60 minutes). If one can estimate that less than 21 students register, the examination will be an oral examination (duration: 20 min.). The type of examination will be announced in the beginning of the lecture.</li> </ul>								
5		Prerequisite for the award of credit points Passing the final module examination							
6	Grading Module exam: • Module exa	•							
7	Usability of the M.Sc. etit - AUT,	module M.Sc. etit - KTS, M.Sc. etit - VAS, M.Sc. iCE, M.Sc. MEC, M.Sc	c. WI-etit, B.Sc. u	nd M.Sc. iST					
8	Grade bonus co	mpliant to §25 (2)							
	Cambridge • Aleksandrs	Sutton and Andrew G. Barto, "Reinforcement Learning: An Is , MA, USA, 2018. Slivkins, "Introduction to Multi-Armed Bandits", Foundations a o. 1-2, 2019.							
Со	urses								
	<b>Course nr.</b> 18-kl-2070-vl	<b>Course name</b> Fundamentals of Reinforcement Learning							
InstructorTypeProf. DrIng. Anja Klein, DrIng. Andrea JimenezLecture									
	<b>Course nr.</b> 18-kl-2070-ue	<b>Course name</b> Fundamentals of Reinforcement Learning							
Instructor       Type         Prof. DrIng. Anja Klein, DrIng. Andrea Jimenez, M.Sc. Sumedh Dongare,       Practice         M.Sc. Bernd Simon, M.Sc. Wanja de Sombre       Practice									

	<b>dule name</b> ious Games						
Мо	<b>dule nr.</b> de-2050	Credit points 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Summer term	
	iguage	0 CP	180 11	Module owner			
	man/English			PD DrIng. Stefa	n Göbel		
1	Individual le Introduction Game Dev Game Tech Personaliz Interactive Authoring Multiplaye Game Inter Effects, Aff Mobile Game	to the topic of "Seriesting of the topic of "Seriesting of the seriestic of the seriestic of the seriest of the series of th	sign ngines 1 tion echnology ience		foundations, applicat	cion areas and trends.	
	The exercise	e consists of theoretic	al and practical p	arts. Students are t	aught how to use a (	Game Engine.	
2	transfer it to for developin interactive d	sfully completing this different application ng computer games a	n domains (like ec and can apply basi side from that stud	lucation or health) c principles of game dents are able to sk	. They can describe t e design, personalisat	tious Games" and can he general approach tion / adaptation and nt research questions	
3	Recommen	ded prerequisites fo	or participation				
4	The examina 8 students r	m: e exam (Technical ex ation takes place in fo	orm of a written ex ion will be an ora	am (duration: 90 n		., Default RS) stimate that less than type of examination	
5	<b>Prerequisite</b> Pass exam (	e for the award of c 100%)	redit points				
6	Grading Module exan • Modul		xamination, Oral/	written examinatio	on, Weighting: 100 %	))	
7	•	t <b>he module</b> t, M.Sc. etit - DT, M.S	Sc. iCE, B.Sc. und	M.Sc. iST			
8	In dieser Vo Novelle der A		nrechnung von vo			die lt. 25 (2) der 5. er Notenverbesserung	
9	References						

urses			
<b>Course nr.</b> 18-de-2050-vl	<b>Course name</b> Serious Games		
<b>Instructor</b> PD DrIng. Stefa	n Göbel	<b>Type</b> Lecture	<b>SW</b> 3
<b>Course nr.</b> 18-de-2050-ue	<b>Course name</b> Serious Games		
Instructor		Туре	SW
PD DrIng. Stefa	n Göbel	Practice	1

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
		6 CP	180 h	120 h	1 Term	Every 2. Semester
	<b>nguage</b> glish			Module owner DrIng. Michael Kreutzer		
1	network sec and cryptog the applicat	ted course Network S urity with particular e raphy to the networki ton layer, the course pr ll known mechanisms,	mphasis on Intern ng domain, we fo rovides a detailed	net security. After tr llow a top-down ap discussion of netwo	ansferring the fundar oproach to network se ork security principles	nentals of IT securit ecurity. Starting wit and protocols. In a
	<ul> <li>Fundamer security thr</li> <li>Cryptograp crypto and i</li> <li>Application</li> <li>Transport i</li> <li>Network la</li> <li>Link layer</li> <li>Physical lat</li> <li>Operational</li> </ul>	ecurity: introduction, itals: a reference mo eats, attacks, services phic foundations for its use in networks, su a layer security layer security security yer security and phys al network security: fi opics in network securi	del for network s , and mechanisms networking secur ipport functions t ical security rewalls, intrusion	security, security s rity: symmetric cr o implement netwo	ypto and its use in r ork security	
2	cation netw important f are able to o thorough un layer, netwo and princip field. Addin peer-to-peer	bjectives sfully attending the co ork security with em undamentals from IT listinguish the most in nderstanding of secur rk layer, link layer, ph les in the area of netw ionally, students are security, mobile netw , which consist of liter	phasis on Interne security and cryp nportant basic tec ity mechanisms of ysical layer). As a vork security and able to describe york security, etc.)	t security. Student tography to the fie chniques for securi- on the different ne result, they are ab exhibit detailed th recent developme . The exercise deep	es are able to apply a eld of communication ng communication ne twork layers (applica- le to thoroughly discu- neoretical and practic nts in the area of ne pens the theoretical for	nd transfer the most networks. Student tworks. They have tion layer, transpor- ss the characteristic al knowledge in this etwork security (e., bundations by mean
3		<b>ded prerequisites fo</b> in the area IT Securit		Cryptography and	Communication Net	works
4	Form of exa Course relat	amination				
5	Prerequisit Pass exam (	e for the award of cr 100%)	edit points			
6	Grading Course relat		overnination Or	l/witton overning	tion, Weighting: 100	

	B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaft B.Sc. Psychologie Joint B.A. Inform B.Sc. Sportwisse	sinformatik e in IT		
	Can be used in o	ther degree programs.		
8	In dieser Vorlesu	<b>mpliant to §25 (2)</b> ng findet eine Anrechnung von vorlesungsbegleitenden Leistu Ind den vom FB 20 am 30.3.2017 beschlossenen Anrechnungsreg Iren kann.	•	
9		, Radia Perlman, Mike Speciner: Network Security - Private Co ntice Hall, 2002, ISBN: 978-0-14-046019-6; additional texts m		ic World,
Co	urses			
	<b>Course nr.</b> 20-00-0512-iv	<b>Course name</b> Network Security		
	<b>Instructor</b> DrIng. Michael	Kreutzer	<b>Type</b> Integrated course	SWS 4

00	odule nr. 00-0120	Credit points 6 CP	<b>Workload</b> 180 h	Self-study 120 h	Module duration	Module cycle
Language			Module owner			
Gei 1	rman <b>Teaching co</b> Objectives:	ontent		Prof. Dr. rer. nat.	Eberhard Mühlhäuse	er
2	<ul> <li>Knowledge</li> <li>Methodic k</li> <li>Course Cont</li> <li>Introductio</li> <li>Mobile Cor</li> <li>Internet of</li> <li>Service Dis</li> <li>Context- ar</li> <li>Human Co</li> <li>Privacy and</li> <li>Learning ol</li> <li>After success</li> </ul>	n to Ubiquitous Com nmunication Things: RFID and Sr covery & Cloudlets nd Location-aware Co mputer Interaction l Trust in Ubiquitous <b>ojectives</b> sfully attending the c	eges of the Ubiquir ent approaches to puting nart Items omputing Computing	tous Computing these challenges	technical basis of mo	
3	these challes	nges. They are able to ded prerequisites fo	o apply their know or participation		g. They know current quitous computing sy	
4	Form of exa Course relat			al/written examina	tion, Default RS)	
5	-	e for the award of c 100%)	redit points			
	Pass exam (100%)         Grading         Course related exam:         • [20-00-0120-iv] (Technical examination, Oral/written examination, Weighting: 100 %)					
6	• [20-00				, , ,	%)
6	Usability of B.Sc. Inform M.Sc. Inform M.Sc. Wirts B.Sc. Psycho Joint B.A. In B.Sc. Sporty	natik chaftsinformatik ologie in IT				%)

als of Mobile & Pervasive Computing McGraw Hill 2004, Viley 2009, ISBN 978-0-470-03560-3 r: Grundkurs Mobile Kommunikationssysteme: UMTS, HSI g-Teubner Studium 2010 Fundamentals, CRC Press 2010 s, Wiley 2005	DPA unc				
Viley 2009, ISBN 978-0-470-03560-3 r: Grundkurs Mobile Kommunikationssysteme: UMTS, HSI g-Teubner Studium 2010 Fundamentals, CRC Press 2010	DPA unc				
008, Information Science Reference, ISBN-10: 159904832	9				
References Literature recommendations will be updated regularly, an example might be: A Primary Literature: Handbook of Research: Ubiquitous Computing Technology for Real Time Enterprises edited by Prof.					

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle	
18-			180 h		1 Term	Winter term	
	<b>1guage</b> glish			Module owner Prof. DrIng. Michael Muma			
1	<ul> <li>Basics</li> <li>Robus</li> <li>Robus</li> <li>Robus</li> <li>Robus</li> <li>High-c</li> <li>Biomedical</li> <li>Body</li> <li>Electro</li> <li>Bioma</li> <li>Eye re</li> <li>Genon</li> <li>Intract</li> <li>The lecture of learning and can tolerate</li> <li>Robust data machine learning lear</li></ul>	a Science for Signal on robust statistical t regression models t clustering and class t time-series and speed limensional robust da Applications worn and radar-based ocardiogram (ECG) a rker selection search nics ranial Pressure (ICP) covers fundamental to d signal processing, impulsive noise, out science and biomedi	learning ification ctral analysis ata science d sensing of vital s and Photoplethysm opics and recent do which relies stron liers and artifacts cal application lec	ogram (PPG) evelopments in rob gly on the normal that are frequently tures alternate. Ex	(Gaussian) distribut y encountered in bio ercises revise the the	ion, robust methods medical applications	
	and R that i	mplement the lecture					
2	<b>Learning ol</b> Students un variety of pr outliers and	mplement the lecture ojectives iderstand the basics coblems. They are fa impulsive noise. The	e contents are ava of robust signal p miliar with variou	ilable to the studer rocessing and data is biomedical appli	ts. science and are ablected and some solutions and know th	es in Python, Matla e to apply them to e causes of artifact	
2	Learning ol Students un variety of pr outliers and spectral ana Recommen	mplement the lecture ojectives iderstand the basics coblems. They are fa impulsive noise. The	e contents are ava of robust signal p miliar with variou y can apply algorit or participation	ilable to the studer rocessing and data is biomedical appli thms for robust reg	ts. science and are ablected and some solutions and know th	es in Python, Matla e to apply them to e causes of artifacts	
	Learning ol Students un variety of pr outliers and spectral ana Recommenta Fundamenta Form of exa Module exam	mplement the lecture ojectives Iderstand the basics coblems. They are fa impulsive noise. The lysis. ded prerequisites fo al knowledge of statis	e contents are ava of robust signal p miliar with variou y can apply algorit or participation stical signal proces	ilable to the studer rocessing and data is biomedical appli thms for robust reg	nts. I science and are able cations and know th ression, cluster analy	es in Python, Matla e to apply them to e causes of artifact sis, classification and	
3	Learning ol Students un variety of pr outliers and spectral ana Recommenta Fundamenta Form of exa Module exan • Modul	mplement the lecture ojectives aderstand the basics coblems. They are fa impulsive noise. The lysis. ded prerequisites for al knowledge of statis amination m: le exam (Technical example e for the award of c	e contents are ava of robust signal p miliar with variou y can apply algorit or participation stical signal proces xamination, Exam	ilable to the studer rocessing and data is biomedical appli thms for robust reg	nts. I science and are able cations and know th ression, cluster analy	es in Python, Matla e to apply them to e causes of artifact sis, classification an	
3 4 5	Learning of Students un variety of pro- outliers and spectral ana Recommenta Fundamenta Form of exa Module exan • Modul Prerequisite Pass module Grading Module exan	mplement the lecture ojectives aderstand the basics coblems. They are fa impulsive noise. The lysis. ded prerequisites fo al knowledge of statis amination m: e exam (Technical ex e for the award of cr final exam	e contents are ava of robust signal p miliar with variou y can apply algorit or participation stical signal proces kamination, Exam redit points	ilable to the studer rocessing and data is biomedical appli thms for robust reg ssing	nts. I science and are able cations and know th ression, cluster analy 180 Min., Default RS	es in Python, Matla e to apply them to e causes of artifact sis, classification an	
3	Learning ol Students un variety of pro outliers and spectral ana Recomment Fundamenta Form of exa Module exan • Module Prerequisite Pass module Grading Module exan • Modul Usability of	mplement the lecture ojectives aderstand the basics coblems. They are fa impulsive noise. The lysis. ded prerequisites fo al knowledge of statis amination m: le exam (Technical exam e for the award of cr final exam	e contents are ava of robust signal p miliar with variou y can apply algorit or participation stical signal proces kamination, Exam redit points	ilable to the studer rocessing and data is biomedical appli thms for robust reg ssing ination, Duration: ination, Weighting	nts. a science and are able a cations and know th ression, cluster analy 180 Min., Default RS : 100 %)	es in Python, Matla e to apply them to e causes of artifact sis, classification an	

A manuscript and lecture slides can be downloaded via Moodle. Further reading

- Zoubir, A. M. and Koivunen, V. and Ollila, E. and Muma, M.: Robust Statistics for Signal Processing. Cambridge University Press, 2018.
- Zoubir, A. M. and Koivunen, V. and Chackchoukh J, and Muma, M. Robust Estimation in Signal Processing: A Tutorial-Style Treatment of Fundamental Concepts. IEEE Signal Proc. Mag. Vol. 29, No. 4, 2012, pp. 61-80.
- Huber, P. J. and Ronchetti, E. M.: Robust Statistics. Wiley Series in Probability and Statistics, 2009.
- Maronna, R. A. and Martin, R. D. and Yohai, V. J.: Robust Statistics: Theory and Methods. Wiley Series in Probability and Statistics, 2006.

<b>Course nr.</b> 18-mu-2010-vl	<b>Course name</b> Robust Signal Processing With Biomedical Applications		
<b>Instructor</b>		<b>Type</b>	<b>SWS</b>
Prof. DrIng. Mi		Lecture	3
<b>Course nr.</b> 18-mu-2010-ue	<b>Course name</b> Robust Data Science With Biomedical Applications		,
Instructor	chael Muma	<b>Type</b>	<b>SWS</b>
Prof. DrIng. Mie		Practice	1

## 2.3.2 Communication Algorithms - Labs and Projects

	<b>dule nr.</b> zo-2030	Credit points 6 CP	Workload 180 h	Self-study 135 h	Module duration 1 Term	Module cycle Every Semester
	<b>nguage</b> glish			Module owner Prof. DrIng. Abdelhak Zoubir		
1	Teaching co	ntent				
	<ol> <li>Discret</li> <li>Frequest</li> <li>Frequest</li> <li>Digital</li> <li>IIR Filt</li> <li>Nonpar</li> </ol>	ection to MATLAB e-Time Signals and ncy-Domain Analysi FIR Filter Design er Design using Ana ametric Spectrum Estim	s using the DFT log Prototypes estimation			
2	of digital FIF how MATLAI	are able to apply sk and IIR filters as v	well as non-paran	netric and parame	gnal Processing. The tric spectrum estima ate signal processing	tion. Students lear
3		<b>ed prerequisites fo</b> s of Signal Processi				
4		n: e exam (Study achie			ion: 120 Min., Defau announced at the beg	
5		for the award of c				
6	<b>Grading</b> Module exan • Module	n: e exam (Study achie	vement, Written e	examination, Weigh	nting: 100 %)	
7	<b>Usability of</b> M.Sc. etit - K		, M.Sc. iCE, M.Sc.	MedTec, M.Sc. W	I-etit, B.Sc. und M.So	c. iST
8	Grade bonus	s compliant to §25	(2)			
9	<b>References</b> Lab manual					
Co	urses	1				
	<b>Course nr.</b> 18-zo-2030-p	or Digital Signal	Processing Lab			
	Instructor	Abdelhak Zoubir			<b>Type</b> Lab	<b>SWS</b> 3

	dule nr. zo-2040	in Statistical Signal Credit points 8 CP	Workload 240 h	Self-study 180 h	Module duration	Module cycle Winter term
	<b>nguage</b> glish	I	I	<b>Module owner</b> Prof. DrIng. Abo	lelhak Zoubir	I
1	topics in sta Applications Processing, f from semest The course i The main to • Estima • Detect • Robus • Semin	covers the fundame tistical signal proces ; Robust Estimation; Direction of Arrival E er to semester. ncludes a series of lec pics covered are: ation theory ion theory t estimation theory	sing. Applications Prediction, Filterir stimation, and Sou ctures followed by icrophone arrays/	s are typically from ng, and Tracking w urce Detection; Tim a supervised resear /beamforming, loc	heory. These are ext in the following areas ith the Kalman Filter; he-Frequency Analysis rch seminar over appr calization and tracking	Detection in Rada Sensor Array Signa Topics may chang roximately 2 months
	magn	-8,	,		Jources	
2	Learning ol After comple	<b>ojectives</b> eting the module, stud	lents will be able to	o work independen	tly on advanced topics s and discuss them so	
	Learning of After comple and reprodu Recommen	<b>ojectives</b> eting the module, stud	lents will be able to he students can p <b>or participation</b>	o work independen	tly on advanced topics	
2 3 4	Learning of After comple and reprodu Recommen DSP, genera Form of exa Module exat • Modul	ojectives eting the module, stud ace existing results. T ded prerequisites for l interest in signal pr mination m: e exam (Study achie	dents will be able to the students can p or participation occessing wement, Oral/writ	o work independen resent these result tten examination, I	tly on advanced topics s and discuss them so	ientifically.
3	Learning of After comple and reprodu Recommen DSP, genera Form of exa Module exat • Modul Report and/ the lecture. Prerequisit	ojectives eting the module, stud ace existing results. T ded prerequisites for l interest in signal pr mination m: e exam (Study achie	dents will be able to the students can p or participation occessing evement, Oral/write or Colloquium. Th redit points	o work independen resent these result tten examination, I	tly on advanced topics s and discuss them so Default RS)	ientifically.
3 4 5	Learning of After complete and reproduct Recomment DSP, generat Form of exat Module exat • Modul Report and/ the lecture. Prerequisite Passing the Grading Module exat	ojectives eting the module, stuc- ice existing results. T ded prerequisites for l interest in signal pr inination m: e exam (Study achie or Presentation and/ e for the award of c final module examina	dents will be able to the students can p or participation rocessing evement, Oral/write or Colloquium. Th redit points ation	o work independen resent these result tten examination, I te type of examinat	tly on advanced topics s and discuss them so Default RS) ion will be announced	ientifically.
3	Learning of After complete and reprodut Recommen DSP, genera Form of exat Module exat • Modul Report and/ the lecture. Prerequisite Passing the Grading Module exat • Modul Usability of	ojectives eting the module, stud ice existing results. T ded prerequisites for l interest in signal pr imination m: e exam (Study achie or Presentation and/ e for the award of c final module examina- m: e exam (Study achie	lents will be able to the students can p or participation focessing evement, Oral/write or Colloquium. Th redit points ation	o work independen resent these result tten examination, I te type of examinat	tly on advanced topics s and discuss them so Default RS) ion will be announced	d in the beginning o

- Lecture slides
- Jerry D. Gibson and James L. Melsa. Introduction to Nonparametric Detection with Applications. IEEE Press, 1996.
- S. Kassam. Signal Detection in Non-Gaussian Noise. Springer Verlag, 1988.
- S. Kay. Fundamentals of Statistical Signal Processing: Estimation Theory. Prentice Hall, 1993.
- S. Kay. Fundamentals of Statistical Signal Processing: Detection Theory. Prentice Hall, 1998.
- E. L. Lehmann. Testing Statistical Hypotheses. Springer Verlag, 2nd edition, 1997.
- E. L. Lehmann and George Casella. Theory of Point Estimation. Springer Verlag, 2nd edition, 1999.
- Leon-Garcia. Probability and Random Processes for Electrical Engineering. Addison Wesley, 2nd edition, 1994.
- P. Peebles. Probability, Random Variables, and Random Signal Principles. McGraw-Hill, 3rd edition, 1993.
- H. Vincent Poor. An Introduction to Signal Detection and Estimation. Springer Verlag, 2nd edition, 1994.
  Louis L. Scharf. Statistical Signal Processing: Detection, Estimation, and Time Series Analysis. Pearson
- Education POD, 2002.Harry L. Van Trees. Detection, Estimation, and Modulation Theory, volume I,II,III,IV. John Wiley & Sons, 2003.
- A. M. Zoubir and D. R. Iskander. Bootstrap Techniques for Signal Processing. Cambridge University Press, May 2004.

00	uises			
	Course nr.	Course name		
	18-zo-2040-se	Advanced Topics in Statistical Signal Processing		
	Instructor		Туре	SWS
	Prof. DrIng. Ab	delhak Zoubir, M.Sc. Pertami Kunz	Seminar	4

	<b>dule nr.</b> zo-2050	Credit points 8 CP	<b>Workload</b> 240 h	Self-study 180 h	Module duration 1 Term	Module cycle Summer term
Language English			240 11	Module owner         Prof. DrIng. Abdelhak Zoubir		
1	many comm estimation v estimation s These lectur • Funda	tion and parameter on engineering opera vill be presented, allo	tions under a varie wing a better und	ety of names. In th erstanding of how	processing tasks. In is course, the theory l (and why) to design	pehind detection ar
	- R - U - M • Estima - T - M - S - U - F	ayesian/Ideal Observ eceiver Operating Ch Iniformly Most Power Iatched Filter tion Theory: ypes of Estimators Iaxmimum Likelihoo ufficiency and the Fis Inbiasedness and min- isher Information and symptotic properties	aracteristics ful Tests d Estimators sher-Neyman/Fact imum variance d the CRB			
	After succes can design h In addition,	<b>Learning objectives</b> After successful completion of the module, students know the basics of detection and estimation theory. T can design hypothesis tests and estimators for existing problems and implement them in Matlab on their In addition, students will be able to review existing work on detection and estimation independently. They adequately present the methods and results from existing publications and discuss them scientifically.				
;		<b>ded prerequisites fo</b> l interest in signal pr				
ŀ		n: e exam (Study achie			Default RS) ion will be announce	d in the beginning
5		e <b>for the award of c</b> r final module examina				
,	Grading Module exa • Modul	n: e exam (Study achie	vement, Oral/writ	tten examination, V	Weighting: 100 %)	
7	•	<b>the module</b> KTS, M.Sc. etit - VAS,	M.Sc. iCE, M.Sc.	MedTec, M.Sc. W	I-etit, B.Sc. und M.Sc	e. iST, M.Sc. CE
8	Grade bon	s compliant to §25	( <b>0</b> )			

9	References			
	<ul> <li>Press, 1996</li> <li>S. Kassam.</li> <li>S. Kay. Fun 1993.</li> <li>S. Kay. Fun</li> <li>E. L. Lehma</li> <li>E. L. Lehma</li> <li>Leon-Garci 1994.</li> <li>P. Peebles.</li> <li>H. Vincent 1994.</li> <li>Louis L. Sc Education I</li> <li>Harry L. Va 2003.</li> </ul>	oson and James L. Melsa. Introduction to Nonparametri Signal Detection in Non-Gaussian Noise. Springer Verlag damentals of Statistical Signal Processing: Estimation The damentals of Statistical Signal Processing: Detection The nn. Testing Statistical Hypotheses. Springer Verlag, 2nd nn and George Casella. Theory of Point Estimation. Spri a. Probability and Random Processes for Electrical Engin Probability, Random Variables, and Random Signal Princip Poor. An Introduction to Signal Detection and Estimation narf. Statistical Signal Processing: Detection, Estimation	, 1988. eory. Prentice Hall, 1998 edition, 1997. Inger Verlag, 2nd editio eering. Addison Wesley ples. McGraw-Hill, 3rd . Springer Verlag, 2nd a, and Time Series Anal volume I,II,III,IV. John V	3. n, 1999. g, 2nd edition, edition, 1993 edition, ysis. Pearson Wiley & Sons,
Co	urses			
	<b>Course nr.</b> 18-zo-2050-se	<b>Course name</b> Signal Detection and Parameter Estimation		
	Instructor Prof. DrIng. Abo	elhak Zoubir	<b>Type</b> Seminar	SWS 4

20-	<b>dule nr. C</b> 00-0418	redit points 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Every 2. Semester
Lar	nguage rman/English	0.61	100 11	Module owner Prof. Dr. Bernt Schiele		
1	<b>Teaching cont</b> Students work a talk at the en	n this lab on sele	The specific topics		uting. Project results ab change every sem	
2	<b>Learning objectives</b> After successful completion of this course, the students will be able to independently analyze and solve a problem in the area of visual computing and to evaluate the results.					
3	Practical progra Basic knowledg	Recommended prerequisites for participation Practical programming skills, e.g. Java, C++ Basic knowledge or interest within Visual Computing Participation in one basic lecture within Visiual Computing				
4	Form of exami Course related • [20-00-04	exam:	hievement, Oral/v	vritten examination	n, Default RS)	
5	<b>Prerequisite fo</b> Pass exam (100	or the award of c %)	redit points			
6	Grading         Course related exam:         • [20-00-0418-pr] (Study achievement, Oral/written examination, Weighting: 100 %)					
	• [20-00-04		hievement, Oral/v	vritten examination	n, Weighting: 100 %)	)
7	Usability of the B.Sc. Informati M.Sc. Informati B.Sc. Computat M.Sc. Computat M.Sc. Wirtscha B.Sc. Psycholog Joint B.A. Infor B.Sc. Sportwiss M.Sc. Sportwiss	and the senschaft und Info senschaft und Info senschaft und Info	g g ormatik ormatik	vritten examination	n, Weighting: 100 %	)
	Usability of the B.Sc. Informati M.Sc. Informati B.Sc. Computa M.Sc. Computa M.Sc. Wirtscha B.Sc. Psycholog Joint B.A. Infor B.Sc. Sportwiss M.Sc. Sportwiss Can be used in	18-pr] (Study ac module k ik cional Engineering tional Engineering ftsinformatik çie in IT matik enschaft und Info	g ormatik ormatik grams.	vritten examination	n, Weighting: 100 %)	)
8	Usability of the B.Sc. Informati M.Sc. Informati B.Sc. Computa M.Sc. Computa M.Sc. Wirtscha B.Sc. Psycholog Joint B.A. Infor B.Sc. Sportwiss M.Sc. Sportwiss Can be used in	and the senschaft und Info senschaft und Info senschaft und Info senschaft und Info other degree prop ompliant to §25	g ormatik ormatik grams.	vritten examination	n, Weighting: 100 %	)
8	Usability of the B.Sc. Informati M.Sc. Informati B.Sc. Computa M.Sc. Computa M.Sc. Wirtscha B.Sc. Psycholog Joint B.A. Infor B.Sc. Sportwiss M.Sc. Sportwiss Can be used in Grade bonus c References Will be announ urses	and the senschaft und Info senschaft und Info senschaft und Info other degree prop ompliant to §25	g ormatik ormatik grams. (2)	vritten examination	n, Weighting: 100 %)	)
7 8 9 Cot	Usability of the B.Sc. Informati M.Sc. Informati B.Sc. Computat M.Sc. Computat M.Sc. Wirtscha B.Sc. Psycholog Joint B.A. Infor B.Sc. Sportwiss M.Sc. Sportwiss Can be used in Grade bonus c References Will be announ	and the senschaft und Info senschaft und Info senschaft und Info senschaft und Info other degree prop ompliant to §25	g ormatik formatik grams. (2)	vritten examination	n, Weighting: 100 %)	)

	odule nr. 00-1022	Credit points 3 CP	Workload 90 h	Self-study 60 h	Module duration 1 Term	Module cycle Every 2. Semeste
	nguage		90 11	Module owner		
	rman/English			Prof. Dr. techn. Stefan Katzenbeisser		
1	chance to read - Trust - Privacy - Resilience	on Protection in Inf	imarize current sc		of seminars where st s. The topics are rela	
2	these topics. Your task will	cipating in the sem be to understand	state-of-the-art sc	ientific publication	n and conduct resear ns in order to explair pic assigned to you.	
3	Recommended prerequisites for participation         Basic knowledge about it-security and distributed systems.         Lectures:         Computersystemsicherheit (CSS)         Computer-Netzwerke und verteilte Systeme (CNuvS)					
4	Form of exam Course relate • [20-00-		hievement, Oral/v	vritten examination	n, Default RS)	
5	Prerequisite Pass exam (10	<b>for the award of c</b> 00%)	redit points			
6	Grading Course related • [20-00-7		hievement, Oral/v	vritten examination	n, Weighting: 100 %)	)
7	Usability of t B.Sc. Informa M.Sc. Informa May be used i	tik	gramss			
8	Grade bonus	compliant to §25	(2)			
9	References					
Co	urses					
	Course nr.	Course name				
	20-00-1022-s	e   Protection in I	nfrastructures and	i Networks		

	<b>dule nr.</b> 00-0553	Credit points 9 CP	Workload 270 h	<b>Self-study</b> 180 h	Module duration 1 Term	Module cycle Every 2. Semester
	<b>nguage</b> rman/English			<b>Module owner</b> Prof. Dr. rer. nat.	Karsten Weihe	
1 Teaching content The Project on Secure Mobile Networking covers the development. Topic areas covered are communic communications as well as the combination of thes in a team.				ation networks, II	security, mobile ne	twokrs and wireles
	netwokrs an - Project plan - Survey on s - Conception - Software/h - Prototypica - Evaluation	nt solving of a devel d wireless communic aning and project ma solution alternatives of a software archite ardware design for t il realization on the t of the system with re	cations anagement and discussion of ecture or a combin he target platform arget platform espect to performa	pros and cons ned hardware-softv 1 nce aspects	nunication networks ware architecture cumentation of the p	
2	Learning of After success of secure mo define, man The student one/multiple They are ab evaluate the	ojectives Sfully attending the c obile networking usi age and carrry out a s have gained insigl of the areas of comm le to implement the	ourse, students hang software techn project. ht into the design nunication networl chosen protocols students are able	we aquired the abin nology. To this end n/implementation ks, IT security, mob and application, a to document the	lity to solve complex l, the students are al of complex protoco ile netwokrs and wire and to test the functi project planning an	problems in the area ole to independently ls or applications in less communications onality as well as to
3	Recommend	ded prerequisites for participation of an least termination of an least termin	r participation			
4	Form of exa Course relat • [20-00		hievement, Oral/v	written examinatio	n, Default RS)	
5	Prerequisite Pass exam (1	e for the award of c 100%)	redit points			
6	Grading Course relat				n, Weighting: 100 %	

	B.Sc. Informatik						
	M.Sc. Informatik	-					
		M.Sc. Wirtschaftsinformatik					
	B.Sc. Psychologie						
	Joint B.A. Inform						
	B.Sc. Sportwisse	nschaft und Informatik					
	Can be used in o	ther degree programs.					
8	Grade bonus compliant to §25 (2)						
		-					
9	References						
-	Will be given in p	project.					
Cor	urses						
00		_					
	Course nr.	Course name					
	20-00-0553-pp	Secure Mobile Networking Project					
	Instructor			Туре	SWS		
	Prof. DrIng. Ma	tthias Hollick		Lab	6		

	dule name					
		munications Semina				
	<b>dule nr.</b> sm-2090	Credit points 4 CP	Workload 120 h	Self-study 90 h	Module duration 1 Term	Module cycle Every Semester
	iguage	1.01	120 11	Module owner		
	man/English				Björn Scheuermann	
1	<ul> <li>Teaching content         This seminar deals with current and upcoming trends relevant to the future development of multimedia communication systems. The educational objective of this seminar is to gain knowledge about future research trends in different areas. To this aim, an extensive literature research will be performed, as well as the writing-up of a report and the presentation of selected, high-quality research topics from current leading magazines, newspapers and conferences in the web technologies research area.     </li> <li>Some potential topics are:         <ul> <li>Knowledge &amp; Educational Technologies</li> <li>Self organizing Systems &amp; Overlay Communication</li> <li>Mobile Systems &amp; Sensor Networking</li> <li>Service-oriented Computing</li> <li>Multimedia Technologies &amp; Serious Games</li> </ul> </li> </ul>					
2	multimedia students wil • Search • Analys • Write	all acquire profound	ems and applicat ng competencies: vant scientific liter lex technical and fic abstracts and su	ions which will bu rature. scientific informati	ild the future Intern	rds and literature on net. In so doing, the
3				tworks. Lectures is	n Communication N	etworks I and II are
4		m: le exam (Study achie				d in the beginning of
5	-	e for the award of c	· ·			
6	Grading Module exan • Modul	m: le exam (Study achie	vement, Oral/writ	tten examination, V	Weighting: 100 %)	
7		<b>the module</b> DT, M.Sc. iCE, M.Sc.	WI-etit, B.Sc. und	l M.Sc. iST		
8	Grade bonu	is compliant to §25	(2)			
9	<b>References</b> Depending of	on specific topic (sele	ected articles of ion	urnals, magazines.	and conferences).	
Co	irses	1				

	Course nr. 8-sm-2090-se	<b>Course name</b> Multimedia Communications Seminar II		
P	<b>nstructor</b> Prof. Dr. rer. nat Altenhofen	. Björn Scheuermann, Dr. Ing. Julian Zobel, M.Sc. Konrad	<b>Type</b> Seminar	<b>SWS</b> 2

	dule name	munications Lab II				
Мо	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
18-	sm-2070	6 CP	180 h	135 h	1 Term	Every Semester
	<b>iguage</b> man/English			Module owner Prof. Dr. rer. nat. Björn Scheuermann		
1	<ul> <li>Teaching content         The course deals with cutting-edge development topics in the area of multimedia communication system Besides a general overview, it provides a deep insight into a special development topic. The topics are selecter according to the specific working areas of the participating researchers and convey technical and basic scientific competencies in one or more of the following topics:         <ul> <li>Network planning and traffic analysis</li> <li>Performance evaluation of network applications</li> <li>Discrete event simulation for network services</li> <li>Protocols for mobile ad hoc networks / sensor networks</li> <li>Infrastructure networks for mobile communication / mesh networks</li> <li>Context-aware communication and services</li> <li>Peer-to-peer systems and architectures</li> <li>Content distribution and management systems for multimedia/e-learning</li> <li>Multimedia authoring and re-authoring tools</li> <li>Web service technologies and service-oriented architectures</li> </ul> </li> </ul>					
	• Natura	ve educational techn ll language processin e list of topics can be	ng in education	ster on the corresp	onding teaching web	site of KOM.
2	nication net Design Impler Applic Acquis Writin		ns shall be acquir nication application of software compo- ted analysis and d agement technique entation and proje	ed. Acquired composed. Acquired composed compo	etences are: ed systems	e multimedia commu-
3	<ul> <li>3 Recommended prerequisites for participation         Keen interest to explore challenging topics which are cutting edge in technology and research. Further we expect:         <ul> <li>Solid experience in programming Java and/or C# (C/C++)</li> <li>Solid knowledge in object oriented analysis and design</li> <li>Solid knowledge in computer communication networks are recommended</li> <li>Lectures in Communication Networks I (II, III, or IV) are an additional plus</li> </ul> </li> </ul>					esearch. Further we
4	<ul> <li>Form of examination         Module exam:             <ul></ul></li></ul>					
5		e for the award of c final module examina				

6	Grading Module exam: • Module exa							
7	•	Usability of the module						
8	-	M.Sc. etit - DT, M.Sc. iCE, M.Sc. WI-etit, B.Sc. und M.Sc. iST Grade bonus compliant to §25 (2)						
9	chapters from fol Andrew Tat Christian U 6" (ISBN-1: Joshua Bloo Erich Gama Software" (	rered by a selection of papers and articles. In addition we r lowing books: nenbaum: "Computer Networks". Prentice Hall PTR (ISBN 013 llenboom: "Java ist auch eine Insel: Programmieren mit der Ja 3: 978-3898428385) ch: "Effective Java Programming Language Guide" (ISBN-13: 9 na, Richard Helm, Ralph E. Johnson: "Design Patterns: Object ISBN 0-201-63361-2) "Extreme Programming Explained - Embrace Changes" (ISBN	30384887) ava Standard Edition 978-0201310054) cts of Reusable Objec	Version 5 / ct Oriented				
Co	urses							
	<b>Course nr.</b> 18-sm-2070-pr	<b>Course name</b> Multimedia Communications Lab II						
	<b>Instructor</b> Prof. Dr. rer. nat Altenhofen	. Björn Scheuermann, Dr. Ing. Julian Zobel, M.Sc. Konrad	<b>Type</b> Lab	<b>SWS</b> 3				

	dule nr.	Credit points	Workload	Self-study	Module duration	Module cycle
	00-0552	6 CP	180 h	120 h	1 Term	Every 2. Semester
	<b>nguage</b> rman/English			Module owner Prof. Dr. rer. nat.	Karsten Weihe	
1	software de wireless co	ercise on Secure Mob evelopment. Topic ar mmunications as we ation in software or ha	eas covered are colling and the combination of the	ommunication net tion of these. Go	works, IT security, n	nobile networks and
	<ul> <li>Solving of communica</li> <li>Survey on</li> <li>Conception</li> <li>Software/2</li> <li>Prototypic</li> <li>Evaluation</li> </ul>	f a problem in the ar	and discussion of ecture or a combin he target platform arget platform espect to performa	pros and cons ned hardware-softw 1		tworks and wireles
2	mobile netv of complex netwokrs and to test the f	bjectives sfully attending the covorking using software protocols or application ad wireless communic functionality as well a tefacts and to present	e technology. The sons in one/multiple cations. They are a sons to evaluate the p	students have gaine e of the areas of con able to implement to performance. Stud	ed insight into the des nmunication network the chosen protocols	sign/implementation s, IT security, mobile and application, and
3		ded prerequisites fo participation in an lea				
4	Form of ex Course rela • [20-0		hievement, Oral/v	vritten examinatio	n, Default RS)	
5	<b>Prerequisit</b> Pass exam (	e for the award of cr (100%)	redit points			
5	Grading	tod ovom.				
	Course rela • [20-0	0-0552-pr] (Study ac	hievement, Oral/v	vritten examinatio	n, Weighting: 100 %)	)
6 7	• [20-0 Usability o B.Sc. Inforr M.Sc. Inforr M.Sc. Wirts B.Sc. Psych Joint B.A. In	0-0552-pr] (Study act f <b>the module</b> natik matik chaftsinformatik ologie in IT		vritten examinatio	n, Weighting: 100 %)	)
6	• [20-0 Usability o B.Sc. Inform M.Sc. Inform M.Sc. Wirts B.Sc. Psych Joint B.A. In B.Sc. Sport	0-0552-pr] (Study act f <b>the module</b> natik matik chaftsinformatik ologie in IT nformatik	ormatik	vritten examinatio	n, Weighting: 100 %)	)

9	<b>References</b> Will be given in lab.					
	will be given in	iaD.				
Cot	urses					
	Course nr.	Course name				
	20-00-0552-pr	Secure Mobile Networking Lab				
	Instructor		Туре	SWS		
	Prof. DrIng. Ma	tthias Hollick	Lab	4		

	<b>dule name</b> ltimedia Com	munications Project	II			
Мо	<b>dule nr.</b> sm-2130	Credit points 9 CP	Workload 270 h	Self-study 180 h	<b>Module duration</b> 1 Term	Module cycle Every Semester
Lar	nguage rman/English			Module owner Prof. Dr. rer. nat. Björn Scheuermann		
1						
2	future multi acquired. Ac • Search • Desigr • Impler • Applic • Acquis • Systen • Writin		on networks and a are: project relevant litentication application of software composed analysis and d agement technique analyzing of techni entation and proje	applications using s erature ons and protocols onents for distribute esign techniques es for small develop nical and scientific o ect reports	tate of the art scient ed systems oment teams	and development of ific methods shall be
3	<ul> <li>3 Recommended prerequisites for participation</li> <li>Keen interest to develop and explore challenging solutions and applications in cutting edge multimedia comnications systems using scientific methods. Further we expect: <ul> <li>Solid experience in programming Java and/or C# (C/C++).</li> <li>Solid knowledge in object oriented analysis and design.</li> <li>Basic knowledge of design patterns, refactoring and project management.</li> <li>Solid knowledge in computer communication networks is recommended.</li> <li>Lectures in "Communication Networks I" and "Communication Networks II" are recommended</li> </ul> </li> </ul>					
4	Report (incl Colloquium	m: e exam (Study achie uding submission of	programming co	ode) and/or Preser	ntation and/or Oral	examination and/or be announced in the

5	Prerequisite for the award of credit points Passing the final module examination							
6	<ul><li>Grading</li><li>Module exam:</li><li>Module exam (Study achievement, Oral/written examination, Weighting: 100 %)</li></ul>							
7	Usability of the module M.Sc. iCE, B.Sc. und M.Sc. iST							
8	Grade bonus compliant to §25 (2)							
9	<ul> <li>References</li> <li>Each topic is covered by a selection of papers and articles. In addition we recommend reading of selected chapters from following books: <ul> <li>Andrew Tanenbaum: "Computer Networks". Prentice Hall PTR (ISBN 0130384887)</li> <li>Raj Jain: "The Art of Computer Systems Performance Analysis: Techniques for Experimental Design, Measurement, Simulation, and Modeling" (ISBN 0-471-50336-3)</li> <li>Joshua Bloch: "Effective Java - Programming Language Guide" (ISBN-13: 978-0201310054)</li> <li>Erich Gamma, Richard Helm, Ralph E. Johnson: "Design Patterns: Objects of Reusable Object Oriented Software" (ISBN 0-201-63361-2)</li> <li>Martin Fowler: "Refactorings - Improving the Design of Existing Code" (ISBN-13: 978-0201485677)</li> <li>Kent Beck: "Extreme Programming Explained - Embrace Changes" (ISBN-13: 978-0321278654)</li> </ul> </li> </ul>							
Coi	Courses							
	Course nr.Course name18-sm-2130-prMultimedia Communications Project Lab							
			<b>Type</b> Lab	<b>SWS</b> 6				

20.	odule nr. Ci -00-0418	r <b>edit points</b> 6 CP	Workload 180 h	Self-study 120 h	Module duration 1 Term	Module cycle Every 2. Semeste
Language German/English		100 11	Module owner         Prof. Dr. Bernt Schiele			
1	<b>Teaching content</b> Students work in this lab on selected topics in the area of visual computing. Project results will be presented in a talk at the end of the course. The specific topics addressed in the lab change every semester and should be discussed directly with one of the instructors.					
2	<b>Learning objectives</b> After successful completion of this course, the students will be able to independently analyze and solve a problem in the area of visual computing and to evaluate the results.					
3	Recommended prerequisites for participation Practical programming skills, e.g. Java, C++ Basic knowledge or interest within Visual Computing Participation in one basic lecture within Visiual Computing					
4	<ul> <li>Form of examination</li> <li>Course related exam:</li> <li>• [20-00-0418-pr] (Study achievement, Oral/written examination, Default RS)</li> </ul>					
5	Prerequisite for the award of credit points Pass exam (100%)					
6	<ul> <li>Grading</li> <li>Course related exam:</li> <li>• [20-00-0418-pr] (Study achievement, Oral/written examination, Weighting: 100 %)</li> </ul>					
	- [20-00-04		hievement, Oral/v	vritten examinatio		)
7	Usability of the B.Sc. Informatil M.Sc. Informatil B.Sc. Computat M.Sc. Computat M.Sc. Wirtschaf B.Sc. Psycholog Joint B.A. Inforr B.Sc. Sportwisse M.Sc. Sportwisse	e module k ional Engineering tional Engineering tional Engineering tisinformatik ie in IT natik enschaft und Info senschaft und Info	g g ormatik ormatik	vritten examinatio	n, weighting: 100 %	)
	Usability of the B.Sc. Informatil M.Sc. Informatil B.Sc. Computat M.Sc. Computat M.Sc. Wirtschaf B.Sc. Psycholog Joint B.A. Inforr B.Sc. Sportwisse M.Sc. Sportwisse Can be used in o	e module k ional Engineerin itsinformatik ie in IT natik enschaft und Info	g g ormatik ormatik grams.	vritten examinatio	n, weighting: 100 %	)
8	Usability of the B.Sc. Informatil M.Sc. Informatil B.Sc. Computat M.Sc. Computat M.Sc. Wirtschaf B.Sc. Psycholog Joint B.A. Inforr B.Sc. Sportwisse M.Sc. Sportwisse Can be used in o	e module k ional Engineering itional Engineeri	g g ormatik ormatik grams.	vritten examinatio	n, weighting: 100 %	)
8	Usability of the B.Sc. Informatil M.Sc. Informatil B.Sc. Computat M.Sc. Computat M.Sc. Wirtschaf B.Sc. Psycholog Joint B.A. Inforr B.Sc. Sportwisse M.Sc. Sportwisse Can be used in o Grade bonus co References Will be announce	e module c k ional Engineering itional Engineer	g g ormatik ormatik grams.	vritten examinatio	n, weighting: 100 %	)
7 8 9 <u>Co</u>	Usability of the B.Sc. Informatil M.Sc. Informatil B.Sc. Computat M.Sc. Computat M.Sc. Wirtschaf B.Sc. Psycholog Joint B.A. Inforr B.Sc. Sportwiss M.Sc. Sportwiss Can be used in o Grade bonus co References Will be annound	e module k ional Engineering itional Engineeri	g g ormatik ormatik grams. (2)	vritten examinatio	n, weighting: 100 %	)

n /	ta Science II	1				1
<b>Module nr.</b> 18-zo-2120		Credit points 8 CP	Workload 240 h	<b>Self-study</b> 180 h	Module duration 1 Term	Module cycle Winter term
<b>Language</b> English			<b>Module owner</b> Prof. DrIng. Abdelhak Zoubir			
1	<ul> <li>Teaching content</li> <li>The course covers the following topics: <ul> <li>Data Science Advanced Methods</li> <li>Data Management + Big data frameworks</li> <li>Statistical Learning <ul> <li>Recommender Systems</li> <li>Deep Learning</li> <li>Unsupervised Learning</li> <li>Text data analysis</li> </ul> </li> <li>Final application project. Flexibility to choose from list of projects or come up with own project. Examples</li> <li>Sound classification <ul> <li>Heart rate analysis</li> <li>Activity recognition with acceleration data</li> <li>Hyperspectral data</li> <li>Image classification <ul> <li>Health survey</li> </ul> </li> </ul></li></ul></li></ul>					
2	<b>Learning objectives</b> After successful completion of the module, the students have an in-depth understanding of data science with a strong practical relevance. They have become familiar with modern data science technologies (from big data to novel methods in machine learning) and can apply them in a project with real world data.					
3	Recommended prerequisites for participation Data Science I (Lecture)					
4	<ul> <li>Form of examination Module exam:</li> <li>Module exam (Study achievement, Oral/written examination, Duration: 90 Min., Default RS) Report and/or Presentation and/or Colloquium. The type of examination will be announced in the beginning o the lecture.</li> </ul>					
	Prerequisite for the award of credit points Passing the final module examination					
5						
5	Passing the Grading Module exam	final module examina	ation	ten examination, V	Neighting: 100 %)	
	Passing the Grading Module exa • Modul Usability of	final module examina	ation vement, Oral/writ			Sc. iST, M.Sc. CE

Lecture notes and slides can be downloaded here:

- http://www.spg.tu-darmstadt.de
- Moodle platform

Further reading:

- Wes McKinney: Python for Data Analysis, O'Reilly, 2017
- Christopher M. Bishop: Pattern Recognition and Machine Learning, 2011
- James, Witten, Hastie and Tibshirani, Introduction to Statistical Learning, Springer, 2017

<b>Course nr.</b> 18-zo-2120-se	Course name Data Science II		
<b>Instructor</b>	1 Debes	<b>Type</b>	SWS
DrIng. Christian		Seminar	4

# 3 Optional supplements (all modules from the subareas 2.1, 2.2, 2.3)

## **4** Studium Generale (usually no FB18 modules)

Please find a detailed module handbook about the Studium Generale online