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

Module handbook
FB 18
Date: 01.03.2026

TECHNISCHE UNIVERSITÄT DARMSTADT

FB 18

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

Date: 01.03.2026

FB 18
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Contents

1 Core Competencies

Module name Advanced Digital Integrated Circuit Design					
Module nr. 18-ho-2010	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

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	**Learning objectives** A student is, after successful completion of this module, able to • understand the short-channel effects of modern CMOS transistors, • derive and analyse the most important circuit concepts for digital logic gates, • understand the design flow of digital ASICs based on standard cells (design, layout, simulation/verification), • know the pros and cons of synchronous vs. asynchronous logic, multiclockphase systems, • understand the differential design methods of integrated circuits (ASIC, ASIP, Full-custom/Semicustom, PLA, PLD, FPGA), • understand basic circuitry of logic and arithmetic units (adders, multipliers, PLL/DLL), • understand the concepts of A/D and D/A-converters, and their fundamental technical properties and architectures, • know the design principles and properties of integrated semiconductor memory (DRAM, SRAM, Flash. MRAM, FeRAM)
3	**Recommended prerequisites for participation** Lecture "Electronics"
4	**Form of examination** Module exam: • Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - DT, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. iCE, M.Sc. iST
8	**Grade bonus compliant to §25 (2)** A grade improvement of up to 1,0 due to a bonus is possible, which can be earned with tests.
9	**References**

Lecture Slide Copies

- John P. Uyemura: Fundamentals of MOS Digital Integrated Circuits
- Neil Weste et al.: Principles of CMOS VLSI Design

Courses

Course nr.	**Course name**		
18-ho-2010-vl	Advanced Digital Integrated Circuit Design		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Klaus Hofmann		Lecture	3

Course nr.	**Course name**		
18-ho-2010-ue	Advanced Digital Integrated Circuit Design		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Klaus Hofmann		Practice	1

Module name Antennas and Adaptive Beamforming					
Module nr. 18-jk-2020	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1	**Teaching content** 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.
2	**Learning objectives** 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 and frequency-independent antennas (V antennas, biconical antennas, helical antennas, spiral and log-periodic antennas).
3	**Recommended prerequisites for participation** Fundamentals of Communications, Microwave Engineering 1
4	**Form of examination** Module exam: • Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading**

	Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)			
7	**Usability of the module** M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, B.Sc. WI-etit			
8	**Grade bonus compliant to §25 (2)**			
9	**References** Skriptum “Antennas and Adaptive Beamforming” will be provided electronically at the beginning of the lecture.			
Courses				
	Course nr. 18-jk-2020-vl	**Course name** Antennas and Adaptive Beamforming		
	Instructor M.Sc. Jesús Pastor, Dr.-Ing. Alejandro Sáez, Dr.-Ing. Martin Schüßler		**Type** Lecture	**SWS** 3
	Course nr. 18-jk-2020-ue	**Course name** Antennas and Adaptive Beamforming		
	Instructor M.Sc. Jesús Pastor, Dr.-Ing. Alejandro Sáez, Dr.-Ing. Martin Schüßler		**Type** Practice	**SWS** 1

Module name Communication Networks II					
Module nr. 18-sm-2010	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Ralf Steinmetz		

1 Teaching content

The course Communication Networks II covers the principles and practice of computer networking and telecommunications with emphasis on the Internet. Starting with the history, the course discusses past, current and future aspects of communication networks. In addition to the basics including well known protocols and technologies, recent developments in the area of multimedia communication (e.g., Video Streaming, P2P, IP-Telephony, Cloud Computing and Service-oriented Architectures) will be examined thoroughly. The course is designed as follow-up to Communication Networks I.

Topics are:

- Basics and History of Communication Networks (Telegraphy vs. Telephony, Reference Models, ...)
- Transport Layer (Addressing, Flow Control, Connection Management, Error Detection, Congestion Control, ...)
- Transport Protocols (TCP, SCTP)
- Interactive Protocols (Telnet, SSH, FTP, ...)
- Electronic Mail (SMTP, POP3, IMAP, MIME, ...)
- World Wide Web (HTML, URL, HTTP, DNS, ...)
- Distributed Programming (RPC, Web Services, Event-based Communication)
- SOA (WSDL, SOAP, REST, UDDI, ...)
- Cloud Computing (SaaS, PaaS, IaaS, Virtualization, ...)
- Overlay Networks (Unstructured P2P, DHT Systems, Application Layer Multicast, ...)
- Video Streaming (HTTP Streaming, Flash Streaming, RTP/RTSP, P2P Streaming, ...)
- VoIP and Instant Messaging (SIP, H.323)

2 Learning objectives

Upon successful completion, the module provides students with an understanding of the principles and practice of computer networking and telecommunications with emphasis on the Internet. Starting with the history, the course discusses past, current and future aspects of communication networks. In addition to the basics including well known protocols and technologies, recent developments in the area of multimedia communication (e.g., Video Streaming, P2P, IP-Telephony, Cloud Computing and Service-oriented Architectures) will be examined thoroughly. The course is designed as follow-up to Communication Networks I.

3 Recommended prerequisites for participation

Basic courses of first 4 semesters are required. Knowledge in the topics covered by the course Communication Networks I is recommended. Theoretical knowledge obtained in the course Communication Networks II will be strengthened in practical programming exercises. So, basic programming skills are beneficial.

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 120 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

	M.Sc. MEC, M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, B.Sc. CE, M.Sc. MedTec, M.Sc. iCE, M.Sc. iST, 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 improvemnet 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

Courses

	Course nr. 18-sm-2010-vl	**Course name** Communication Networks II		
	Instructor Dr.-Ing. Tobias Meuser, M.Sc. Christoph Gärtner, Prof. Dr.-Ing. Ralf Steinmetz, M.Sc. Pratyush Agnihotri		**Type** Lecture	**SWS** 3
	Course nr. 18-sm-2010-ue	**Course name** Communication Networks II		
	Instructor Dr.-Ing. Tobias Meuser, M.Sc. Christoph Gärtner, Prof. Dr.-Ing. Ralf Steinmetz, M.Sc. Pratyush Agnihotri		**Type** Practice	**SWS** 1

Module name Communication Technology II					
Module nr. 18-kl-2010	**Credit points** 5 CP	**Workload** 150 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Anja Klein		

1	**Teaching content** Linear and nonlinear digital modulation schemes, optimum receivers for AWGN channels, error probability, channel capacity, channel models, channel estimation and data detection for multipath channels, multicarrier schemes, OFDM
2	**Learning objectives** After completion of the lecture, students possess: • the ability of comparing, evaluating, classifying an analyzing linear and nonlinear modulation schemes by means of signal space representations; • the ability to understand, describe and analyze the influence of AWGN on the signal; • the ability to understand and derive optimum receivers in case of AWGN channels; • the ability to understand, describe and analyze the influence of multipath propagation on the signal; • the ability to describe the influence of a multipath channel mathematically (channel model) and estimate the multipath channel at the receiver; • 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; • the ability to analyze and evaluate the properties and application areas of multicarrier transmission systems, e.g. OFDM-systems; • the ability to design and evaluate the system parameters of multicarrier schemes for the application in realistic wireless communication scenarios; • the ability to mathematically express and analyze all above system models in matrix-vector-notation.
3	**Recommended prerequisites for participation** Deterministische Signale und Systeme, Communication Technology I, Basics of Telecommunication, Mathematics I to III, Statistics/Probability Theory, Scientific Computing
4	**Form of examination** Module exam: • Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** will be announced in the lecture
Courses	

	Course nr. 18-kl-2010-vl	**Course name** Communication Technology II		
	Instructor Prof. Dr.-Ing. Anja Klein		**Type** Lecture	**SWS** 2
	Course nr. 18-kl-2010-ue	**Course name** Communication Technology II		
	Instructor M.Sc. Yi Wang, M.Sc. Sumedh Dongare, Prof. Dr.-Ing. Anja Klein		**Type** Practice	**SWS** 2

Module name Convex Optimization in Signal Processing and Communications					
Module nr. 18-pe-2020	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1 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 compuation, applications.

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 processing and mobile communication systems.

3 Recommended prerequisites for participation

Knowledge in linear algebra and the basic concepts of signal processing and communications.

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS)

The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 14 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.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Ed. etit, B.Sc. und M.Sc. iST, B.Sc. WI-etit, M.Sc. etit - CMEE, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

- S. Boyd and L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004. (online Verfügbar:http://www.stanford.edu/ boyd/cvxbook/)
- D. P. Bertsekas, Nonlinear Programming, Athena Scientific, Belmont, Massachusetts, 2nd Ed., 1999.
- Daniel P. Palomar and Yonina C. Eldar, Convex Optimization in Signal Processing and Communications, Cambridge University Press, 2009.

Courses

	Course nr. 18-pe-2020-vl	**Course name** Convex Optimization in Signal Processing and Communications		
	Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lecture	**SWS** 2
	Course nr. 18-pe-2020-ue	**Course name** Convex Optimization in Signal Processing and Communications		
	Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Practice	**SWS** 1
	Course nr. 18-pe-2020-pr	**Course name** Convex Optimization in Signal Processing and Communications Lab		
	Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lab	**SWS** 1

Module name Digital Signal Processing					
Module nr. 18-zo-2060	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Teaching content

1) Discrete-Time Signals and Linear Systems - Sampling and Reconstruction of Analog Signals
2) Digital Filter Design - Filter Design Principles; Linear Phase Filters; Finite Impulse Response Filters; Infinite Impulse Response Filters; Implementations
3) Digital Spectral Analysis - Random Signals; Nonparametric Methods for Spectrum Estimation; Parametric Spectrum Estimation; Applications;
4) Kalman Filter

2 Learning objectives

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 Recommended prerequisites for participation

Deterministic signals and systems theory

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 180 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

M.Sc. MEC, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. MedTec, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

Course manuscript
Additional References:

- A. Oppenheim, W. Schafer: Discrete-time Signal Processing, 2nd ed.
- J.F. Böhme: Stochastische Signale, Teubner Studienbücher, 1998

Courses

Course nr.	**Course name**		
18-zo-2060-vl	Digital Signal Processing		
Instructor		**Type**	**SWS**
M.Sc. Christian Schroth, M.Sc. Christian Eckrich, Prof. Dr.-Ing. Abdelhak Zoubir		Lecture	3

	Course nr. 18-zo-2060-ue	**Course name** Digital Signal Processing		
	Instructor M.Sc. Christian Schroth, M.Sc. Christian Eckrich, Prof. Dr.-Ing. Abdelhak Zoubir		**Type** Practice	**SWS** 1

Module name Data-driven Modeling - Machine Learning					
Module nr. 18-kp-2110	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr. techn. Heinz Köppl		

1 Teaching content

The module provides an introduction to the emerging field of machine learning from an engineering perspective. Important models and learning methods are presented and exemplified through problems from information and communication technology.

- Fundamentals of probability theory and multivariate statistics
- Taxonomy of machine learning problems and models (supervised, unsupervised, generative, discriminative)
- Regression and classification: theory, methods and ICT applications
- Dimensionality reduction, clustering and big data analytics: methods and application in communications and signal processing
- Probabilistic graphical models: categories, inference and parameter estimation
- Fundamentals of Bayesian inference, Monte Carlo methods, Bayesian non-parametrics
- Fundamentals of convex optimization: Solution methods and application in communications
- Approximate algorithms for scalable Bayesian inference; application in signal processing and information theory (e.g. decoding of LDPC codes)
- Hidden Markov models (HMM): Theory, Algorithms and ICT applications (e.g. Viterbi decoding of convolutional codes)
- High-dimensional statistics ("large p small n" setting), learning dependency structure in high-dimensional data, learning causality relations from observational data.
- Sparse estimation, random projections, compressive sensing: Theory and applications in signal processing
- Deep neural networks (deep learning): Models, learning algorithms, libraries and ICT applications

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.

They are able to implement all necessary algorithms from scratch, but they are also familiar with the state-of-the-art libraries in machine learning.

They are able to determine the involved computational complexity of a method and choose an appropriate solution algorithms based on application constraints.

They are able to apply the acquired methods to other domains, such as data analysis in biomedical engineering, analysis of social network data, etc.

3 Recommended prerequisites for participation

Good command of Matlab (for instance knowledge from course 18-st-2030 Matlab Grundkurs) and engineering mathematics

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS)

The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 10 students register, the examination will be an oral examination (duration: 30 min.). The type of examination will be announced in the beginning of the lecture.

5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, B.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST, B.Sc. WI-etit, M.Sc. etit - CMEE, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** • Kevin P. Murphy. Machine Learning - A probabilistic perspective, MIT Press, 2012 • Christopher M. Bishop. Pattern recognition and Machine Learning, Springer, 2006 • Peter Bühlmann und Sara van de Geer. Statistics of high-dimensional data - Methods, theory and applications, Springer, 2011

Courses

	Course nr. 18-kp-2110-vl	**Course name** Data-driven Modeling - Machine Learning		
	Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein		**Type** Lecture	**SWS** 2
	Course nr. 18-kp-2110-ue	**Course name** Data-driven Modeling - Machine Learning		
	Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein		**Type** Practice	**SWS** 1
	Course nr. 18-kp-2110-pr	**Course name** Data-driven Modeling - Machine Learning Lab		
	Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein		**Type** Lab	**SWS** 1

Module name Matrix Analysis and Computations					
Module nr. 18-pe-2070	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

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	**Learning objectives** Students will have learned advanced topics in matrix analysis and related algorithms at an advanced level upon completion of the module.
3	**Recommended prerequisites for participation** Basic knowledge in linear algebra.
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS) The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 10 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.
5	**Prerequisite for the award of credit points** Pass module final exam.
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. etit, M.Sc. MEC, M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. etit - AUT, M.Sc. iCE, B.Ed. etit, B.Sc. und M.Sc. iST, B.Sc. WI-etit, M.Sc. etit - CMEE
8	**Grade bonus 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

Course nr.	**Course name**		
18-pe-2070-vl	Matrix Analysis and Computations		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Lecture	3

Course nr.	**Course name**		
18-pe-2070-ue	Matrix Analysis and Computations		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Practice	1

Module name Mobile Communications					
Module nr. 18-kl-2020	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Anja Klein		

1 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

2 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

3 Recommended prerequisites for participation

Deterministic Signals and Systems, Communication Technology I, Mathematics I to III, Statistics/Probability Theory, Scientific Computing

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

	will be announced in the lecture			
Courses				
	Course nr. 18-kl-2020-vl	**Course name** Mobile Communications		
	Instructor Prof. Dr.-Ing. Anja Klein, Dr.-Ing. Lin Xiang		**Type** Lecture	**SWS** 3
	Course nr. 18-kl-2020-ue	**Course name** Mobile Communications		
	Instructor Prof. Dr.-Ing. Anja Klein, Dr.-Ing. Lin Xiang		**Type** Practice	**SWS** 1

Module name Optical Communications - Components					
Module nr. 18-pr-1050	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr. rer. nat. Sascha Preu		

1 Teaching content

The lecture discusses the working principle of the most important devices and components of modern telecommunication 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 objectives

Students understand concepts, basics of physics, design criteria and system requirements (component specifications) of the most important passive and active components of optical communications.

3 Recommended prerequisites for participation

etit 1 + 2, Physics

4 Form of examination

Module exam:
- Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:
- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

B.Sc. etit, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. iCE, B.Ed. etit, B.Sc. und M.Sc. iST, B.Sc. WI-etit

8 Grade bonus compliant to §25 (2)

9	**References** Lecture slides Textbook (M. Cvijetic, I. B. Djordjevic: „Advanced Optical Communication Systems and Networks“)			
Courses				
	Course nr. 18-pr-1050-vl	**Course name** Optical Communications - Components		
	Instructor Prof. Dr. rer. nat. Sascha Preu		**Type** Lecture	**SWS** 3
	Course nr. 18-pr-1050-ue	**Course name** Optical Communications - Components		
	Instructor Prof. Dr. rer. nat. Sascha Preu		**Type** Practice	**SWS** 1

Module name Technical Electrodynamics for iCE					
Module nr. 18-dg-2150	**Credit points** 5 CP	**Workload** 150 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Herbert De Gersem		

1 Teaching content

1. Fundamentals of electromagnetic field theory - Maxwell‘s equations in differential and integral form; Electromagnetic waves: propagation in free space, polarization, reflection/refraction.
2. 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.
3. 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.
4. Application to typical high-frequency devices: Waveguide / resonator structures, planar structures

2 Learning objectives

Students will understand fundamental principles of wave propagation, guided waves and antennas. They will be able to model microwave components with simulation software tools. They will have experience with state of the art software tools for electromagnetic fields.

3 Recommended prerequisites for participation

Fundamentals of electrodynamics (Grundlagen der Elektrodynamik)

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 180 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

M.Sc. CE, M.Sc. iCE

8 Grade bonus compliant to §25 (2)

9 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.

Courses

	Course nr. 18-dg-2150-vl	**Course name** Technical Electrodynamics for iCE		
	Instructor Prof. Dr. Irina Munteanu, Prof. Dr. Peter Thoma		**Type** Lecture	**SWS** 2
	Course nr. 18-dg-2150-ue	**Course name** Technical Electrodynamics for iCE		
	Instructor Prof. Dr. Irina Munteanu, Prof. Dr. Peter Thoma		**Type** Practice	**SWS** 2

2 Optionals

2.1 Communication Hardware

2.1.1 Communication Hardware - Lectures

Module name Printed Electronics						
Module nr. 16-17-5110	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Summer term	
Language English			**Module owner** Prof. Dr. Edgar Dörsam			
1	**Teaching content** Printing technologies for functional printing (printing methods and systems); Design and materials for printed electronics (aerial, OFET, RFID); Activities for quality assurance; Examples of application (aerial, RFID, OFET, photovoltaic, batteries, lab on a chip).					
2	**Learning objectives** On successful completion of this module, students should be able to: 1. Describe the printing technologies that are applicable for “Printed Electronics”. 2. Name materials that are appropriate to printing processes and to describe the impact of the materials on the design e.g. of antennas and OFETs. 3. Classify and rate different activites for quality assurance. 4. Explain basic functions, configurations, materials, and specific properties of printed antennas, RFIDs, photovoltaics and batteries. 5. Describe “Printed Electronics” as a multidisciplinary task that consists of electrical engineering, material science, and mechanical engineering.					
3	**Recommended prerequisites for participation** Mechanical components and Mechatronics I and II recommended					
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral examination, Duration: 30 Min., Default RS) Oral exam 30 min					
5	**Prerequisite for the award of credit points** Passing the examination					
6	**Grading** Module exam: • Module exam (Technical examination, Oral examination, Weighting: 100 %)					
7	**Usability of the module** WPB Master MB III (Wahlfächer aus Natur- und Ingenieurwissenschaft) WPB Master PST III (Fächer aus Natur- und Ingenieurwissenschaft für Papiertechnik) Master ETiT IMNT; Master Mechatronik					
8	**Grade bonus compliant to §25 (2)**					

9	**References** The current lecture notes can be downloaded from the web pages of the institute while the semester is in session.			
Courses				
	Course nr. 16-17-5110-vl	**Course name** Printed Electronics		
	Instructor		**Type** Lecture	**SWS** 2

Module name Microsystem Technology					
Module nr. 18-bu-2010	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Module duration** 1 Term	**Module cycle** Winter term
Language German			**Module owner** Prof. Ph.D. Thomas Burg		

1	**Teaching content** Students are able to explain the structure and function of microsystemes for common applications (e.g. pressure sensors, accelerometers, biological and chemical sensors, micro-optical systems), calculate design parameters to achieve given specifications, and to judge the impact of scaling on the device performance. They can select appropriate materials, devise basic fabrication process flows, and identify compatibility issues between processes and/or materials.
2	**Learning objectives** Students are able to explain the structure and function of microsystemes for common applications (e.g. pressure sensors, accelerometers, biological and chemical sensors, micro-optical systems), calculate design parameters to achieve given specifications, and to judge the impact of scaling on the device performance. They can select appropriate materials, devise basic fabrication process flows, and identify compatibility issues between processes and/or materials.
3	**Recommended prerequisites for participation**
4	**Form of examination** Module exam: • Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. MEC, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. MedTec, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)** Up to 1.0 depending on problem sets and course participation
9	**References** Lecture notes, Moodle course

Courses

Course nr. 18-bu-2010-vl	**Course name** Microsystem Technology		
Instructor Prof. Ph.D. Thomas Burg		**Type** Lecture	**SWS** 2
Course nr. 18-bu-2010-ue	**Course name** Microsystem Technology		
Instructor Prof. Ph.D. Thomas Burg		**Type** Practice	**SWS** 1

Module name Lab-on-Chip Systems					
Module nr. 18-bu-2030	**Credit points** 5 CP	**Workload** 150 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Summer term
Language German			**Module owner** Prof. Ph.D. Thomas Burg		

1	**Teaching content** • Bioanalytical methods • Opportunities and fundamental limitations of miniaturization • Technology of microfluidic systems • The solid-liquid-interface • Transport processes • Biosensors • Single molecule methods • PCR-based micro-analytical systems • Single-cell sequencing • Flow cytometry • Optofluidics • Organ-on-Chip-Technologies • Advanced microscopy techniques
2	**Learning objectives** Students will learn to evaluate and compare conventional and microfluidic bioanalytical methods for laboratory medicine and Point-of-Care applications. They become familiar with the underlying physical principles and scaling laws and learn to analyze the impact of miniaturization quantitatively. The skills acquired in this course will enable the participants to select appropriate techniques, to advance knowledge, and to address technological gaps in the biomedical sciences with the help of microfluidic systems.
3	**Recommended prerequisites for participation**
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS) Performance will be evaluated based on a written final exam (duration: 90 min.). In case of low enrollment (<11), an oral exam may be offered instead (duration: 30 min.). The mode of the final exam (written or oral) will be announced at the beginning of each semester.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - SAE, M.Sc. MedTec, M.Sc. iCE
8	**Grade bonus compliant to §25 (2)**
9	**References** Lecture notes and reading assignments on Moodle.
Courses	

	Course nr. 18-bu-2030-vl	**Course name** Lab-on-Chip Systeme		
	Instructor Prof. Ph.D. Thomas Burg		**Type** Lecture	**SWS** 2
	Course nr. 18-bu-2030-ue	**Course name** Lab-on-Chip Systems		
	Instructor Prof. Ph.D. Thomas Burg		**Type** Practice	**SWS** 2

Module name Low-Level Synthesis					
Module nr. 18-hb-2010	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Christian Hochberger		

1	**Teaching content** The module deals with synthesis steps on all abstraction layers below the register transfer level focusing on approaches suitable for FPGAs. At the logic level different types of minimization are explained (exact and heuristic two level minimizations, exact and heuristic multi level logic minimizations). The transition to the technology level is achieved by different decomposition and structural mapping techniques (FlowMap). Place&Route add geometric information to the technology mapped circuit. Analytical and heuristic placers are discussed (Simulated Annealing, Genetic Placers) and routing is illustrated through the PathFinder algorithm.
2	**Learning objectives** After completion of the module, students are enabled to investigate synthesis approaches for low level synthesis tasks. They can evaluate these approaches regarding their time and space complexity, as well as regarding their applicability to specific implementation technologies. Students can apply these approaches to new architectures and technologies.
3	**Recommended prerequisites for participation** Knowledge of hardware synthesis on the basis of at least one hardware description language is required (e.g. Reese/Thornton: Introduction to Logic Synthesis Using Verilog Hdl oder Brown/Vranesic: Fundamentals of Digital Logic with VHDL Design). The student should have basic knowledge of at least one object oriented programming language, preferably Java.
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral examination, Duration: 30 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** The slides of the lecture will be distributed through moodle.

Courses

Course nr. 18-hb-2010-vl	**Course name** Low-Level Synthesis		
Instructor Prof. Dr.-Ing. Christian Hochberger		**Type** Lecture	**SWS** 2

	Course nr. 18-hb-2010-pr	**Course name** Low-Level Synthesis		
	Instructor Prof. Dr.-Ing. Christian Hochberger		**Type** Lab	**SWS** 2

Module name High-Level Synthesis					
Module nr. 18-hb-2020	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Christian Hochberger		

1	**Teaching content** Mapping of behavioral descriptions (e.g. in the form of program fragments) on FPGA and CGRA structures • Sub-tasks allocation, scheduling, binding • Exact or heuristic solutions • Design principles of heuristic solutions
2	**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 technologies.
3	**Recommended prerequisites for participation** Knowledge of hardware synthesis on the basis of at least one hardware description language is required (e.g. Reese/Thornton: Introduction to Logic Synthesis Using Verilog Hdl oder Brown/Vranesic: Fundamentals of Digital Logic with VHDL Design). The student should have basic knowledge of at least one object oriented programming language, preferably Java
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral examination, Duration: 30 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** English slides can be obtained through Moodle.

Courses

Course nr. 18-hb-2020-vl	**Course name** High-Level Synthesis		
Instructor Prof. Dr.-Ing. Christian Hochberger		**Type** Lecture	**SWS** 2
Course nr. 18-hb-2020-pr	**Course name** High-Level Synthesis		
Instructor Prof. Dr.-Ing. Christian Hochberger		**Type** Lab	**SWS** 2

Module name Microprocessor Systems					
Module nr. 18-ho-2040	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1 Teaching content

Microprocessor Architectures, DSP Architectures and Hardware related Programming

2 Learning objectives

Upon successful completion of the module, students will be able to:

1. gain the overview on the fundamentals of computer architecture and the different processor classes (RISC, CISC, Mikrocontroller, CPU, DSP),
2. understand the central building blocks of a CPU
3. understand the major properties of the required semiconductor memories, I/O blocks and data busses (USB, PCI, RS232),
4. understand the most commonly used Interrupt- and Trap-handling algorithms,
5. know the common software development methodologies for microcontrollers (assembler, pseudooperations, makros, subprograms and subroutines),
6. understand the most important fundamentals of hardware oriented programming using C.

3 Recommended prerequisites for participation

Basics of Computer Architectures

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

M.Sc. MEC, M.Sc. etit - DT, M.Sc. iCE, B.Sc. und M.Sc. iST

8 Grade bonus compliant to §25 (2)

During the semester, a maximum grade improvement of 1.0 can be achieved. The grade improvement has no influence on passing the final module examination. Bonus points are awarded for the successful completion of tests. The points achieved in the bonus system are converted linearly into exam points, with 50% of the achievable bonus points 0 exam points are added accordingly, from 95% of the achievable bonus points exam points are added for a grade improvement of 1.0. Bonus points are scored from a maximum of three tests, each of which must be on a different topic. Several tests can be offered for each topic; tests can also be offered for more than three topics. The exact bonus system will be presented at the beginning of the course. The aim of the bonus system is to be able to test the programming of microcontrollers in a more practical way.

9 References

Slide Copies

Courses

	Course nr. 18-ho-2040-vl	**Course name** Microprocessor Systems		
	Instructor Dr.-Ing. Matthias Rychetsky, M.Sc. Dirk Leiacker		**Type** Lecture	**SWS** 2
	Course nr. 18-ho-2040-ue	**Course name** Microprocessor Systems		
	Instructor Dr.-Ing. Matthias Rychetsky, M.Sc. Dirk Leiacker		**Type** Practice	**SWS** 1

Module name Computer Aided Design for SoCs					
Module nr. 18-ho-2200	**Credit points** 5 CP	**Workload** 150 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Teaching content** CAD-Concepts for the design and simulation of integrated system-on-chips
2	**Learning objectives** A student is, after successful completion of this module, able to understand • the most important design and verification abstractions as well as the design flow for the design of integrated electronic systems, • selected algorithms for optimization, simulation and solving of design tasks, • advanced methods for the design and simulation of analog integrated circuits in modern CMOS technologies, • advanced concepts of hardware description languages and their concepts (Verilog, VHDL, Verilog-A, Verilog-AMS, System-Verilog)
3	**Recommended prerequisites for participation** Lecture "Advanced Digital Integrated Circuit Design" (can be attended in parallel) and „Electronic and Integrated Circuits" and "Logic Design"
4	**Form of examination** Module exam: • Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. MEC, M.Sc. etit - DT, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)** A grade improvement of up to 1,0 due to a bonus is possible, which can be earned by successful participation in the embedded labs.
9	**References** Slide Copies

Courses

	Course nr. 18-ho-2200-vl	**Course name** Computer Aided Design for SoCs		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Lecture	**SWS** 2
	Course nr. 18-ho-2200-ue	**Course name** Computer Aided Design for SoCs		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Practice	**SWS** 1

	Course nr. 18-ho-2200-pr	**Course name** Computer Aided Design for SoCs		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Lab	**SWS** 1

Module name Industrial Electronics					
Module nr. 18-ho-2210	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Module duration** 1 Term	**Module cycle** Winter term
Language German/English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1 Teaching content

Typical Struture of Industrial Electronics Components. Characteristics of Typical Building Blocks (Digital Core, Sensor Frontend, Actuator Frontend, Supply and Reference Level), Functioning of Relevant Field Bus Systems, Knowledge of Relevant Standards and Technical Regulations.

2 Learning objectives

After successfull completion of the module, students are able to:

1. understand the use of electronic components in typical industrial environments,
2. understand the function of the building blocks of typical IE comonents,
3. deeply understand the functioning of analog bulding blocks,
4. understand relevant field bus systemes,
5. understand the regulatory and technical standards of industrial electronics components.

3 Recommended prerequisites for participation

Lecture "Elektronik" and "Electronic and Integrated Circuits"

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS)

The examination takes place in form of a written exam (duration: 90 minutes). If one can estimate that less than 5 students register, the examination will be an oral examination (duration: 30 min.). The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. MEC, M.Sc. etit - DT, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. etit - AUT, M.Sc. iCE, B.Sc. und M.Sc. iST

8 Grade bonus compliant to §25 (2)

9 References

- Dietmar Schmid, Gregor Häberle, Bernd Schiemann, Werner Philipp, Bernhard Grimm, Günther Buchholz, Jörg Oestreich, Oliver Gomber, Albrecht Schilling: „Fachkunde Industrieelektronik und Informationstechnik“; Verlag Europa-Lehrmittel, 11 th Ed. 2013.
- Gunter Wellenreuther, Dieter Zastrow; „Automatisieren mit SPS - Theorie und Praxis“; Springer Verlag, 6 th Ed. 2015.
- Ulrich Tietze, Christoph Schenk, Eberhard Gamm: „Halbleiter-Schaltungstechnik“; Springer Verlag, 15 th Ed. 2016.

Courses

	Course nr. 18-ho-2210-vl	**Course name** Industrieelektronik		
	Instructor Dr.-Ing. Roland Steck		**Type** Lecture	**SWS** 2
	Course nr. 18-ho-2210-ue	**Course name** Industrieelektronik		
	Instructor Dr.-Ing. Roland Steck		**Type** Practice	**SWS** 1

Module name Introduction to Spintronics					
Module nr. 18-me-2020	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr. rer. nat. Markus Meinert		

1 Teaching content

The lecture covers the following subjects:

- Basics of atomic physics (structure of the atoms, electron hull)
- Basics of solid state physics (crystalline materials)
- Introduction to electron transport in solids (classical treatment, band structures)
- Basic notions and simple models of magnetism
- Magnetism in thin films
- Spin-dependent electronic transport
- Magnetoresistive effects, anisotropic magnetoresistance
- Giant magnetoresistance (GMR)
- Tunneling magnetoresistance (TMR)
- Spin-Transfer Torque
- Magnetic microwave oscillators
- Spin-Hall effect and other spin-orbit effects
- Materials for spintronics (ferromagnets, antiferromagnets)
- Magnetic data storage
- Spintronic devices as sensors
- Magnetic random-access memory (MRAM)

2 Learning objectives

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 scientific literature and to dive deeper into the field.

3 Recommended prerequisites for participation

Module 11-01-6419 Materials of Electrical Engineering

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS)

The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 16 students register, the examination will be an oral examination (duration: 45 min.). The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. etit - SAE, M.Sc. iCE

8 Grade bonus compliant to §25 (2)

Yes

9 References

- 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		**Type**	**SWS**
Prof. Dr. rer. nat. Markus Meinert		Practice	1

Module name Terahertz Systems and Applications					
Module nr. 18-pr-2010	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr. rer. nat. Sascha Preu		

1	**Teaching content** The lecture will give an overview of Terahertz applications, sources and detectors with the focus on photonic and semiconductor-based devices and Terahertz systems. Terahertz detection and generation will be discussed in detail for two types of highly important devices: Schottky diodes (mixers, multi-pliers and rectifiers) and photomixers (photo-diode based and photoconductive). The exercise, where performance parameters of the discussed devices will be derived for experimentally relevant cases, will help to deepen the understanding. The last day will be used for a lab tour showing our measurements facilities and hands-on Experiments.
2	**Learning objectives** After completion of this module, the student has gained basic knowledge in the fields of THz generation, detection, systems, and applications of THz radiation, with deepened knowledge in: • A general overview about the state of the art in Terahertz technology • Working principle, spectra and limits of continuous-wave photomixer systems • Working principle of Schottky diode mixers/multipliers and rectifiers in the THz range • THz Applications
3	**Recommended prerequisites for participation** Bachelor in Electrical engineering, Physics, or Material Science Helpful: Basic knowledge in semiconductor physics, High frequency 1
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS) The examination takes place in form of a written exam (duration: 90 minutes). If one can estimate that less than 20 students register, the examination will be an oral examination (duration: 25 min.). The type of examination will be announced in the beginning of the lecture.
5	**Prerequisite for the award of credit points** • Pass module final exam
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE
8	**Grade bonus compliant to §25 (2)**
9	**References** • Yun-Shik Lee, „Principles of Terahertz Science and Technology,“ Springer 2009, ISBN 978-0-387-09540-0 • G. Carpintero et al., “Semiconductor Terahertz Technology: Devices and Systems at Room Temperature Operation,” Wiley 2015, ISBN: 978-1-118-92042-8

Courses

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

Module name Real-Time Systems					
Module nr. 18-su-2020	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language German			**Module owner** Prof. Dr. rer. nat. Andreas Schürr		

1	**Teaching content** The lecture basically covers a model-driven software engineering process which is specially customized for real-time systems. This process is more deeply explored in the exercise using an automotive example. A focus is laid on object-oriented techniques. In this context, a real-time specific state-of-the-art CASE tool is introduced and used. Furthermore, fundamental characteristics of real-time systems and system architectures are introduced. Scheduling algorithms are discussed to get insights into real-time operating systems. Finally, a comparison between the Java programming language and its expansion for real-time operating systems (RT Java) will conclude the lecture.
2	**Learning objectives** After successful completion of the module, students are able to use and evaluate model-based (object-oriented) techniques for the development of embedded real-time systems. This includes a deeper understanding of the following topics: • classification of real-time systems • create and analyze executable models • application of real-time scheduling algorithms • evaluation and comparison of pros/cons of real-time programming languages as well as real-time operating systems
3	**Recommended prerequisites for participation** Basic knowledge of software engineering techniques and excellent knowledge of at least one object-oriented programming language (preferably Java)
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS) The examination takes place in form of a written exam (duration: 90 minutes). If one can estimate that less than 15 students register, the examination will be an oral examination (duration: 30 min.). The type of examination will be announced in the beginning of the lecture.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. MEC, M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, B.Sc. CE, M.Sc. iCE, M.Sc. iST, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)** Grade improvements up to 0.4 per APB 25 (2) due to bonus for regularly submitted homework tasks
9	**References** https://www.es.tu-darmstadt.de/lehre/aktuelle-veranstaltungen/es-v and Moodle
Courses	

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

Module name Foundations of Precision Engineering					
Module nr. 18-bu-1010	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language German			**Module owner** Prof. Ph.D. Thomas Burg		

1	**Teaching content** 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	**Learning objectives** 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	**Recommended prerequisites for participation**
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS) The examination takes place in form of a written exam (duration: 90 minutes). If enrollment is expected to be less than 6 students, the examination will be an oral examination (duration: 30 min.). The type of examination will be announced at the beginning of the course.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. etit, M.Sc. MEC, B.Sc. CE, M.Sc. MedTec, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** Lecture notes, Moodle course

Courses

Course nr.	**Course name**		
18-bu-1010-vl	Technology of Micro- and Precision Engineering		
Instructor		**Type**	**SWS**
Prof. Ph.D. Thomas Burg		Lecture	2

	Course nr. 18-bu-1010-ue	**Course name** Foundations of Precision Engineering		
	Instructor Prof. Ph.D. Thomas Burg		**Type** Practice	**SWS** 1
	Course nr. 18-bu-1010-pr	**Course name** Foundations of Precision Engineering Lab		
	Instructor Prof. Ph.D. Thomas Burg		**Type** Lab	**SWS** 1

Module name Nanoelectronics					
Module nr. 18-me-2040	**Credit points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr. rer. nat. Markus Meinert		

1 Teaching content

The lecture gives an overview of the technologies of nanoelectronics:

- Fabrication of devices on the nanometer scale
- Nanomaterials: quantum dots, nanowires, 2D materials (e.g. graphene)
- Quantum Metrology Triangle (single-electron transistor, quantum Hall effect, Josephson effect)
- FinFET transistors and other nanoscale devices

2 Learning objectives

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 Recommended prerequisites for participation

Basic knowledge of semiconductors

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS)

The examination takes place in form of a written exam (duration: 90 minutes). If one can estimate that less than 10 students register, the examination will be an oral examination (duration: 30 min.). The type of examination will be announced in the beginning of the lecture.
Seminar presentation about a subject of Nanoelectronics, individual (15 to 20 minutes) or as teams of two (25 to 30 minutes).

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. iCE, B.Sc. und M.Sc. iST

8 Grade bonus compliant to §25 (2)

9 References

- Lecture slides will be made available electronically
- Further literature will be announced during the lecture

Courses

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

Module name Electromechanical Systems I					
Module nr. 18-kn-1050	**Credit points** 5 CP	**Workload** 150 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Winter term
Language German			**Module owner** Prof. Dr. Mario Kupnik		

1	**Teaching content** Structure and design methods of elektromechanical systems, mechanical, acoustical and thermal networks, transducers between mechanical and acoustical networks. Design and devices of electromechanical transducers.
2	**Learning objectives** The module provides the following competencies upon successful completion: Comprehension, description, calculation and application of the most relevant electromechanical transducers, comprising electrostatic transducer (e.g. microphone and accelerometer), piezoelectric transducers (e.g micro motors, micro sensors), electrodynamic 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	**Recommended prerequisites for participation** Electrical Engineering and Information Technology I
4	**Form of examination** Module exam: • Module exam (Technical examination, Examination, Duration: 120 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. etit, M.Sc. MEC, B.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST, B.Sc. WI-etit
8	**Grade bonus compliant to §25 (2)**
9	**References** Book: Electromechanical Systems in Microtechnic und Mechatronic, Springer 2012, Script for lecture Electromechanical Systems I, Workbook

Courses

Course nr. 18-kn-1050-vl	**Course name** Electromechanical Systems I		
Instructor Prof. Dr. techn. Dr.h.c. Andreas Binder, Prof. Dr. Mario Kupnik, M.Sc. Omar Dali		**Type** Lecture	**SWS** 2
Course nr. 18-kn-1050-ue	**Course name** Electromechanical Systems I		
Instructor Prof. Dr. techn. Dr.h.c. Andreas Binder, Prof. Dr. Mario Kupnik, M.Sc. Omar Dali		**Type** Practice	**SWS** 2

Module name Computer Systems II					
Module nr. 18-hb-2030	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language German			**Module owner** Prof. Dr.-Ing. Christian Hochberger		

1 Teaching content

- Configurable Technologies
- FPGA architectures and properties
- System-On-Chip, HW components, SW toolchain, support SW
- Coarse grained reconfigurable architectures, PE architecture, Modulo 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 Recommended prerequisites for participation

Thorough basic knowledge of digital circuits and computer achitecture. as can be ob-tained in the lectures “Logischer Entwurf” and “Rechnersysteme I”. Additionally, stu-dents should be able to write simple programs in the programming language C.

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral examination, Duration: 30 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral examination, Weighting: 100 %)

7 Usability of the module

M.Sc. MEC, M.Sc. etit - DT, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. iCE, M.Sc. iST

8 Grade bonus compliant to §25 (2)

9 References

The slides (in German) of the lecture can be obtained through moodle.

Courses

Course nr. 18-hb-2030-vl	**Course name** Computer Systems II		
Instructor M.Sc. Ramon Wirsch, Prof. Dr.-Ing. Christian Hochberger		**Type** Lecture	**SWS** 3
Course nr. 18-hb-2030-ue	**Course name** Computer Systems II		
Instructor M.Sc. Ramon Wirsch, Prof. Dr.-Ing. Christian Hochberger		**Type** Practice	**SWS** 1

Module name Antennas and Adaptive Beamforming					
Module nr. 18-jk-2020	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1	**Teaching content** 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.
2	**Learning objectives** 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 and frequency-independent antennas (V antennas, biconical antennas, helical antennas, spiral and log-periodic antennas).
3	**Recommended prerequisites for participation** Fundamentals of Communications, Microwave Engineering 1
4	**Form of examination** Module exam: • Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading**

	Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)			
7	**Usability of the module** M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, B.Sc. WI-etit			
8	**Grade bonus compliant to §25 (2)**			
9	**References** Skriptum “Antennas and Adaptive Beamforming” will be provided electronically at the beginning of the lecture.			
Courses				
	Course nr. 18-jk-2020-vl	**Course name** Antennas and Adaptive Beamforming		
	Instructor M.Sc. Jesús Pastor, Dr.-Ing. Alejandro Sáez, Dr.-Ing. Martin Schüßler		**Type** Lecture	**SWS** 3
	Course nr. 18-jk-2020-ue	**Course name** Antennas and Adaptive Beamforming		
	Instructor M.Sc. Jesús Pastor, Dr.-Ing. Alejandro Sáez, Dr.-Ing. Martin Schüßler		**Type** Practice	**SWS** 1

Module name Microwave Engineering II					
Module nr. 18-jk-2130	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1 Teaching content

Part 1 Passive microwave components:

- Calculation of the two-port parameters of simple passive components and circuits (transmission lines and lumped elements) for MMICs
- Wave parameters and S-parameters
- Smith chart and matching circuits with line elements or lumped elements
- Design and equivalent circuits of passive microwave components (transmission lines, capacitors, inductors and resistors)

Part 2 Active microwave components:

- Design and equivalent circuits of field effect transistors (FET) and heterostructure transistors (HEMTs)
- Gain and cut-off frequencies
- Schottky contacts: function and characteristics

Part 3 Active microwave circuits (main part):

- FET amplifiers: operation, equivalent circuit, gain, matching circuit, stability and circuit implementation
- Oscillator design
- Mixer design
- Material choice (compound semiconductor material systems: properties, fabrication and requirements)

Applications of these circuits range from communication systems such as cell phones to satellite transceivers as well as high-frequency sources up to Terahertz.
Topics of good scientific practice, as well as societal or ethical aspects of product design, optimization, and algorithms are addressed in an accompanying manner, where technically appropriate.

2 Learning objectives

After successful completion of the module students understand the physics of microwave waveguides, resonators, microwave components (passive and active) as well as microwave circuits.

3 Recommended prerequisites for participation

Introduction to Electrodynamics, Microwave Engineering I

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST

8 Grade bonus compliant to §25 (2)

9 References

Script and slides will be handed out. Literature will be recommended in the lecture.

Courses

	Course nr. 18-jk-2130-vl	**Course name** Microwave Engineering II		
	Instructor PD Dr.-Ing. Oktay Yilmazoglu		**Type** Lecture	**SWS** 3
	Course nr. 18-jk-2130-ue	**Course name** Microwave Engineering II		
	Instructor PD Dr.-Ing. Oktay Yilmazoglu		**Type** Practice	**SWS** 1

Module name MIMO - Communication and Space-Time-Coding					
Module nr. 18-ja-2010	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Vahid Kooshkghazi		

1 Teaching content

This lecture course introduces the principles of space-time and multiple-input multiple-output (MIMO) communications.

Outline: Motivation and background; overview of space-time and MIMO communications; fading MIMO channel models, MIMO information theory, receive and transmit diversity; channel estimation, MIMO detectors, Alamouti space-time block code, orthogonal space-time block codes; linear dispersion codes; coherent and non-coherent decoders, differential space-time block coding; MIMO with limited feedback, Multiantenna- and multiuser diversity, BER performance analysis, MIMO in moden wireless communication networks, multicell and multiuser MIMO (coordinated multipoint).

2 Learning objectives

Students will understand modern MIMO communications and existing space-time coding techniques.

3 Recommended prerequisites for participation

Knowledge of basic communication theory and basic information theory.

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS)

The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 10 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.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. MEC, M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

- A.B.Gershman and N.D.Sidiropoulos, Editors, Space-Time Processing for MIMO Communications, Wiley and Sons, 2005.
- E.G.Larsson and P.Stoica, Space-Time Block Coding for Wireless Communications, Cambridge University Press, 2003;
- A.Paulraj, R.Nabar, and D.Gore, Introduction to Space-Time Wireless Communications, Cambridge University Press, 2003.
- Lin Bai and Jinho Choi, Low Complexity MIMO detectors, Springer, 2012.
- Howard Huang, Constantinos B. Papadias, and Sivarama Venkatesan, MIMO Communication for Cellular Networks, Springer, 2012.

Courses

	Course nr. 18-ja-2010-vl	**Course name** MIMO - Communication and Space-Time-Coding		
	Instructor Prof. Dr.-Ing. Vahid Kooshkghazi		**Type** Lecture	**SWS** 2
	Course nr. 18-ja-2010-ue	**Course name** MIMO - Communication and Space-Time-Coding		
	Instructor Prof. Dr.-Ing. Vahid Kooshkghazi		**Type** Practice	**SWS** 1

Module name Speech and Audio Signal Processing					
Module nr. 18-zo-2070	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language German			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1	**Teaching content** Algorithms of speech and audio signal processing: Introduction to the models of speech and audio signals and basic methods of audio signal processing. Procedures of codebook based processing and audio coding. Beamforming for spatial filtering and noise reduction for spectral filtering. Cepstral filtering and fundamental frequency estimation. Mel-filterind cepstral coefficients (MFCCs) as basis for speaker detection and speech recognition. Classification methods based on GMM (Gaussian mixture models) and speech recognition with HMM (Hidden markov models). Introduction to the methods of music signal processing, e.g. Shazam-App or beat detection.
2	**Learning objectives** Based on the module you acquire an advanced knowledge of digital audio signal processing mainly with the help 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	**Recommended prerequisites for participation** Knowlegde about satistical signal processing (lecture „Digital Signal Processing“). Desired - but not mandatory - is knowledge about adaptive filters.
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS) Seminar presentation: Scientific talk about a topic in the field of “Speech and Audio Signal Processing”, single (duration 10-15 min) or in groups of two students (15-20 min) or in a group of 20 students and more a written exam (duration 90 min)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. MedTec, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** Slides (for further details see homepage of the lecture)
Courses	

	Course nr. 18-zo-2070-vl	**Course name** Speech and Audio Signal Processing		
	Instructor Prof. Dr.-Ing. Henning Puder		**Type** Lecture	**SWS** 2
	Course nr. 18-zo-2070-ue	**Course name** Speech and Audio Signal Processing		
	Instructor Prof. Dr.-Ing. Henning Puder		**Type** Practice	**SWS** 1
	Course nr. 18-zo-2070-se	**Course name** Sprach- und Audiosignalverarbeitung		
	Instructor Prof. Dr.-Ing. Henning Puder		**Type** Seminar	**SWS** 1

Module name Finite Integration Technique					
Module nr. 18-dg-1030	**Credit points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Module duration** 1 Term	**Module cycle** Summer term
Language German			**Module owner** Prof. Dr.-Ing. Herbert De Gersem		

1	**Teaching content** Basics FIT, electrostatics, magnetostatics, magnetoquasistatics, high frequency simulations, convergence studies, discretisation, time- and frequency domain simulations.
2	**Learning objectives** 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	**Recommended prerequisites for participation** Basics of Maxwell's equations, linear algebra. Recommended: Basic knowledge in knowledge in "Technical Electrodynamics"
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral examination, Duration: 30 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. etit, B.Sc. CE, M.Sc. iCE, M.Sc. etit - CMEE
8	**Grade bonus compliant to §25 (2)**
9	**References** Course notes, lecture slides.

Courses

Course nr.	**Course name**		
18-dg-1030-vl	Finite Integration Technique		
Instructor		**Type**	**SWS**
Dr.-Ing. Wolfgang Ackermann		Lecture	2

Module name Optical Communications - Components					
Module nr. 18-pr-1050	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr. rer. nat. Sascha Preu		

1 Teaching content

The lecture discusses the working principle of the most important devices and components of modern telecommunication 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 objectives

Students understand concepts, basics of physics, design criteria and system requirements (component specifications) of the most important passive and active components of optical communications.

3 Recommended prerequisites for participation

etit 1 + 2, Physics

4 Form of examination

Module exam:
- Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:
- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

B.Sc. etit, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. iCE, B.Ed. etit, B.Sc. und M.Sc. iST, B.Sc. WI-etit

8 Grade bonus compliant to §25 (2)

9	**References** Lecture slides Textbook (M. Cvijetic, I. B. Djordjevic: „Advanced Optical Communication Systems and Networks“)			
Courses				
	Course nr. 18-pr-1050-vl	**Course name** Optical Communications - Components		
	Instructor Prof. Dr. rer. nat. Sascha Preu		**Type** Lecture	**SWS** 3
	Course nr. 18-pr-1050-ue	**Course name** Optical Communications - Components		
	Instructor Prof. Dr. rer. nat. Sascha Preu		**Type** Practice	**SWS** 1

Module name Technical Electrodynamics for iCE					
Module nr. 18-dg-2150	**Credit points** 5 CP	**Workload** 150 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Herbert De Gersem		

1 Teaching content

1. Fundamentals of electromagnetic field theory - Maxwell‘s equations in differential and integral form; Electromagnetic waves: propagation in free space, polarization, reflection/refraction.
2. 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.
3. 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.
4. Application to typical high-frequency devices: Waveguide / resonator structures, planar structures

2 Learning objectives

Students will understand fundamental principles of wave propagation, guided waves and antennas. They will be able to model microwave components with simulation software tools. They will have experience with state of the art software tools for electromagnetic fields.

3 Recommended prerequisites for participation

Fundamentals of electrodynamics (Grundlagen der Elektrodynamik)

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 180 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

M.Sc. CE, M.Sc. iCE

8 Grade bonus compliant to §25 (2)

9 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.

Courses

	Course nr. 18-dg-2150-vl	**Course name** Technical Electrodynamics for iCE		
	Instructor Prof. Dr. Irina Munteanu, Prof. Dr. Peter Thoma		**Type** Lecture	**SWS** 2
	Course nr. 18-dg-2150-ue	**Course name** Technical Electrodynamics for iCE		
	Instructor Prof. Dr. Irina Munteanu, Prof. Dr. Peter Thoma		**Type** Practice	**SWS** 2

Module name Advanced Digital Integrated Circuit Design					
Module nr. 18-ho-2010	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

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	**Learning objectives** A student is, after successful completion of this module, able to • understand the short-channel effects of modern CMOS transistors, • derive and analyse the most important circuit concepts for digital logic gates, • understand the design flow of digital ASICs based on standard cells (design, layout, simulation/verification), • know the pros and cons of synchronous vs. asynchronous logic, multiclockphase systems, • understand the differential design methods of integrated circuits (ASIC, ASIP, Full-custom/Semicustom, PLA, PLD, FPGA), • understand basic circuitry of logic and arithmetic units (adders, multipliers, PLL/DLL), • understand the concepts of A/D and D/A-converters, and their fundamental technical properties and architectures, • know the design principles and properties of integrated semiconductor memory (DRAM, SRAM, Flash. MRAM, FeRAM)
3	**Recommended prerequisites for participation** Lecture "Electronics"
4	**Form of examination** Module exam: • Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - DT, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. iCE, M.Sc. iST
8	**Grade bonus compliant to §25 (2)** A grade improvement of up to 1,0 due to a bonus is possible, which can be earned with tests.
9	**References** Lecture Slide Copies • John P. Uyemura: Fundamentals of MOS Digital Integrated Circuits • Neil Weste et al.: Principles of CMOS VLSI Design
Courses	

	Course nr. 18-ho-2010-vl	**Course name** Advanced Digital Integrated Circuit Design		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Lecture	**SWS** 3
	Course nr. 18-ho-2010-ue	**Course name** Advanced Digital Integrated Circuit Design		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Practice	**SWS** 1

Module name Modelling and Simulation of Circuits					
Module nr. 18-sc-2010	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Module duration** 1 Term	**Module cycle** Summer term
Language 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 Recommended prerequisites for participation

18-hs-1070 Elektrotechnik und Informationstechnik I, 18-gt-1020 Elektrotechnik und Informationstechnik II, 20-00-0304 Allgemeine Informatik I, 04-10-0602 Statistics/Probability Theory, 04-10-0603 Scientific Computing

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral examination, Duration: 20 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral examination, Weighting: 100 %)

7 Usability of the module

B.Sc. etit, M.Sc. WI-etit, M.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST, B.Sc. WI-etit, M.Sc. etit - CMEE

8 Grade bonus compliant to §25 (2)

Grade bonus of 0,4 if correctly implemented programs 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

Course nr.	**Course name**		
18-sc-2010-vl	Modelling and simulation of circuits		
Instructor		**Type** Lecture	**SWS** 2
Course nr.	**Course name**		
18-sc-2010-ue	Modelling and simulation of circuits		
Instructor		**Type** Practice	**SWS** 1

Module name
Hardware for Neural Networks

Module nr.	Credit points	Workload	Self-study	Module duration	Module cycle
18-zh-2010	6 CP	180 h	120 h	1 Term	Summer term

Language	Module owner
English	Prof. Dr.-Ing. Li Zhang

1 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 Recommended prerequisites for participation
Basic programming skills in Python.

4 Form of examination
Module exam:

- Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)

5 Prerequisite for the award of credit points
Passing the final module examination

6 Grading
Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module
M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. etit - AUT, M.Sc. iCE, B.Sc. und M.Sc. iST

8 Grade bonus compliant to §25 (2)

9 References
Slides can be downloaded through Moodle platform.

Courses

Course nr.	Course name	Type	SWS
18-zh-2010-vl	Hardware for Neural Networks		
Instructor			
Prof. Dr.-Ing. Li Zhang		Lecture	2
18-zh-2010-pr	Hardware for Neural Networks		
Prof. Dr.-Ing. Li Zhang		Lab	2

Module name Radio Frequency Systems for Particle Accelerators					
Module nr. 18-kb-2040	**Credit points** 5 CP	**Workload** 150 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Harald Klingbeil		

1	**Teaching content** Repetition of transmission lines and waveguides, S-parameters. RF components, RF measurements, cavities loaded with magnetically permeable materials, cavities based on classical resonators, cavity equivalent circuit, beam loading, basic terms and definitions of nonlinear dynamics, RF acceleration, longitudinal phase space, particle tracking equations, Liouville's theorem, adiabaticity, RF systems for special beam manipulations, closed-loop and open-loop control (LLRF) systems.
2	**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 for participation**
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral examination, Duration: 30 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - CMEE
8	**Grade bonus compliant to §25 (2)**
9	**References** Lecture slides are offered for download. Further references are given in the lecture.

Courses

Course nr. 18-kb-2040-vl	**Course name** Radio Frequency Systems for Particle Accelerators		
Instructor Prof. Dr.-Ing. Harald Klingbeil		**Type** Lecture	**SWS** 2
Course nr. 18-kb-2040-ue	**Course name** Radio Frequency Systems for Particle Accelerators		
Instructor Prof. Dr.-Ing. Harald Klingbeil, M.Sc. Sebastian Orth, M.Sc. Christoph Wegmann, M.Sc. Yi Jin		**Type** Practice	**SWS** 2

2.1.2 Communication Hardware - Labs and Projects

Module name Project Seminar Reconfigurable Systems					
Module nr. 18-hb-2040	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language German			**Module owner** Prof. Dr.-Ing. Christian Hochberger		

1	**Teaching content** Students will work on their own or in two-person teams in this course. Topics and application context will be defined individually for each group. In this course reconfigurable architectures will be investigated. This particularly means the extension, improvement, or adaptation of components and tools for reconfigurable architectures as well as the prototypical implementation of applications on such reconfigurable architectures. Usually, the course starts with a literature search to get acquainted with the underlying architecture. This is followed by the practical part and finally the results are presented in a written report and a presentation.
2	**Learning objectives** Successful students will know how to use reconfigurable systems within a given application context. They can use 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	**Recommended prerequisites for participation** • Knowledge of reconfigurable devices (cf. course computer systems II) • Knowledge of computer architecture (cf. course computer systems I) • Solid programming skills (either in C or Java depending on the application scenario).
4	**Form of examination** Module exam: • Module exam (Study achievement, Oral/written examination, Default RS) Report and/or Presentation. The type of examination will be announced in the beginning of the lecture.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** Will be given to the students during the individual seminar kick-off meeting.

Courses

Course nr. 18-hb-2040-pj	**Course name** Project Seminar Reconfigurable Systems		
Instructor Prof. Dr.-Ing. Christian Hochberger		**Type** Project seminar	**SWS** 3

Module name
Advanced Integrated Circuit Design Lab

Module nr.	Credit points	Workload	Self-study	Module duration	Module cycle
18-ho-2120	6 CP	180 h	135 h	1 Term	Summer term

Language	Module owner
English	Prof. Dr.-Ing. Klaus Hofmann

1 Teaching content
Practical Design Tasks in Full Custom Design of Digital or Analog Ciruits using State-of-the-Art Commercial CAD Tools

2 Learning objectives
A student is, after successful completion of this module, able to

1. develop and verify transistor circuitry using Cadence
2. simulate logic and analog circuits (Pre- and Postlayout)
3. draw, verify and extract layout

After successful completion of this module the students are able to work constructively on a feasible solution. Aside, they are able to mutually support each other and present intermediate results to peers, and achieve an overall feasible solution.

3 Recommended prerequisites for participation
Lecture "Advanced Digital Integrated Circuit Design" or “Electronic and Integrated Circuits”

4 Form of examination
Module exam:
- Module exam (Study achievement, Oral/written examination, Default RS)

Report (including submission of programming code) and/or Presentation and/or Oral examination (25 minutes) and/or Colloquium (testate). The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points
Passing the final module examination

6 Grading
Module exam:
- Module exam (Study achievement, Oral/written examination, Weighting: 100 %)

7 Usability of the module
M.Sc. MEC, M.Sc. etit - DT, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST

8 Grade bonus compliant to §25 (2)

9 References
ADIC Lecture Slide Copies
- John P. Uyemura: Fundamentals of MOS Digital Integrated Circuits
- Neil Weste et al.: Principles of CMOS VLSI Design

Courses

Course nr.	Course name		
18-ho-2120-pr	Advanced Integrated Circuit Design Lab		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Klaus Hofmann		Lab	3

Module name Seminar Integrated Electronic Systems Design A					
Module nr. 18-ho-2160	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Teaching content** Research oriented Formulation of a Topic within the area of Microelectronics System Design; Creation of a written Documentation and Presentation; Team Work
2	**Learning objectives** A student is, after successful completion of this module, able to 1. gain a deep understanding of the chosen research subject in the field of integrated electronic systems, 2. write an essay on the chosen subject in a comprehesive form and present the outcome to an audience
3	**Recommended prerequisites for participation** Advanced Digital Integrated Circuit Design, CAD Methods, Computer Architectures, Programming Know-How
4	**Form of examination** Module exam: • Module exam (Study achievement, Oral examination, Duration: 45 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Study achievement, Oral examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - DT, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** Topic-oriented Materials will be provided

Courses

Course nr.	**Course name**		
18-ho-2160-se	Seminar Integrated Electronic Systems Design A		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Klaus Hofmann		Seminar	2

Module name Project Seminar Advanced µWave Components & Antennas					
Module nr. 18-jk-2060	**Credit points** 8 CP	**Workload** 240 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language German/English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1 Teaching content

Groups of 2-3 students per project. Students work out a well defined fundamental or actual research- related problem. The projects will be actualized in each cycle being offered and introduced at the beginning. Each group will be supervised individually. The projects comprises modern antennas for multitudinous applications, electronically-steerable antennas, RFIDs, RF sensors, adaptive tunable components such as matching networks, filter, passive mixer and modulator for next-generation mobile terminals and sensor systems.

2 Learning objectives

Research-oriented Project Seminar in groups of 2-3 students per project with individual supervision. Students will learn

- how to solve scientific hardware-oriented problems
- working out concepts
- how to design, realize and characterize RF devices
- how to use commercial software and characterization tools
- to evaluate and discuss their work in the context of the state-of-art in this field
- to write a brief scientific report about their work
- to present and discus their results at the end of the Project Seminar

3 Recommended prerequisites for participation

Fundamentals of Microwave Engineering I and Antennas and Adaptive Beamforming

4 Form of examination

Module exam:

- Module exam (Study achievement, Oral examination, Duration: 30 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Study achievement, Oral examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE

8 Grade bonus compliant to §25 (2)

9 References

Publications will be hand out to them. Software and characterization tools as well as tools to realize RF devices are available.

Courses

Course nr.	**Course name**		
18-jk-2060-pj	Project Seminar Advanced µWave Components & Antennas		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Rolf Jakoby, Dr.-Ing. Martin Schüßler		Project seminar	4

Module name
Project Seminar Emerging Topics in Sensor Array and Multichannel Processing

Module nr.	Credit points	Workload	Self-study	Module duration	Module cycle
18-pe-2040	8 CP	240 h	180 h	1 Term	Winter term

Language	Module owner
English	Prof. Dr.-Ing. Marius Pesavento

1 Teaching content
This project-seminar addresses new trends in sensor array and multichannel processing with multidimensional tensor data representations.
The specific thematic focus of the seminar will be adapted from year to year according to the latest trends in the research field. The topics will be announced on the course website well in advance.

2 Learning objectives
Students will understand theory, algorithms and applications of sensor array and multichannel system.

3 Recommended prerequisites for participation
Basic knowledge in linear algebra.

4 Form of examination
Module exam:
- Module exam (Study achievement, Oral examination, Duration: 40 Min., Default RS)

5 Prerequisite for the award of credit points
Passing the final module examination

6 Grading
Module exam:
- Module exam (Study achievement, Oral examination, Weighting: 100 %)

7 Usability of the module
M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References
Harry L. Van Trees, Optimum Array Processing: Part IV of Detection, Estimation, and Modulation Theory, John Wiley & Sons, 2002.
References include the latest scientific publications, seminars and books.

Courses

Course nr.	Course name		
18-pe-2040-pj	Project Seminar Emerging Topics in Sensor Array and Multichannel Processing		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento, M.Sc. Raphael Müller		Project seminar	4

Module name Project Seminar Emerging topics in MIMO Communication Networks					
Module nr. 18-pe-2050	**Credit points** 8 CP	**Workload** 240 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1	**Teaching content** This project-seminar addresses new trends in MIMO communications for the next generation of wireless communication systems. The specific thematic focus of the seminar will be adapted from year to year according to the latest trends in wireless communications. The topics will be announced on the course website well in advance.
2	**Learning objectives** 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	**Recommended prerequisites for participation**
4	**Form of examination** Module exam: • Module exam (Study achievement, Oral examination, Duration: 40 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Study achievement, Oral examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Ed. etit, B.Sc. WI-etit, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** References include the latest scientific publications, seminars and books.

Courses

Course nr.	**Course name**		
18-pe-2050-pj	Project Seminar Emerging Topics in MIMO Communication Networks		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Project seminar	4

Module name Project Seminar Terahertz Technology, Communication and Sensors					
Module nr. 18-pr-2030	**Credit points** 8 CP	**Workload** 240 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language German/English			**Module owner** Prof. Dr. rer. nat. Sascha Preu		

1	**Teaching content** Investigating and solving specific problems concerning the development of Terahertz devices, of applications of THz technology as well as topics of the area of Optics and communication technology. The specific task will be defined based on current research topics. The project seminar includes working on a given task by one's own, organizing and structuring of a seminar task, searching and analyzing of scientific reference publications, summarizing achieved results and conclusions by means of a written report, presenting achieved results and conclusions and defending them in an oral discussion including audience. Topics include, e.g.: • Terahertz Optics • Optics/photonics • Spectroscopy • Semiconductor devices • Light-matter interaction
2	**Learning objectives** After completion of the course, students possess: • the ability to apply theoretical models to practical problems • deep and special knowledge in a particular field related to THz science, optics or semiconductor physics • the skills to find, analyze and evaluate scientific reference papers for a particular topic • the capability to summarize the achieved scientific findings in the form of a concise report, and to present and discuss achieved results in the form of a presentation in front of an audience
3	**Recommended prerequisites for participation** Previous knowledge in at least one of the following disciplines: Optics, semiconductor physics, or THz technology
4	**Form of examination** Module exam: • Module exam (Study achievement, Oral/written examination, Default RS) Report and/or Presentation. The type of examination will be announced in the beginning of the project.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE
8	**Grade bonus compliant to §25 (2)**
9	**References** Will be announced once the topic is defined.
Courses	

	Course nr. 18-pr-2030-pj	**Course name** Project Seminar Terahertz Technology, Communication and Sensors		
	Instructor Prof. Dr. rer. nat. Sascha Preu		**Type** Project seminar	**SWS** 4

Module name Seminar Software System Technology					
Module nr. 18-su-2080	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Summer term
Language German			**Module owner** Prof. Dr. rer. nat. Andreas Schürr		

1	**Teaching content** In this course, the students produce scientific reports from changing subject areas. Each student has to explore a subject related to IT system development and produce a written report as well as a final talk with a presentation.
2	**Learning objectives** Upon successful completion of the module, the students will be able to assess the reliability of information sources and explore an unknown topic under scientific aspects. The students learn to support the exploration by a literature research and to analyze the subject critically. They achieve the skills to present a definite subject in a written report as well as in an oral presentation.
3	**Recommended prerequisites for participation** Basic knowledge in software engineering and programming languages
4	**Form of examination** Module exam: • Module exam (Study achievement, Oral/written examination, Default RS) Report and/or Presentation and/or Colloquium. The type of examination will be announced in the beginning of the lecture.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. MEC, M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, B.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** https://www.es.tu-darmstadt.de/lehre/aktuelle-veranstaltungen/sst-s

Courses

Course nr.	**Course name**		
18-su-2080-se	Seminar Software System Technology		
Instructor		**Type**	**SWS**
M.Sc. Alexej Andres, Prof. Dr. rer. nat. Andreas Schürr		Seminar	2

Module name HDL Lab					
Module nr. 18-ho-1090	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Teaching content** Realisation of a VHDL- or Verilog-based VLSI System Design Project in a Team with industrial constraints
2	**Learning objectives** A student is, after successful completion of this module, able to 1. design, optimize and verify a complex digital system (e.g. a pipelined CPU or signal processor) using Verilog or VHDL, 2. synthesize the HDL description using commercial CAD software to a gate level description After successful completion of this module the students are able to work constructively on a feasible solution. Aside, they are able to mutually support each other and present intermediate results to peers, and achieve an overall feasible solution.
3	**Recommended prerequisites for participation** Lecture Computer Aided Design for System on Chips, At least one high-level Programming Language, Basic Know-How Linux/Unix, Computer Architectures
4	**Form of examination** Module exam: • Module exam (Study achievement, Oral/written examination, Default RS) Report (including submission of programming code) and/or Presentation and/or Oral examination (25 minutes) and/or Colloquium (testate), but never more than two out of it. The type of examination will be announced in the beginning of the lecture.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. MEC, M.Sc. etit - DT, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** Lecture slides „CAD4SoC"

Courses

Course nr. 18-ho-1090-pr	**Course name** HDL Lab	
Instructor Prof. Dr.-Ing. Klaus Hofmann	**Type** Lab	**SWS** 3

Module name Seminar: Integrated Electronic Systems Design B					
Module nr. 18-ho-2161	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Teaching content** Research oriented Formulation of a Topic within the area of Microelectronics System Design; Creation of a written Documentation and Presentation; Team Work
2	**Learning objectives** A student is, after successful completion of this module, able to 1. gain a deep understanding of the chosen research subject in the field of integrated electronic systems, 2. write an essay on the chosen subject in a comprehesive form and present the outcome to an audience
3	**Recommended prerequisites for participation** Advanced Digital Integrated Circuit Design, CAD Methods, Computer Architectures, Programming Know-How
4	**Form of examination** Module exam: • Module exam (Study achievement, Oral examination, Duration: 45 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Study achievement, Oral examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - SAE, M.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** Topic-oriented Materials will be provided

Courses

Course nr. 18-ho-2161-se	**Course name** Seminar: Integrated Electronic Systems Design B	
Instructor Prof. Dr.-Ing. Klaus Hofmann	**Type** Seminar	**SWS** 3

Module name Embedded Systems Hands-On 2: Designing Hardware Accelerators for Systems-on-Chip					
Module nr. 20-00-0968	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language German			**Module owner** Prof. Dr.-Ing. Andreas Koch		

1	**Teaching content** These practical labs are intended for students interested in learning how to design hardware accelerators for systems-on-chips. It covers a wide 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 stereovision computations.
2	**Learning objectives** 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	**Recommended prerequisites for participation** 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 examination** Course related exam: • [20-00-0968-pr] (Study achievement, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-0968-pr] (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module**
8	**Grade bonus compliant to §25 (2)**
9	**References**

Courses

Course nr.	**Course name**		
20-00-0968-pr	Embedded Systems Hands-On 2: Designing Hardware Accelerators for Systems-on-Chip		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Andreas Koch		Lab	4

Module name Advanced Topics in Embedded Systems and Applications					
Module nr. 20-00-1001	**Credit points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language German/English			**Module owner** Prof. Dr.-Ing. Andreas Koch		

1	**Teaching content** The course covers current topics in research and development of computing systems and programming tools, including focused ones in the areas of embedded and application-specific architectures. The subjects are determined by current research efforts in the ESA group and are intended to guide students towards acquiring technical as well as introductory scientific skills, for example, including one or more of the following domains: - Computing systems architecture at the processor and systems-level - Design of digital electronic circuits and hardware systems - Use of Field-Programmable Gate Arrays Hardware/Software design and programming tools - Operating systems and low-level programming Hardware/Software Co-Design Application-specific architectures and techniques - Design and/or programming of compute accelerators - Debugging and analysis techniques for hardware/software-systems
2	**Learning objectives** 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	**Recommended prerequisites for participation** An interest to develop high-quality solutions in the assigned problem domain. For different domains, different pre-requisites will be required. These can include digital design, compiler construction, system-level and parallel programming. Such skills can be acquired by successfully completing the appropriate lectures.
4	**Form of examination** Course related exam: • [20-00-1001-pp] (Study achievement, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-1001-pp] (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatjk M.Sc Informatik May be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**
9	**References**

Courses

	Course nr. 20-00-1001-pp	**Course name** Advanced Topics in Embedded Systems and Applications		
	Instructor Prof. Dr.-Ing. Andreas Koch		**Type** Project	**SWS** 6

Module name Project Seminar Electromagnetic CAD					
Module nr. 18-sc-1020	**Credit points** 8 CP	**Workload** 240 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language German/English			**Module owner** Prof. Dr. rer. nat. Sebastian Schöps		

1	**Teaching content** Work on a project in numerical field calculation using commercial tools or own software. Topics of good scientific practice, as well as societal or ethical aspects of product design, optimization, and algorithms are addressed in an accompanying manner, where technically appropriate.
2	**Learning objectives** Students will be able to simulate engineering problems with numerical field simulation software. They are able to estimate modelling and numerical errors. They know how to present the results on a scientific level in talks and a paper. Students are able to organize teamwork.
3	**Recommended prerequisites for participation** Good understanding of electromagnetic fields, knowledge about numerical simulation methods.
4	**Form of examination** Module exam: • Module exam (Study achievement, Oral/written examination, Default RS) Report and/or Presentation. The type of examination will be announced in the beginning of the lecture.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. etit, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, B.Sc. CE, M.Sc. MedTec, M.Sc. iCE
8	**Grade bonus compliant to §25 (2)**
9	**References** Documents will be made available via Moodle if necessary.

Courses

Course nr. 18-sc-1020-pj	**Course name** Project Seminar Electromagnetic CAD		
Instructor Prof. Dr. rer. nat. Sebastian Schöps		**Type** Project seminar	**SWS** 4

Module name Digital Signal Processing Lab					
Module nr. 18-zo-2030	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1	**Teaching content** 1. Introduction to MATLAB 2. Discrete-Time Signals and Systems 3. Frequency-Domain Analysis using the DFT 4. Digital FIR Filter Design 5. IIR Filter Design using Analog Prototypes 6. Nonparametric Spectrum Estimation 7. Parametric Spectrum Estimation.
2	**Learning objectives** The students are able to apply skills acquired in the course Digital Signal Processing. These include the design of digital FIR and IIR filters as well as non-parametric and parametric spectrum estimation. Students learn how MATLAB is used to apply theoretical concepts and to demonstrate signal processing techniques by using hands-on application examples.
3	**Recommended prerequisites for participation** Fundamentals of Signal Processing
4	**Form of examination** Module exam: • Module exam (Study achievement, Written examination, Duration: 120 Min., Default RS) Exam (Duration: 120 min) and a Report (Lab Reports), Details will be announced at the beginning of the lecture.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Study achievement, Written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** Lab manual

Courses

Course nr.	**Course name**		
18-zo-2030-pr	Digital Signal Processing Lab		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Abdelhak Zoubir		Lab	3

Module name International Summer School 'Microwaves and Lightwaves'					
Module nr. 18-pr-2020	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr. rer. nat. Sascha Preu		

1	**Teaching content** This summer school covers the fundamentals and the latest developments of microwave electronics, THz technology, and optical communication systems with particular focus on the physical concepts involved.
2	**Learning objectives** Students understand the presented research topics, e.g. • topics of microwave engineering, THz engineering, and optical communications • of related electronics • the influence of the relevant properties of materials and of waveguides on signal processing. They gain inside into the latest developments in these fields.
3	**Recommended prerequisites for participation**
4	**Form of examination** Module exam: • Module exam (Study achievement, Oral examination, Duration: 30 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Study achievement, Oral examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** A script (English) will be distributed or slides can be downloaded.

Courses

Course nr. 18-pr-2020-se	**Course name** International Summer School "Microwaves and Lightwaves"		
Instructor Prof. Dr. rer. nat. Sascha Preu		**Type** Seminar	**SWS** 2

Module name
Project Seminar Hardware for Neural Networks

Module nr.	Credit points	Workload	Self-study	Module duration	Module cycle
18-zh-2020	6 CP	180 h	135 h	1 Term	Every Semester

Language	Module owner
English	Prof. Dr.-Ing. Li Zhang

1 Teaching content

Students will work on their own in this course. Topics and application context will be defined individually for each student. In this course hardware for neural networks will be investigated. This particularly means the improvement of software and hardware methods for efficient hardware for neural networks and the implementation of such hardware with commercial or open-source tools or FPGAs. Usually, the course starts with a literature search to get acquainted with the hardware for neural networks. This is followed by the practical part and finally the results are presented in a written report and a presentation.

2 Learning objectives

Successful students will know how to implement hardware for neural networks within a given application context. They can use tools to train a neural network and know how to realize it on a given hardware architecture. They are capable to evaluate the performance of an application.

3 Recommended prerequisites for participation

- Knowledge of neural network training and inference (cf. course hardware for neural network)
- Knowledge of digital or analog circuits (cf. course hardware for neural network)
- Solid programming skills (either in Python or VHDL depending on the application scenario)

4 Form of examination

Module exam:

- Module exam (Study achievement, Oral examination, Duration: 30 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Study achievement, Oral examination, Weighting: 100 %)

7 Usability of the module

M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST

8 Grade bonus compliant to §25 (2)

9 References

Will be given to the students during the individual seminar kick-off meeting.

Courses

Course nr.	Course name		
18-zh-2020-pj	Project Seminar Hardware for Neural Networks		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Li Zhang		Project seminar	3

Module name Project Seminar Spintronic Devices					
Module nr. 18-me-2030	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language German/English			**Module owner** Prof. Dr. rer. nat. Markus Meinert		

1	**Teaching content** In the project seminar, students have the opportunity to deal with various aspects of spintronic devices. These range from the development of measurement systems for the characterization of spintronic devices, to the fabrication and characterization of functional thin film systems, to the lithographic preparation of spintronic sensor devices or memory cell (MRAM) prototypes. Students gain valuable insights into the entire chain of device fabrication from the deposition of atomically thin film systems to their basic characterization and lithography under clean room conditions.
2	**Learning objectives** Students learn the basics of fabrication and application of spintronic devices as sensors or magnetic memory cells. Individual projects are carried out in small groups. The students deepen the material learned in the lectures in the form of a project work and learn and deepen their knowledge in the application of electronic measurement technology to answer concrete questions from research and development.
3	**Recommended prerequisites for participation** • Introduction to Spintronics (desirable) • Materials of Electrical Engineering (desirable)
4	**Form of examination** Module exam: • Module exam (Study achievement, Oral/written examination, Default RS) Report and/or Presentation. The type of examination will be announced in the beginning of the lecture.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** Lecture notes Introduction to Spintronics (Meinert), subject-specific literature and publications.

Courses

Course nr.	**Course name**		
18-me-2030-pj	Project seminar Spintronic Devices		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Markus Meinert		Project seminar	3

Module name Thin films and spintronics lab					
Module nr. 18-me-2050	**Credit points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language English			**Module owner** Prof. Dr. rer. nat. Markus Meinert		

1	**Teaching content** In several blocks, students have the opportunity to produce magnetic thin films and devices in the lab and cleanroom and to measure their properties: • Production of metallic thin films using magnetron sputtering, giant magnetoresistance (GMR), and interlayer coupling (RKKY) • Production of an AMR-based "barber pole" magnetic field sensor using lift-off lithography • Measurement of magnetic hysteresis in thin films, characterization of magnetization and magnetic damping with GHz broadband spectroscopy, characteristics of magnetic tunnel junctions
2	**Learning objectives** Through the module, students learn how to handle equipment for the production of thin metallic layer systems. They carry out lithographic preparation in the cleanroom under the guidance of the instructor. Upon completion of the module, students will have a basic understanding of thin film technology, the associated process technology, and highly sensitive magnetic field sensors.
3	**Recommended prerequisites for participation** Introduction to spintronics
4	**Form of examination** Module exam: • Module exam (Study achievement, Oral/written examination, Duration: 25 Min., Default RS) Report (including submission of programming code) and/or Presentation and/or Oral examination (25 minutes) and/or Colloquium (testate), but never more than two out of it. The type of examination will be announced in the beginning of the lecture.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** Script and slides for the internship Thin films and spintronics lab

Courses

Course nr.	**Course name**		
18-me-2050-pr	Thin films and spintronics lab		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Markus Meinert		Lab	3

2.2 Communication Systems and Networking

2.2.1 Communication Systems and Networking - Lectures

Module name Radar Techniques						
Module nr. 18-jk-2040	**Credit points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Module duration** 1 Term	**Module cycle** Winter term	
Language German			**Module owner** Prof. Dr.-Ing. Rolf Jakoby			
1	**Teaching content** First, there will be an introduction of different radar techniques, describing their concepts and principles, their applications and the operating frequency ranges. In a historical survey, the radar ranges and propagation effects will be dealt with. In the second part, various primary and secondary radar techniques will be investigated in detail, including specific techniques of radar signal processing and -analysis.					
2	**Learning objectives** Students will know about concepts and principles to detect objects as well as to determine the angular position and range of objects. They learn about the functional principles of various radar systems, including signal processing. They will understand the major physical propagation effects.					
3	**Recommended prerequisites for participation** Fundamentals of Communications, Microwave Engineering I					
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral examination, Duration: 30 Min., Default RS)					
5	**Prerequisite for the award of credit points** Passing the final module examination					
6	**Grading** Module exam: • Module exam (Technical examination, Oral examination, Weighting: 100 %)					
7	**Usability of the module** M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, B.Sc. WI-etit					
8	**Grade bonus compliant to §25 (2)**					
9	**References** Slides, Latest Publications and Books					
Courses						
	Course nr. 18-jk-2040-vl	**Course name** Radar Techniques				
	Instructor Prof. Dr.-Ing. Rolf Jakoby, Dr.-Ing. Alejandro Sáez			**Type** Lecture	**SWS** 2	

Module name Information Theory I: Fundaments					
Module nr. 18-kp-1010	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr. techn. Heinz Köppl		

1	**Teaching content** This lecture course introduces the fundamentals of information theory, network information theory and coding theory. Outline: information, uncertainty, entropy, mutual information, capacity, differential entropy, typical sequences, Gaussian channels, basics of source and channel coding, linear block codes, Shannon's source coding theorem, Shannon's channel coding theorem, capacity of Gaussian channels, capacity of bandlimited channels, Shannon's bound, bandwidth efficiency, capacity of multiple parallel channels and waterfilling, Gaussian vector channel, Multiple Access Channel, Broadcast Channel, rate region.
2	**Learning objectives** Upon completion of the module, students will have an understanding of the fundamentals of classic information theory.
3	**Recommended prerequisites for participation** Basic knowledge of probability theory
4	**Form of examination** Module exam: • Module exam (Technical examination, Examination, Duration: 120 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. etit, M.Sc. CE, B.Sc. CE, M.Sc. iCE, B.Ed. etit, B.Sc. und M.Sc. iST, B.Sc. WI-etit, M.Sc. etit - CMEE
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.

Courses

Course nr. 18-kp-1010-vl	**Course name** Information Theory I: Fundaments	
Instructor Prof. Dr. techn. Heinz Köppl, M.Sc. Anam Tahir	**Type** Lecture	**SWS** 3

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

Module name Information Theory II: Networks					
Module nr. 18-pe-2010	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1	**Teaching content** This 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 objectives** Upon completion of the module, students will have an understanding of the advanced concepts and strategies in network information theory.
3	**Recommended prerequisites for participation** Knowledge of basic communication theory
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS) The examination takes place in form of a written exam (duration: 120 minutes). If apparent that less than 10 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.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - CMEE, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** • Abbas El Gamal and Young-Han Kim, Network Information Theory, Cambrige, 2011. • T.M. Cover and J.A. Thomas, Elements of Information Theory, Wiley Sons, 1991. • D. Tse and P. Vishwanath, Fundamentals of Wireless Communications, Cambridge University Press, 2005.

Courses

Course nr. 18-pe-2010-vl	**Course name** Information Theory II: Networks		
Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lecture	**SWS** 3

	Course nr. 18-pe-2010-ue	**Course name** Information Theory II: Networks		
	Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Practice	**SWS** 1

Module name MIMO - Communication and Space-Time-Coding					
Module nr. 18-ja-2010	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Vahid Kooshkghazi		

1	**Teaching content** This lecture course introduces the principles of space-time and multiple-input multiple-output (MIMO) communications. Outline: Motivation and background; overview of space-time and MIMO communications; fading MIMO channel models, MIMO information theory, receive and transmit diversity; channel estimation, MIMO detectors, Alamouti space-time block code, orthogonal space-time block codes; linear dispersion codes; coherent and non-coherent decoders, differential space-time block coding; MIMO with limited feedback, Multiantenna- and multiuser diversity, BER performance analysis, MIMO in moden wireless communication networks, multicell and multiuser MIMO (coordinated multipoint).
2	**Learning objectives** Students will understand modern MIMO communications and existing space-time coding techniques.
3	**Recommended prerequisites for participation** Knowledge of basic communication theory and basic information theory.
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS) The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 10 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.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. MEC, M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** • A.B.Gershman and N.D.Sidiropoulos, Editors, Space-Time Processing for MIMO Communications, Wiley and Sons, 2005. • E.G.Larsson and P.Stoica, Space-Time Block Coding for Wireless Communications, Cambridge University Press, 2003; • A.Paulraj, R.Nabar, and D.Gore, Introduction to Space-Time Wireless Communications, Cambridge University Press, 2003. • Lin Bai and Jinho Choi, Low Complexity MIMO detectors, Springer, 2012. • Howard Huang, Constantinos B. Papadias, and Sivarama Venkatesan, MIMO Communication for Cellular Networks, Springer, 2012.
Courses	

	Course nr. 18-ja-2010-vl	**Course name** MIMO - Communication and Space-Time-Coding		
	Instructor Prof. Dr.-Ing. Vahid Kooshkghazi		**Type** Lecture	**SWS** 2
	Course nr. 18-ja-2010-ue	**Course name** MIMO - Communication and Space-Time-Coding		
	Instructor Prof. Dr.-Ing. Vahid Kooshkghazi		**Type** Practice	**SWS** 1

Module name Sensor Array Processing and Adaptive Beamforming					
Module nr. 18-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. Dr.-Ing. Marius Pesavento		

1	**Teaching content** This lecture course introduces the principles of modern sensor array processing and adaptive beamforming. Outline: Motivation and background; applications, narrowband and wideband signal model Direction-of-arrival estimation (DoA): traditional methods based on beamforming, super resolution methods, Maximum-Likelihood methods, Subspace based methods, MUSIC, ESPRIT, MODE, root-MUSIC, multidimensional source localization, approximate Maximum Likelihood methods, Expectation Maximization (EM) algorithm, partial relaxation method, beamspace processing, array interpolation, partly calibrated arrays, wideband DOA estimation, spatial smoothing, forward-backward averaging, redundancy averaging, correlated sources, minimum redundancy arrays, compressed sensing and sparse reconstruction based DoA estimation, performance bounds Adaptive beamforming: Point-source model, covariance model, Wiener-Hopf equation, Minimum Variance Distortionless Response (MVDR) beamformer, Capon Beamformer, sample matrix inversion, signal self-nulling effect, robust adaptive beamforming, Hung-Turner projection beamformer, Generalized Sidelobe canceller beamformer, Eigenspace-based beamformer, non-stationary environments, modern convex optimization based beamforming, worst-case based beamforming, multiuser beamforming.
2	**Learning objectives** Upon completion of the module, students will have learned the application of theory and algorithms for processing Sensor-Arry and Tensor data.
3	**Recommended prerequisites for participation** Knowledge in linear algebra.
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS) The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 10 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.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. MEC, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, B.Sc. WI-etit, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References**

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.

Courses

Course nr.	**Course name**		
18-pe-2060-vl	Sensor Array Processing and Adaptive Beamforming		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Lecture	2

Course nr.	**Course name**		
18-pe-2060-ue	Sensor Array Processing and Adaptive Beamforming		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Practice	1

Module name
Graph Signal Processing, Learning and Optimization

Module nr.	Credit points	Workload	Self-study	Module duration	Module cycle
18-pe-2080	6 CP	180 h	120 h	1 Term	Winter term

Language	Module owner
English	Prof. Dr.-Ing. 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
  - Pearson product-moment correlation
  - Causality, Partial correlation
  - Conditional independence graph
  - Gaussian Markov Random Fields
  - Graphical LASSO, Graphical LASSO with Laplacian constraint
  - Applications
- Graph analysis
  - Subgraph identification
  - Cliques identification
- Optimization over graphs
  - Average consensus, diffusion, exact diffusion
  - Gradient tracking, push-sum algorithm, etc.
  - Applications
- Graph neuronal (convolutional) network

2 Learning objectives

Graph signal processing (i.e., the processing of signals defined over graphs) and network analysis form an interdisciplinary research field with numerous and diverse applications. Upon completion of the module, students will have gained systematic knowledge in graph signal processing theory, graph network analysis, graph topology learning, optimization in graph networks, and learning using graph neural networks. They have learned essential concepts, algorithms and application areas of graph signal processing.

3 Recommended prerequisites for participation

Basic knowledge in linear algebra and matrix analysis.

4 Form of examination

	Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS) In general, the examination takes place in form of a written exam (duration: 120 minutes). If up to 20 students register in semesters in which the lecture does not take place, there will will be an oral examination (duration: 20 min.). The type of examination will be announced within one working weeks after the end of the examination registration phase.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - CMEE, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** • Lecture notes and slides can be downloaded here: – www.nts.tu-darmstadt.de – moodle • Further reading: – Petar M. Djuric, Cédric Richard, Cooperative and Graph Signal Processing, Academic Press, 2018, ISBN 9780128136775.

Courses

Course nr. 18-pe-2080-vl	**Course name** Graph signal processing, learning and optimization		
Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lecture	**SWS** 3
Course nr. 18-pe-2080-ue	**Course name** Graph signal processing, learning and optimization		
Instructor Prof. Dr.-Ing. Marius Pesavento, M.Sc. Yufan Fan		**Type** Practice	**SWS** 1

Module name Terahertz Systems and Applications					
Module nr. 18-pr-2010	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr. rer. nat. Sascha Preu		

1 Teaching content

The lecture will give an overview of Terahertz applications, sources and detectors with the focus on photonic and semiconductor-based devices and Terahertz systems. Terahertz detection and generation will be discussed in detail for two types of highly important devices: Schottky diodes (mixers, multi-pliers and rectifiers) and photomixers (photo-diode based and photoconductive). The exercise, where performance parameters of the discussed devices will be derived for experimentally relevant cases, will help to deepen the understanding. The last day will be used for a lab tour showing our measurements facilities and hands-on Experiments.

2 Learning objectives

After completion of this module, the student has gained basic knowledge in the fields of THz generation, detection, systems, and applications of THz radiation, with deepened knowledge in:

- A general overview about the state of the art in Terahertz technology
- Working principle, spectra and limits of continuous-wave photomixer systems
- Working principle of Schottky diode mixers/multipliers and rectifiers in the THz range
- THz Applications

3 Recommended prerequisites for participation

Bachelor in Electrical engineering, Physics, or Material Science
Helpful: Basic knowledge in semiconductor physics, High frequency 1

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS)

The examination takes place in form of a written exam (duration: 90 minutes). If one can estimate that less than 20 students register, the examination will be an oral examination (duration: 25 min.). The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

- Pass module final exam

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE

8 Grade bonus compliant to §25 (2)

9 References

- Yun-Shik Lee, „Principles of Terahertz Science and Technology,“ Springer 2009, ISBN 978-0-387-09540-0
- G. Carpintero et al., “Semiconductor Terahertz Technology: Devices and Systems at Room Temperature Operation,” Wiley 2015, ISBN: 978-1-118-92042-8

Courses

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

Module name Adaptive Filters					
Module nr. 18-zo-2010	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language German/English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Teaching content

Theory:

1. Derivation of optimal filters for stochastic processes, e.g. Wiener filter or linear prediction filter based on suitable cost functions.
2. Elaboration of adaptive procedures, which allow to iteratively approach the optimal solution for non-stationary signals in non-stationary environments. Here, the adaptive procedures such as NLMS adaptation, affine projection, and the RLS algorithm are derived and extensively analysed.
3. Analysis of the adaptation behaviour and control procedures of adaptive filters based on the NLMS procedure.
4. Derivation and analysis of the Kalman filter as optimal filter for non-stationary input signals.
5. Procedures for the decomposition of signals into sub-bands for the realization of optimal filters in the frequency domain, e.g. noise reduction procedures.

Applications:

Parallel to the theory, practical applications are explained. As an example for the Weiner filter, the acoustic noise reduction procedures are explained. Acoustic echo cancellation and feedback cancellation are given as examples for adaptive filters. Furthermore beamforming approaches are introduced.

It is planned to offer an excursion to Siemens Audiology Engineering Group in Erlangen.
In the 4 to 5 exercises, some content of the lecture will be implemented in MATLAB which allows the students to get familiar with practical realizations of the theoretical procedures.

2 Learning objectives

Upon completion of the module, students were taught the fundamentals of adaptive filters. The necessary algorithms are derived, interpreted and applied to examples of speech, audio and video processing. Based on the content of the lecture you are able to apply adaptive filters to real practical applications.
For the admission to the exam you give a talk about a topic in the domain of adaptive filters chosen by you. This will allow you to acquire the know-how to read and understand scientific literature, familiarize yourself 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 Recommended prerequisites for participation

Digital Signal Processing

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS)

The examination takes place in form of a written exam (duration: 90 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.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

	M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** Slides of the lecture. Literature: • E. Hänsler, G. Schmidt: Acoustic Echo and Noise Control, Wiley, 2004 (Textbook of this course); • S. Haykin: Adaptive Filter Theory, Prentice Hall, 2002; • A. Sayed: Fundamentals of Adaptive Filtering, Wiley, 2004; • P. Vary, U. Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 1998 (in German)

Courses

Course nr. 18-zo-2010-vl	**Course name** Adaptive Filters		
Instructor Prof. Dr.-Ing. Henning Puder		**Type** Lecture	**SWS** 3
Course nr. 18-zo-2010-ue	**Course name** Adaptive Filters		
Instructor Prof. Dr.-Ing. Henning Puder		**Type** Practice	**SWS** 1

Module name Speech and Audio Signal Processing					
Module nr. 18-zo-2070	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language German			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1	**Teaching content** Algorithms of speech and audio signal processing: Introduction to the models of speech and audio signals and basic methods of audio signal processing. Procedures of codebook based processing and audio coding. Beamforming for spatial filtering and noise reduction for spectral filtering. Cepstral filtering and fundamental frequency estimation. Mel-filterind cepstral coefficients (MFCCs) as basis for speaker detection and speech recognition. Classification methods based on GMM (Gaussian mixture models) and speech recognition with HMM (Hidden markov models). Introduction to the methods of music signal processing, e.g. Shazam-App or beat detection.
2	**Learning objectives** Based on the module you acquire an advanced knowledge of digital audio signal processing mainly with the help 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	**Recommended prerequisites for participation** Knowlegde about satistical signal processing (lecture „Digital Signal Processing“). Desired - but not mandatory - is knowledge about adaptive filters.
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS) Seminar presentation: Scientific talk about a topic in the field of “Speech and Audio Signal Processing”, single (duration 10-15 min) or in groups of two students (15-20 min) or in a group of 20 students and more a written exam (duration 90 min)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. MedTec, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** Slides (for further details see homepage of the lecture)
Courses	

	Course nr. 18-zo-2070-vl	**Course name** Speech and Audio Signal Processing		
	Instructor Prof. Dr.-Ing. Henning Puder		**Type** Lecture	**SWS** 2
	Course nr. 18-zo-2070-ue	**Course name** Speech and Audio Signal Processing		
	Instructor Prof. Dr.-Ing. Henning Puder		**Type** Practice	**SWS** 1
	Course nr. 18-zo-2070-se	**Course name** Sprach- und Audiosignalverarbeitung		
	Instructor Prof. Dr.-Ing. Henning Puder		**Type** Seminar	**SWS** 1

Module name Software Defined Networking					
Module nr. 18-sm-2280	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language German/English			**Module owner** Prof. Dr.-Ing. Ralf Steinmetz		

1 Teaching content

The course deals with topics in the area of software defined networking:

- SDN Data Plane
- SDN Control Plane
- SDN Application Plane
- Network Function Virtualization
- Network Virtualization and Slicing
- QoS and QoE in Software Defined Networks

2 Learning objectives

Upon completion of the module, students will have gained in-depth insights into Software Defined Networking, as well as basic technologies and applications.

3 Recommended prerequisites for participation

Basic courses of the first 4 semesters are required. Knowledge of lectures Communication Networks I and II are recommended.

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS)

The examination takes place in form of a written exam (duration: 90 minutes). If one can estimate that less than 15 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.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, B.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST

8 Grade bonus compliant to §25 (2)

9 References

Textbooks as indicated.
Slides and paper copies as necessary.

Courses

Course nr.	**Course name**		
18-sm-2280-vl	Software Defined Networking		
Instructor		**Type**	**SWS**
Dr.-Ing. Ralf Kundel, M.Sc. Chengbo Zhou, M.Ed. Benjamin Becker		Lecture	2

	Course nr. 18-sm-2280-ue	**Course name** Software Defined Networking		
	Instructor Dr.-Ing. Ralf Kundel, M.Sc. Chengbo Zhou, M.Ed. Benjamin Becker		**Type** Practice	**SWS** 2

Module name Network, Traffic and Quality Management for Internet Services					
Module nr. 20-00-0056	**Credit points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language English			**Module owner** Prof. Dr. rer. nat. Eberhard Mühlhäuser		

1 Teaching content

Introduction into management of Internet service provider (ISP-)networks for integrating IP service platforms with their quality and traffic profiles.

2 Learning objectives

Course Content:

Requirements and measures to ensure Quality-of-Service (QoS)

- criteria from the application & user perspective (QoE: Quality of Experience).
- QoS Architecture in IP Networks: Differentiated & Integrated Services
- QoS support & impact per application in IP traffic mix (video streaming, VoIP, web browsing, downloads, social networking etc.)

Quality Assurance for Internet Services in ISP Network Infrastructures

- Network and Transport Layer Impact: Routing (OSPF, BGP), Multiprotocol Label Switching (MPLS), TCP with protection against errors and failures.
- measurement, monitoring, optimization of IP traffic regarding QoS

Quality assurance in service overlays and at application level

- Content Delivery Networks (CDN), Clouds and Peer-to-Peer Networks (P2P) incl. distributed caches, transport path optimization, scalability
- -IETF Standardization (CDN Interconnection, ALTO: Appl. Layer Traffic Opt.)

3 Recommended prerequisites for participation

Recommended:

Prerequisites: Basic knowledge in computer science and Internet applications is required. The courses on Kommunikationsnetze I and II are recommended.

4 Form of examination

Course related exam:

- [20-00-0056-vl] (Technical examination, Oral/written examination, Default RS)

The form of the examination will be announced at the beginning of the course. One or a combination of max. two of the following forms is possible.

Written exam (duration 60 or 90 or 120 minutes), oral exam (duration 15 or 30 minutes), homework (optional: including tests).

5 Prerequisite for the award of credit points

Pass exam (100%)

6 Grading

Course related exam:

- [20-00-0056-vl] (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

B.Sc. Informatik

M.Sc. Informatik

Maybe used in other degree programs.

8 Grade bonus compliant to §25 (2)

9	**References** Will be given in lecture.			
Courses				
	Course nr. 20-00-0056-vl	**Course name** Network, traffic and quality management for Internet services		
	Instructor		**Type** Lecture	**SWS** 2

Module name Network Security					
Module nr. 20-00-0512	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language English			**Module owner** Dr.-Ing. Michael Kreutzer		

1 Teaching content

The integrated course Network Security covers the principles and practice of computer and telecommunication network security with particular emphasis on Internet security. After transferring the fundamentals of IT security and cryptography to the networking domain, we follow a top-down approach to network security. Starting with the application layer, the course provides a detailed discussion of network security principles and protocols. In addition to well known mechanisms, selected recent developments in the area of network security will be examined.

Course contents:
- Network security: introduction, motivation, and challenges
- Fundamentals: a reference model for network security, security standards for networks and the Internet, security threats, attacks, services, and mechanisms
- Cryptographic foundations for networking security: symmetric crypto and its use in networks, public-key crypto and its use in networks, support functions to implement network security
- Application layer security
- Transport layer security
- Network layer security
- Link layer security
- Physical layer security and physical security
- Operational network security: firewalls, intrusion detection systems
- Selected topics in network security

2 Learning objectives

After successfully attending the course, students have aquired an in-deep knowledge in the domain of communication network security with emphasis on Internet security. Students are able to apply and transfer the most important fundamentals from IT security and cryptography to the field of communication networks. Students are able to distinguish the most important basic techniques for securing communication networks. They have a thorough understanding of security mechanisms on the different network layers (application layer, transport layer, network layer, link layer, physical layer). As a result, they are able to thoroughly discuss the characteristics and principles in the area of network security and exhibit detailed theoretical and practical knowledge in this field. Additionally, students are able to describe recent developments in the area of network security (e.g. peer-to-peer security, mobile network security, etc.). The exercise deepens the theoretical foundations by means of exercises, which consist of literature, calculation as well as practical implementation/application examples.

3 Recommended prerequisites for participation

Knowledge in the area IT Security, Introduction to Cryptography and Communication Networks

4 Form of examination

Course related exam:
- [20-00-0512-iv] (Technical examination, Oral/written examination, Default RS)

5 Prerequisite for the award of credit points

Pass exam (100%)

6 Grading

Course related exam:
- [20-00-0512-iv] (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

	B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
8	**Grade bonus compliant to §25 (2)** 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** Charlie Kaufman, Radia Perlman, Mike Speciner: Network Security - Private Communication in a Public World, 2nd Edition, Prentice Hall, 2002, ISBN: 978-0-14-046019-6; additional texts may be announced

Courses

	Course nr.	**Course name**		
	20-00-0512-iv	Network Security		
	Instructor		**Type**	**SWS**
	Dr.-Ing. Michael Kreutzer		Integrated course	4

Module name Physical Layer Security in Wireless Systems					
Module nr. 20-00-0745	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language German			**Module owner** Dr.-Ing. Michael Kreutzer		

1 Teaching content

Physical layer security techniques promise information theoretic security on the physical layer for wireless communication. This integrated course discusses the theory and practice of physical layer security. The underlying theory is introduced and the application of these fundamentals towards practical solutions is discussed. Attacks against (practical) physical layer security techniques are presented. Theoretical and practical exercises as well as the presentation of selected recent research results by seminar talks of students further deepen the understanding of the subject matter.

Course contents:
- Properties of the physical layer
- Fundamentals of information theoretic security and delineation from cryptography
- Physical layer security techniques (such as cooperative jamming, orthogonal blinding, zero-forcing, interference alignment, key extraction)
- Practical aspects of physical layer security techniques
- Practical implementations of physical layer security techniques using software-defined radios
- Selected current approaches to physical layer security

2 Learning objectives

After successfully attending the course, students have a basic theoretical knowledge and an in-deep practical knowledge in the area of physical layer security. They are able to describe the most important information-theoretic basics as well as theory and practice of physical layer security techniques. They are able to analyze practical physical layer security techniques and describe their weaknesses. Students have competencies in the practical realization of physical layer security techniques using software-defined radios. They can independently acquire the current state of research on physical layer security and present the aquired knowledge in a comprehensible fashion.

3 Recommended prerequisites for participation

Basics Mobile Networking

4 Form of examination

Course related exam:
- [20-00-0745-iv] (Technical examination, Oral/written examination, Default RS)

5 Prerequisite for the award of credit points

Pass exam (100%)

6 Grading

Course related exam:
- [20-00-0745-iv] (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

	B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
8	**Grade bonus compliant to §25 (2)** 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 literature, will be given in lecture.

Courses

Course nr.	**Course name**		
20-00-0745-iv	Physical Layer Security in Wireless Systems		
Instructor		**Type**	**SWS**
Dr.-Ing. Michael Kreutzer		Integrated course	3

Module name Mobile Networking					
Module nr. 20-00-0748	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Thorsten Strufe		

1 Teaching content

Mobile communications and wireless networking technology has seen a thriving development in recent years. The integrated course addresses the characteristics/principles of mobile networks in detail, and practical solutions are presented. Hereby our focus is on the network layer, which is often regarded as the glue of communication systems. In addition to describing the state of the art in technology we discuss actual research problems and learn about methodologies to approach such problems systematically. The contents of the course will be deepended by exercises.

Course contents:
- Introduction to mobile and wireless communications: Applications, history, market vision
- Overview of wireless transmission: frequencies & regulations, signals, antennas, signal propagation, multiplexing, modulation, spread spectrum, cellular systems
- Medium access control in the wireless domain: SDMA, FDMA, CDMA TDMA (fixed, Aloha, CSMA, DAMA, PRMA, MACA, collision avoidance, polling)
- Wireless local area networks: IEEE 802.11 standard including physical layer, MAC layer and access schemes, quality of service and power management
- Wireless metropolitan area networks: Wireless mesh networks, IEEE 802.16 standard including modes of operation, medium access control, quality of service and scheduling
- Mobility at network layer: Concepts to support mobility on various layers, Mobile IP
- Ad hoc networks: Terminology, basics and applications, characteristics of ad hoc communication, ad hoc routing paradigms and protocols
- Performance evaluation of mobile networks: Overview of performance evaluation, systematic approach / common mistakes and how to avoid them, experimental design and analysis
- Mobility at transport layer: Variants of TCP (indirect TCP, snoop TCP, mobile TCP, wireless TCP)
- Mobility at application layer. Outlook: Applications for mobile networks and wireless sensor networks

2 Learning objectives

After successfully attending the course, students have an in-deep knowledge on the working of mobile communication networks. They have gained insight into media access control mechanisms dedicated to wireless communication and have a thorough understanding of mechanisms based on the network and the transport layers, with a focus on ad hoc and mesh networks. Moreover, the students have acquired knowledge about the connections between the different protocol layers and are able to apply the acquired knowledge on methodological analysis of real communication systems. The students are therefore be conversant with the characteristics and basic principles of wireless and mobile communications in theory and practice. The exercise-parts of the integrated course deepen the theoretical foundations by means of exercises, which consist of literature, calculation as well as practical implementation/application examples.

3 Recommended prerequisites for participation

Basic courses in Communication Networks are recommended.

4 Form of examination

Course related exam:
- [20-00-0748-iv] (Technical examination, Oral/written examination, Default RS)

5 Prerequisite for the award of credit points

Pass exam (100%)

6 Grading

	Course related exam: • [20-00-0748-iv] (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik M.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
8	**Grade bonus compliant to §25 (2)** 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 literature, details are given in lecture.

Courses

Course nr.	**Course name**		
20-00-0748-iv	Mobile Networking		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Thorsten Strufe		Integrated course	4

Module name Wireless Network for Emergency Response: Fundamentals, Design, and Build-up from Scratch					
Module nr. 20-00-0780	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language German			**Module owner** Prof. Dr. rer. nat. Eberhard Mühlhäuser		

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
- Design and practical realization from scratch of wireless communication systems

2 Learning objectives

After successfully attending the course, students have theoretical and practical knowledge in the area of wireless and infrastructureless communication for emergency response. They understand the most important physical and electrotechnical basics of wireless communications and know wireless transmission mechanisms in theory and practice. They are able to build a wireless communication system from scratch and operate it. The students acquire competences in the area of amateur radio and software defined radio technology.

3 Recommended prerequisites for participation

4 Form of examination

Course related exam:
- [20-00-0780-iv] (Technical examination, Oral/written examination, Default RS)

5 Prerequisite for the award of credit points

Pass exam (100%)

6 Grading

Course related exam:
- [20-00-0780-iv] (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

B.Sc. Informatik
M.Sc. Informatik
M.Sc. Wirtschaftsinformatik
B.Sc. Psychologie in IT
Joint B.A. Informatik
B.Sc. Sportwissenschaft und Informatik

Can be used in other degree programs.

8 Grade bonus compliant to §25 (2)

	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 given in lecture.			
Courses				
	Course nr. 20-00-0780-iv	**Course name** Wireless Network for Emergency Response: Fundamentals, Design, and Build-up from Scratch		
	Instructor Prof. Dr. rer. nat. Eberhard Mühlhäuser		**Type** Integrated course	**SWS** 3

Module name TK3: Ubiquitous / Mobile Computing					
Module nr. 20-00-0120	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language German			**Module owner** Prof. Dr. rer. nat. Eberhard Mühlhäuser		

1	**Teaching content** Objectives: - Knowledge of technical basics of the mobile communication - Knowledge of important challenges of the Ubiquitous Computing - Methodic knowledge about current approaches to these challenges Course Content: - Introduction to Ubiquitous Computing - Mobile Communication - Internet of Things: RFID and Smart Items - Service Discovery & Cloudlets - Context- and Location-aware Computing - Human Computer Interaction - Privacy and Trust in Ubiquitous Computing
2	**Learning objectives** After successfully attending the course, students are familiar with the technical basis of mobile communication. They understand the fundamental challenge of ubiquitous computing. They know current approaches to solve these challenges. They are able to apply their knowledge to build ubiquitous computing systems.
3	**Recommended prerequisites for participation** Computer Netzwerke and Distributed Systems
4	**Form of examination** Course related exam: • [20-00-0120-iv] (Technical examination, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-0120-iv] (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik M.Sc. Sportwissenschaft und Informatik May be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**

	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** 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: 1. F. Adelstein, S. Gupta et al.: Fundamentals of Mobile & Pervasive Computing McGraw Hill 2004, 2. Stefan Poslad: Ubiquitous Computing, Wiley 2009, ISBN 978-0-470-03560-3 3. Kapitel Mobilkommunikation: M. Sauter: Grundkurs Mobile Kommunikationssysteme: UMTS, HSDPA und LTE, GSM, GPRS und Wireless LAN; Vieweg-Teubner Studium 2010 4. J. Krumm (Ed.): Ubiquitous Computing Fundamentals, CRC Press 2010 D. Cook, S. Das (Ed.): Smart Environments, Wiley 2005

Courses

	Course nr.	**Course name**		
	20-00-0120-iv	TK3: Ubiquitous / Mobile Computing		
	Instructor		**Type** Integrated course	**SWS** 4

Module name Antennas and Adaptive Beamforming					
Module nr. 18-jk-2020	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1	**Teaching content** 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.
2	**Learning objectives** 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 and frequency-independent antennas (V antennas, biconical antennas, helical antennas, spiral and log-periodic antennas).
3	**Recommended prerequisites for participation** Fundamentals of Communications, Microwave Engineering 1
4	**Form of examination** Module exam: • Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading**

	Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)			
7	**Usability of the module** M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, B.Sc. WI-etit			
8	**Grade bonus compliant to §25 (2)**			
9	**References** Skriptum “Antennas and Adaptive Beamforming” will be provided electronically at the beginning of the lecture.			
Courses				
	Course nr. 18-jk-2020-vl	**Course name** Antennas and Adaptive Beamforming		
	Instructor M.Sc. Jesús Pastor, Dr.-Ing. Alejandro Sáez, Dr.-Ing. Martin Schüßler		**Type** Lecture	**SWS** 3
	Course nr. 18-jk-2020-ue	**Course name** Antennas and Adaptive Beamforming		
	Instructor M.Sc. Jesús Pastor, Dr.-Ing. Alejandro Sáez, Dr.-Ing. Martin Schüßler		**Type** Practice	**SWS** 1

Module name Microwave Engineering II					
Module nr. 18-jk-2130	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1 Teaching content

Part 1 Passive microwave components:

- Calculation of the two-port parameters of simple passive components and circuits (transmission lines and lumped elements) for MMICs
- Wave parameters and S-parameters
- Smith chart and matching circuits with line elements or lumped elements
- Design and equivalent circuits of passive microwave components (transmission lines, capacitors, inductors and resistors)

Part 2 Active microwave components:

- Design and equivalent circuits of field effect transistors (FET) and heterostructure transistors (HEMTs)
- Gain and cut-off frequencies
- Schottky contacts: function and characteristics

Part 3 Active microwave circuits (main part):

- FET amplifiers: operation, equivalent circuit, gain, matching circuit, stability and circuit implementation
- Oscillator design
- Mixer design
- Material choice (compound semiconductor material systems: properties, fabrication and requirements)

Applications of these circuits range from communication systems such as cell phones to satellite transceivers as well as high-frequency sources up to Terahertz.
Topics of good scientific practice, as well as societal or ethical aspects of product design, optimization, and algorithms are addressed in an accompanying manner, where technically appropriate.

2 Learning objectives

After successful completion of the module students understand the physics of microwave waveguides, resonators, microwave components (passive and active) as well as microwave circuits.

3 Recommended prerequisites for participation

Introduction to Electrodynamics, Microwave Engineering I

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST

8 Grade bonus compliant to §25 (2)

9 References

Script and slides will be handed out. Literature will be recommended in the lecture.

Courses

	Course nr. 18-jk-2130-vl	**Course name** Microwave Engineering II		
	Instructor PD Dr.-Ing. Oktay Yilmazoglu		**Type** Lecture	**SWS** 3
	Course nr. 18-jk-2130-ue	**Course name** Microwave Engineering II		
	Instructor PD Dr.-Ing. Oktay Yilmazoglu		**Type** Practice	**SWS** 1

Module name Matrix Analysis and Computations					
Module nr. 18-pe-2070	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

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	**Learning objectives** Students will have learned advanced topics in matrix analysis and related algorithms at an advanced level upon completion of the module.
3	**Recommended prerequisites for participation** Basic knowledge in linear algebra.
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS) The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 10 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.
5	**Prerequisite for the award of credit points** Pass module final exam.
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. etit, M.Sc. MEC, M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. etit - AUT, M.Sc. iCE, B.Ed. etit, B.Sc. und M.Sc. iST, B.Sc. WI-etit, M.Sc. etit - CMEE
8	**Grade bonus 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

Course nr.	**Course name**		
18-pe-2070-vl	Matrix Analysis and Computations		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Lecture	3

Course nr.	**Course name**		
18-pe-2070-ue	Matrix Analysis and Computations		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Practice	1

Module name Robust Data Science With Biomedical Applications					
Module nr. 18-mu-2010	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. 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 implement the lecture contents are available to the students.

2 Learning objectives

Students understand the basics of robust signal processing and data science and are able to apply them to a variety of problems. They are familiar with various biomedical applications and know the causes of artifacts, outliers and impulsive noise. They can apply algorithms for robust regression, cluster analysis, classification and spectral analysis.

3 Recommended prerequisites for participation

Fundamental knowledge of statistical signal processing

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 180 Min., Default RS)

5 Prerequisite for the award of credit points

Pass module final exam

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. MedTec, M.Sc. iCE, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

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

Course nr.	**Course name**		
18-mu-2010-vl	Robust Signal Processing With Biomedical Applications		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Michael Muma		Lecture	3
Course nr.	**Course name**		
18-mu-2010-ue	Robust Data Science With Biomedical Applications		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Michael Muma		Practice	1

Module name Finite Integration Technique					
Module nr. 18-dg-1030	**Credit points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Module duration** 1 Term	**Module cycle** Summer term
Language German			**Module owner** Prof. Dr.-Ing. Herbert De Gersem		

1	**Teaching content** Basics FIT, electrostatics, magnetostatics, magnetoquasistatics, high frequency simulations, convergence studies, discretisation, time- and frequency domain simulations.
2	**Learning objectives** 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	**Recommended prerequisites for participation** Basics of Maxwell's equations, linear algebra. Recommended: Basic knowledge in knowledge in "Technical Electrodynamics"
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral examination, Duration: 30 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. etit, B.Sc. CE, M.Sc. iCE, M.Sc. etit - CMEE
8	**Grade bonus compliant to §25 (2)**
9	**References** Course notes, lecture slides.

Courses

Course nr.	**Course name**		
18-dg-1030-vl	Finite Integration Technique		
Instructor		**Type**	**SWS**
Dr.-Ing. Wolfgang Ackermann		Lecture	2

Module name Convex Optimization in Signal Processing and Communications					
Module nr. 18-pe-2020	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1 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 compuation, applications.

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 processing and mobile communication systems.

3 Recommended prerequisites for participation

Knowledge in linear algebra and the basic concepts of signal processing and communications.

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS)

The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 14 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.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Ed. etit, B.Sc. und M.Sc. iST, B.Sc. WI-etit, M.Sc. etit - CMEE, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

- S. Boyd and L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004. (online Verfügbar:http://www.stanford.edu/ boyd/cvxbook/)
- D. P. Bertsekas, Nonlinear Programming, Athena Scientific, Belmont, Massachusetts, 2nd Ed., 1999.
- Daniel P. Palomar and Yonina C. Eldar, Convex Optimization in Signal Processing and Communications, Cambridge University Press, 2009.

Courses

	Course nr. 18-pe-2020-vl	**Course name** Convex Optimization in Signal Processing and Communications		
	Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lecture	**SWS** 2
	Course nr. 18-pe-2020-ue	**Course name** Convex Optimization in Signal Processing and Communications		
	Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Practice	**SWS** 1
	Course nr. 18-pe-2020-pr	**Course name** Convex Optimization in Signal Processing and Communications Lab		
	Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lab	**SWS** 1

Module name Mobile Communications					
Module nr. 18-kl-2020	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Anja Klein		

1 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

2 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

3 Recommended prerequisites for participation

Deterministic Signals and Systems, Communication Technology I, Mathematics I to III, Statistics/Probability Theory, Scientific Computing

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

	will be announced in the lecture			
Courses				
	Course nr. 18-kl-2020-vl	**Course name** Mobile Communications		
	Instructor Prof. Dr.-Ing. Anja Klein, Dr.-Ing. Lin Xiang		**Type** Lecture	**SWS** 3
	Course nr. 18-kl-2020-ue	**Course name** Mobile Communications		
	Instructor Prof. Dr.-Ing. Anja Klein, Dr.-Ing. Lin Xiang		**Type** Practice	**SWS** 1

Module name Communication Technology II					
Module nr. 18-kl-2010	**Credit points** 5 CP	**Workload** 150 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Anja Klein		

1	**Teaching content** Linear and nonlinear digital modulation schemes, optimum receivers for AWGN channels, error probability, channel capacity, channel models, channel estimation and data detection for multipath channels, multicarrier schemes, OFDM
2	**Learning objectives** After completion of the lecture, students possess: • the ability of comparing, evaluating, classifying an analyzing linear and nonlinear modulation schemes by means of signal space representations; • the ability to understand, describe and analyze the influence of AWGN on the signal; • the ability to understand and derive optimum receivers in case of AWGN channels; • the ability to understand, describe and analyze the influence of multipath propagation on the signal; • the ability to describe the influence of a multipath channel mathematically (channel model) and estimate the multipath channel at the receiver; • 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; • the ability to analyze and evaluate the properties and application areas of multicarrier transmission systems, e.g. OFDM-systems; • the ability to design and evaluate the system parameters of multicarrier schemes for the application in realistic wireless communication scenarios; • the ability to mathematically express and analyze all above system models in matrix-vector-notation.
3	**Recommended prerequisites for participation** Deterministische Signale und Systeme, Communication Technology I, Basics of Telecommunication, Mathematics I to III, Statistics/Probability Theory, Scientific Computing
4	**Form of examination** Module exam: • Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** will be announced in the lecture
Courses	

	Course nr. 18-kl-2010-vl	**Course name** Communication Technology II		
	Instructor Prof. Dr.-Ing. Anja Klein		**Type** Lecture	**SWS** 2
	Course nr. 18-kl-2010-ue	**Course name** Communication Technology II		
	Instructor M.Sc. Yi Wang, M.Sc. Sumedh Dongare, Prof. Dr.-Ing. Anja Klein		**Type** Practice	**SWS** 2

Module name Digital Signal Processing					
Module nr. 18-zo-2060	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Teaching content

1) Discrete-Time Signals and Linear Systems - Sampling and Reconstruction of Analog Signals
2) Digital Filter Design - Filter Design Principles; Linear Phase Filters; Finite Impulse Response Filters; Infinite Impulse Response Filters; Implementations
3) Digital Spectral Analysis - Random Signals; Nonparametric Methods for Spectrum Estimation; Parametric Spectrum Estimation; Applications;
4) Kalman Filter

2 Learning objectives

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 Recommended prerequisites for participation

Deterministic signals and systems theory

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 180 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

M.Sc. MEC, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. MedTec, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

Course manuscript
Additional References:

- A. Oppenheim, W. Schafer: Discrete-time Signal Processing, 2nd ed.
- J.F. Böhme: Stochastische Signale, Teubner Studienbücher, 1998

Courses

Course nr.	**Course name**		
18-zo-2060-vl	Digital Signal Processing		
Instructor		**Type**	**SWS**
M.Sc. Christian Schroth, M.Sc. Christian Eckrich, Prof. Dr.-Ing. Abdelhak Zoubir		Lecture	3

	Course nr. 18-zo-2060-ue	**Course name** Digital Signal Processing		
	Instructor M.Sc. Christian Schroth, M.Sc. Christian Eckrich, Prof. Dr.-Ing. Abdelhak Zoubir		**Type** Practice	**SWS** 1

Module name Data-driven Modeling - Machine Learning					
Module nr. 18-kp-2110	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr. techn. Heinz Köppl		

1 Teaching content

The module provides an introduction to the emerging field of machine learning from an engineering perspective. Important models and learning methods are presented and exemplified through problems from information and communication technology.

- Fundamentals of probability theory and multivariate statistics
- Taxonomy of machine learning problems and models (supervised, unsupervised, generative, discriminative)
- Regression and classification: theory, methods and ICT applications
- Dimensionality reduction, clustering and big data analytics: methods and application in communications and signal processing
- Probabilistic graphical models: categories, inference and parameter estimation
- Fundamentals of Bayesian inference, Monte Carlo methods, Bayesian non-parametrics
- Fundamentals of convex optimization: Solution methods and application in communications
- Approximate algorithms for scalable Bayesian inference; application in signal processing and information theory (e.g. decoding of LDPC codes)
- Hidden Markov models (HMM): Theory, Algorithms and ICT applications (e.g. Viterbi decoding of convolutional codes)
- High-dimensional statistics (“large p small n” setting), learning dependency structure in high-dimensional data, learning causality relations from observational data.
- Sparse estimation, random projections, compressive sensing: Theory and applications in signal processing
- Deep neural networks (deep learning): Models, learning algorithms, libraries and ICT applications

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.

They are able to implement all necessary algorithms from scratch, but they are also familiar with the state-of-the-art libraries in machine learning.

They are able to determine the involved computational complexity of a method and choose an appropriate solution algorithms based on application constraints.

They are able to apply the acquired methods to other domains, such as data analysis in biomedical engineering, analysis of social network data, etc.

3 Recommended prerequisites for participation

Good command of Matlab (for instance knowledge from course 18-st-2030 Matlab Grundkurs) and engineering mathematics

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS)

The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 10 students register, the examination will be an oral examination (duration: 30 min.). The type of examination will be announced in the beginning of the lecture.

5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, B.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST, B.Sc. WI-etit, M.Sc. etit - CMEE, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** • Kevin P. Murphy. Machine Learning - A probabilistic perspective, MIT Press, 2012 • Christopher M. Bishop. Pattern recognition and Machine Learning, Springer, 2006 • Peter Bühlmann und Sara van de Geer. Statistics of high-dimensional data - Methods, theory and applications, Springer, 2011

Courses

	Course nr. 18-kp-2110-vl	**Course name** Data-driven Modeling - Machine Learning		
	Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein		**Type** Lecture	**SWS** 2
	Course nr. 18-kp-2110-ue	**Course name** Data-driven Modeling - Machine Learning		
	Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein		**Type** Practice	**SWS** 1
	Course nr. 18-kp-2110-pr	**Course name** Data-driven Modeling - Machine Learning Lab		
	Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein		**Type** Lab	**SWS** 1

Module name TK3: Ubiquitous / Mobile Computing					
Module nr. 20-00-0120	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language German			**Module owner** Prof. Dr. rer. nat. Eberhard Mühlhäuser		

1	**Teaching content** Objectives: - Knowledge of technical basics of the mobile communication - Knowledge of important challenges of the Ubiquitous Computing - Methodic knowledge about current approaches to these challenges Course Content: - Introduction to Ubiquitous Computing - Mobile Communication - Internet of Things: RFID and Smart Items - Service Discovery & Cloudlets - Context- and Location-aware Computing - Human Computer Interaction - Privacy and Trust in Ubiquitous Computing
2	**Learning objectives** After successfully attending the course, students are familiar with the technical basis of mobile communication. They understand the fundamental challenge of ubiquitous computing. They know current approaches to solve these challenges. They are able to apply their knowledge to build ubiquitous computing systems.
3	**Recommended prerequisites for participation** Computer Netzwerke and Distributed Systems
4	**Form of examination** Course related exam: • [20-00-0120-iv] (Technical examination, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-0120-iv] (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik M.Sc. Sportwissenschaft und Informatik May be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**

	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** 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: 1. F. Adelstein, S. Gupta et al.: Fundamentals of Mobile & Pervasive Computing McGraw Hill 2004, 2. Stefan Poslad: Ubiquitous Computing, Wiley 2009, ISBN 978-0-470-03560-3 3. Kapitel Mobilkommunikation: M. Sauter: Grundkurs Mobile Kommunikationssysteme: UMTS, HSDPA und LTE, GSM, GPRS und Wireless LAN; Vieweg-Teubner Studium 2010 4. J. Krumm (Ed.): Ubiquitous Computing Fundamentals, CRC Press 2010 D. Cook, S. Das (Ed.): Smart Environments, Wiley 2005

Courses

	Course nr.	**Course name**		
	20-00-0120-iv	TK3: Ubiquitous / Mobile Computing		
	Instructor		**Type** Integrated course	**SWS** 4

Module name Resilient Communication Networks					
Module nr. 18-sm-2340	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr. rer. nat. Björn Scheuermann		

1 Teaching content

The course covers the following topics:

- Resilience in the different disciplines
- Resilience in communication networks
- Importance of resilience for communication networks
- Requirements for current communication networks
- Methods to increase resilience in communiation networks
  - Wireless networks (e.g., mobile communications)
  - Wired networks
- Resilient network management in software-defined networks
- Resilience through adaptivity in software-defined networks

2 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 redundancy and diversity, and can apply these methods to the design of communication networks.

3 Recommended prerequisites for participation

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS)

The examination takes place in form of a written exam (duration: 90 min.). If one can estimate that less than 10 students register, the examination will be an oral examination (duration: 30 min.) The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, B.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

Grade improvements up to 0.4 according to APB 25(2) through bonus for regularly completed and submitted bonus exercises.

9 References

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		**Type**	**SWS**
Prof. Dr. rer. nat. Björn Scheuermann, Dr.-Ing. Tobias Meuser		Lecture	2
Course nr.	**Course name**		
18-sm-2340-ue	Resilient Communication Networks		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Björn Scheuermann, Dr.-Ing. Tobias Meuser		Practice	1

Module name Synthetic Molecular Communication					
Module nr. 18-ja-2020	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Vahid Kooshkghazi		

1 Teaching content

This lecture course introduces the basic principles in modeling, design, and analysis of synthetic molecular communication (MC) systems. The course covers the following topics:

- Basic principles of synthetic MC systems and potential application scenarios
- Background concepts from biology and chemistry needed to understand MCs
- Mathematical modeling of MC channels involving advection-reaction-diffusion processes
- Design of modulation and detection schemes for synthetic MC systems
- Channel estimation and parameter estimation for synthetic MC systems
- Review of several experimental MC systems, their practical implementation considerations, and the signal processing of the measurement data

2 Learning objectives

After completion of this interdisciplinary lecture, students will be able to

- explain the basic principles of MCs and differentiate them with respect to conventional electromagnetic-based communications
- explain basic related concepts from chemistry and biology such as chemical reactions, molecules, proteins, communication within and between cells, etc.
- apply the relevant physical/chemical laws (e.g., Fick's law or in general advection-reaction-diffusion equations) to derive communication-theoretical models for MC channels
- name several modulation schemes for embedding information into the properties of molecules and derive optimal and suboptimal detection for recovering information
- derive estimators for estimating the MC channel impulse response or physical parameters of the MC channel
- name several state-of-the-art implementations of synthetic MCs and explain the features/limitations/challenges of building MC systems, in practice

The students will deepen their knowledge of the fundamentals of communication systems by reflecting on and "re-learning" the entire communication blocks (e.g., modulation, detection, estimation, etc.) in the new context of MCs

3 Recommended prerequisites for participation

Knowledge of basic communication theory and digital communication

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS)

The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 10 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.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. MedTec, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8	**Grade bonus compliant to §25 (2)** Grade improvements up to 0.4 according to APB 25(2) through bonus for regularly completed and submitted bonus exercises
9	**References** A lecture notes or slides can be downloaded: Moodle Platform Supplementary and advanced literature: T. Nakano, A. Eckford, and T. Haraguchi. Molecular Communications, Cambridge University Press, 2013 T. Nakano, A. Eckford, and T. Haraguchi. Molecular Communications, Cambridge University Press, 2013 P. Nelson. Biological Physics - Energy, Information, Life, Freeman and Company, 2004.

Courses

Course nr. 18-ja-2020-vl	**Course name** Synthetic Molecular Communication		
Instructor Prof. Dr.-Ing. Vahid Kooshkghazi		**Type** Lecture	**SWS** 2
Course nr. 18-ja-2020-ue	**Course name** Synthetic Molecular Communication		
Instructor Prof. Dr.-Ing. Vahid Kooshkghazi		**Type** Practice	**SWS** 1

2.2.2 Communication Systems and Networking - Labs and Projects

Module name Project Seminar Wireless Communications					
Module nr. 18-kl-2040	**Credit points** 8 CP	**Workload** 240 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Anja Klein		

1 Teaching content

Solving special problems concerning wireless communications (problems concerning signal transmission and processing as well as problems concerning the network are possible, topics will be defined out of the current research topics of the lab);
working on the project in teams (2-3 students);
organizing and structuring of a project;
dealing with scientific publications, reading up the theoretical background of the task;
practical work on a complex task;
scientific presentation of the results (report/presentation);
defending the work in an oral discussion including an audience.

2 Learning objectives

After completion of the course, students possess

- the ability to classify and analyze special problems concerning wireless communications,
- the knowledge to plan and organize projects with temporal limitation,
- the capability to set up and test methodologies for analysis and simulation environments,
- skills to evaluate and present achieved results and achieved conclusions.

3 Recommended prerequisites for participation

Previous knowledge in digital communications, signal processing, wireless communication.

4 Form of examination

Module exam:

- Module exam (Study achievement, Oral/written examination, Default RS)

Report and/or Presentation. The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Study achievement, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

Literature will be announced during the course.

Courses

Course nr.	**Course name**		
18-kl-2040-pj	Project Seminar Wireless Communications		
Instructor		**Type**	**SWS**
M.Sc. Sumedh Dongare, Prof. Dr.-Ing. Anja Klein		Project seminar	4

Module name Project Seminar Emerging Topics in Sensor Array and Multichannel Processing					
Module nr. 18-pe-2040	**Credit points** 8 CP	**Workload** 240 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1	**Teaching content** This project-seminar addresses new trends in sensor array and multichannel processing with multidimensional tensor data representations. The specific thematic focus of the seminar will be adapted from year to year according to the latest trends in the research field. The topics will be announced on the course website well in advance.
2	**Learning objectives** Students will understand theory, algorithms and applications of sensor array and multichannel system.
3	**Recommended prerequisites for participation** Basic knowledge in linear algebra.
4	**Form of examination** Module exam: • Module exam (Study achievement, Oral examination, Duration: 40 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Study achievement, Oral examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** Harry L. Van Trees, Optimum Array Processing: Part IV of Detection, Estimation, and Modulation Theory, John Wiley & Sons, 2002. References include the latest scientific publications, seminars and books.

Courses

Course nr.	**Course name**		
18-pe-2040-pj	Project Seminar Emerging Topics in Sensor Array and Multichannel Processing		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento, M.Sc. Raphael Müller		Project seminar	4

Module name Project Seminar Emerging topics in MIMO Communication Networks					
Module nr. 18-pe-2050	**Credit points** 8 CP	**Workload** 240 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1	**Teaching content** This project-seminar addresses new trends in MIMO communications for the next generation of wireless communication systems. The specific thematic focus of the seminar will be adapted from year to year according to the latest trends in wireless communications. The topics will be announced on the course website well in advance.
2	**Learning objectives** 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	**Recommended prerequisites for participation**
4	**Form of examination** Module exam: • Module exam (Study achievement, Oral examination, Duration: 40 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Study achievement, Oral examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Ed. etit, B.Sc. WI-etit, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** References include the latest scientific publications, seminars and books.

Courses

Course nr.	**Course name**		
18-pe-2050-pj	Project Seminar Emerging Topics in MIMO Communication Networks		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Project seminar	4

Module name Project Seminar Terahertz Technology, Communication and Sensors					
Module nr. 18-pr-2030	**Credit points** 8 CP	**Workload** 240 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language German/English			**Module owner** Prof. Dr. rer. nat. Sascha Preu		

1 Teaching content

Investigating and solving specific problems concerning the development of Terahertz devices, of applications of THz technology as well as topics of the area of Optics and communication technology. The specific task will be defined based on current research topics. The project seminar includes working on a given task by one's own, organizing and structuring of a seminar task, searching and analyzing of scientific reference publications, summarizing achieved results and conclusions by means of a written report, presenting achieved results and conclusions and defending them in an oral discussion including audience. Topics include, e.g.:

- Terahertz Optics
- Optics/photonics
- Spectroscopy
- Semiconductor devices
- Light-matter interaction

2 Learning objectives

After completion of the course, students possess:

- the ability to apply theoretical models to practical problems
- deep and special knowledge in a particular field related to THz science, optics or semiconductor physics
- the skills to find, analyze and evaluate scientific reference papers for a particular topic
- the capability to summarize the achieved scientific findings in the form of a concise report, and to present and discuss achieved results in the form of a presentation in front of an audience

3 Recommended prerequisites for participation

Previous knowledge in at least one of the following disciplines: Optics, semiconductor physics, or THz technology

4 Form of examination

Module exam:

- Module exam (Study achievement, Oral/written examination, Default RS)

Report and/or Presentation. The type of examination will be announced in the beginning of the project.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Study achievement, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE

8 Grade bonus compliant to §25 (2)

9 References

Will be announced once the topic is defined.

Courses

	Course nr. 18-pr-2030-pj	**Course name** Project Seminar Terahertz Technology, Communication and Sensors	
	Instructor Prof. Dr. rer. nat. Sascha Preu	**Type** Project seminar	**SWS** 4

Module name Digital Signal Processing Lab					
Module nr. 18-zo-2030	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Teaching content

1. Introduction to MATLAB
2. Discrete-Time Signals and Systems
3. Frequency-Domain Analysis using the DFT
4. Digital FIR Filter Design
5. IIR Filter Design using Analog Prototypes
6. Nonparametric Spectrum Estimation
7. Parametric Spectrum Estimation.

2 Learning objectives

The students are able to apply skills acquired in the course Digital Signal Processing. These include the design of digital FIR and IIR filters as well as non-parametric and parametric spectrum estimation. Students learn how MATLAB is used to apply theoretical concepts and to demonstrate signal processing techniques by using hands-on application examples.

3 Recommended prerequisites for participation

Fundamentals of Signal Processing

4 Form of examination

Module exam:

- Module exam (Study achievement, Written examination, Duration: 120 Min., Default RS)

Exam (Duration: 120 min) and a Report (Lab Reports), Details will be announced at the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Study achievement, Written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

Lab manual

Courses

Course nr. 18-zo-2030-pr	**Course name** Digital Signal Processing Lab		
Instructor Prof. Dr.-Ing. Abdelhak Zoubir		**Type** Lab	**SWS** 3

Module name Multimedia Communications Seminar II					
Module nr. 18-sm-2090	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language German/English			**Module owner** Prof. Dr.-Ing. Ralf Steinmetz		

1 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.
Some potential topics are:

- Knowledge & Educational Technologies
- Self organizing Systems & Overlay Communication
- Mobile Systems & Sensor Networking
- Service-oriented Computing
- Multimedia Technologies & Serious Games

2 Learning objectives

Students shall acquire profound knowledge from current scientific publications, standards and literature on multimedia communication systems and applications which will build the future Internet. In so doing, the students will develop the following competencies:

- Search for and review relevant scientific literature.
- Analyse and evaluate complex technical and scientific information.
- Write technical and scientific abstracts and summary reports.
- Present technical and scientific information.

3 Recommended prerequisites for participation

Solid knowledge in computer communication networks. Lectures in Communication Networks I and II are recommended.

4 Form of examination

Module exam:

- Module exam (Study achievement, Oral/written examination, Default RS)

Report and/or Presentation and/or Colloquium. The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Study achievement, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST

8 Grade bonus compliant to §25 (2)

9 References

Depending on specific topic (selected articles of journals, magazines, and conferences).

Courses

	Course nr.	Course name		
	18-sm-2090-se	Multimedia Communications Seminar II		
	Instructor		**Type**	**SWS**
	Prof. Dr. rer. nat. Björn Scheuermann, Dr. Ing. Julian Zobel, M.Sc. Fridolin Siegmund, Prof. Dr.-Ing. Ralf Steinmetz		Seminar	2

Module name Multimedia Communications Project II					
Module nr. 18-sm-2130	**Credit points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language German/English			**Module owner** Prof. Dr.-Ing. Ralf Steinmetz		

1 Teaching content

The course deals with cutting edge scientific and development topics in the area of multimedia communication systems. Besides a general overview it provides a deep insight into a special scientific topic. The topics are selected according to the specific working areas of the participating researchers and convey technical and scientific competences in one or more of the following topics:

- Network planning and traffic analysis
- Performance evaluation of network applications
- Discrete event simulation for network services
- Protocols for mobile ad hoc networks / sensor networks
- Infrastructure networks for mobile communication / mesh networks
- Context-aware communication and services
- Peer-to-peer systems and architectures
- Content distribution and management systems for multimedia / e-learning
- Multimedia authoring and re-authoring tools
- Web service technologies and service-oriented architectures
- Resource-based Learning

2 Learning objectives

The ability to solve and evaluate technical and scientific problems in the area of design and development of future multimedia communication networks and applications using state of the art scientific methods shall be acquired. Acquired competences are:

- Searching and reading of project relevant literature
- Design of complex communication applications and protocols
- Implementing and testing of software components for distributed systems
- Application of object-oriented analysis and design techniques
- Acquisition of project management techniques for small development teams
- Systematic evaluation and analyzing of technical and scientific experiments
- Writing of software documentation and project reports
- Presentation of project advances and outcomes

3 Recommended prerequisites for participation

Keen interest to develop and explore challenging solutions and applications in cutting edge multimedia communications systems using scientific methods. Further we expect:

- Solid experience in programming Java and/or C# (C/C++).
- Solid knowledge in object oriented analysis and design.
- Basic knowledge of design patterns, refactoring and project management.
- Solid knowledge in computer communication networks is recommended.
- Lectures in “Communication Networks I” and “Communication Networks II” are recommended

4 Form of examination

Module exam:

- Module exam (Study achievement, Oral/written examination, Default RS)

Report (including submission of programming code) and/or Presentation and/or Oral examination and/or Colloquium (testate), but never more than two out of it. The type of examination will be announced in the beginning of the lecture.

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

Courses

Course nr.	**Course name**		
18-sm-2130-pr	Multimedia Communications Project Lab		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Björn Scheuermann, Dr. Ing. Julian Zobel, M.Sc. Fridolin Siegmund, Prof. Dr.-Ing. Ralf Steinmetz		Lab	6

Module name Advanced Seminar on Networking, Security, Mobility, and Wireless Communications					
Module nr. 20-00-0549	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language German/English			**Module owner** Prof. Dr. rer. nat. Karsten Weihe		

1 Teaching content

The Advanced Seminar on Networking, Security, Mobility, and Wireless Communications covers current research that is considered highly relevant for the future development of the given topic areas. Goal of the seminar is to explore the aforementioned research area by studying, critically analyzing and discussing, summarizing, and presenting selected first-rate research articles. Deliverables are a short presentation, a final presentation, and a seminar paper.

The prospective topics for the advanced seminar will be derived from the current research topics of the SEEMOO group.

Course contents:
- Indepentent exploration of a topic in the area of networking, security, mobility, and wireless communications (typically in english)
- Own, enhanced literature study
- Interpretation and classification of the literature study
- Preparation of an introductory talk as well as a final talk including presentation slides
- Presentation of both talks for a heterogenous audience (experts/non-experts)
- Technical discussion after the talks
- Feedback to the speakers and the talks (including presentation skills) and technical content
- Understanding the process of scientific work as well as of scientific publications

2 Learning objectives

After successfully attending the course, students are able to independently explore new topics in a scientific manner. They have aquired detailed knowledge on selected mechanisms, methodologies as well as applications for the investigated topic area. Techniques such as thoroughly surveying literature, critical discussion and analysis of scientific articles, and the presentation of the obtained results are demonstrated by the students. Students can defend their work against a critical technical audience.

3 Recommended prerequisites for participation

Successfull participation of an lecture of SEEMOO

4 Form of examination

Course related exam:
- [20-00-0549-se] (Study achievement, Oral/written examination, Default RS)

5 Prerequisite for the award of credit points

Pass exam (100%)

6 Grading

Course related exam:
- [20-00-0549-se] (Study achievement, Oral/written examination, Weighting: 100 %)

7 Usability of the module

	B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**
9	**References** Will be announced in seminar.

Courses

Course nr. 20-00-0549-se	**Course name** Advanced Seminar on Networking, Security, Mobility, and Wireless Communications		
Instructor Prof. Dr.-Ing. Matthias Hollick		**Type** Seminar	**SWS** 3

Module name Lab Exercise on Secure Mobile Networking					
Module nr. 20-00-0552	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language German/English			**Module owner** Prof. Dr. rer. nat. Karsten Weihe		

1 Teaching content

The Lab Exercise on Secure Mobile Networking covers the applied software development as well as hardware-software development. Topic areas covered are communication networks, IT security, mobile networks and wireless communications as well as the combination of these. Goal is the solving of a given problem by implementation in software or hardware/software in a team.

Course contents:
- Solving of a problem in the area of communication networks, IT security, mobile networks and wireless communications
- Survey on solution alternatives and discussion of pros and cons
- Conception of a software architecture or a combined hardware-software architecture
- Software/hardware design for the target platform
- Prototypical realization on the target platform
- Evaluation of the system with respect to performance aspects
- Documentation of the implemented solution

2 Learning objectives

After successfully attending the course, students have aquired the ability to solve problems in the area of secure mobile networking using software technology. The students have gained insight into the design/implementation of complex protocols or applications in one/multiple of the areas of communication networks, IT security, mobile netwokrs and wireless communications. They are able to implement the chosen protocols and application, and to test the functionality as well as to evaluate the performance. Students are able to document the developed software artefacts and to present the project progress and outcomes.

3 Recommended prerequisites for participation

Successfull participation in an lecture of SEEMOO.

4 Form of examination

Course related exam:
- [20-00-0552-pr] (Study achievement, Oral/written examination, Default RS)

5 Prerequisite for the award of credit points

Pass exam (100%)

6 Grading

Course related exam:
- [20-00-0552-pr] (Study achievement, Oral/written examination, Weighting: 100 %)

7 Usability of the module

B.Sc. Informatik
M.Sc. Informatik
M.Sc. Wirtschaftsinformatik
B.Sc. Psychologie in IT
Joint B.A. Informatik
B.Sc. Sportwissenschaft und Informatik

Can be used in other degree programs.

8 Grade bonus compliant to §25 (2)

9	**References** Will be given in lab.

Courses

Course nr.	**Course name**		
20-00-0552-pr	Secure Mobile Networking Lab		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Matthias Hollick		Lab	4

Module name Seminar on Networking, Security, Mobility, and Wireless Communications					
Module nr. 20-00-0582	**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** Prof. Dr.-Ing. Matthias Hollick		

1	**Teaching content** The Seminar on Networking, Security, Mobility, and Wireless Communications covers current research in the given topic areas. Under supervision of the tutors, the seminar imcludes studying, critically analyzing and discussing, summarizing, and presenting selected research articles. Deliverables are a short presentation, a final presentation, and a seminar paper. Course contents: - Indepentent exploration of a topic in the area of networking, security, mobility, and wireless communications (typically in english) - Own, enhanced literature study, gudided by tutor - Interpretation and classification of the literature study, gudided by tutor - Preparation of an introductory talk as well as a final talk including presentation slides, gudided by tutor - Presentation of both talks for a heterogenous audience (experts/non-experts) - Technical discussion after the talks - Feedback to the speakers and the talks (including presentation skills) and technical content
2	**Learning objectives** After successfully attending the course, students are able to work in a scientific manner under guidance. They know the fundamental techniques for scientific literature work and can apply them to a well-defined topic area. They have aquired intermediate knowledge on selected mechanisms, methodologies as well as applications for the investigated topic area. Students can present this aquired knowledge to a heterogeneous audience and explain the technical details of the investigated topic.
3	**Recommended prerequisites for participation** Successfull participation in a lecture of SEEMOO.
4	**Form of examination** Course related exam: • [20-00-0582-se] (Study achievement, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-0582-se] (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**

9	**References** Depending on topic.			
Courses				
	Course nr. 20-00-0582-se	**Course name** Seminar on Networking, Security, Mobility, and Wireless Communications		
	Instructor Prof. Dr.-Ing. Matthias Hollick		**Type** Seminar	**SWS** 2

Module name
Practical Lab on System and IoT Security

Module nr.	Credit points	Workload	Self-study	Module duration	Module cycle
20-00-0615	6 CP	180 h	120 h	1 Term	Every 2. Semester

Language	Module owner
German	Dr.-Ing. Michael Kreutzer

1 Teaching content

In this practical course, the students deal with different aspects of smartphone security. The project tasks specifically target the open-source Android OS and comprise the following areas:
- Design and implementation of selected software attacks (ethical hacking)
- Design and implemenation of secure user apps
- Modifications of the Android Middleware and Kernel to build security architectures
- System programming in general

2 Learning objectives

After successfully completing this lab students will have gained knowledge and hands-on expercience with security mechanisms in modern smartphone operating systems. Futhermore they gain experience in system programming in general.

3 Recommended prerequisites for participation

- Basics operating systems
- Knowledge in C++ and Java

4 Form of examination

Course related exam:
- [20-00-0615-pr] (Study achievement, Oral/written examination, Default RS)

5 Prerequisite for the award of credit points

Pass exam (100%)

6 Grading

Course related exam:
- [20-00-0615-pr] (Study achievement, Oral/written examination, Weighting: 100 %)

7 Usability of the module

B.Sc. Informatik
M.Sc. Informatik
M.Sc. Wirtschaftsinformatik
B.Sc. Psychologie in IT
Joint B.A. Informatik
B.Sc. Sportwissenschaft und Informatik

Can be used in other degree programs.

8 Grade bonus compliant to §25 (2)

9 References

Will be given in lab.

Courses

Course nr.	Course name
20-00-0615-pr	Practical Lab on System and IoT Security

Instructor	Type	SWS
	Lab	4

Module name Privacy-Preserving Technologies					
Module nr. 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			**Module owner** Dr.-Ing. Michael Kreutzer		

1	**Teaching content** Data is the oil of the 21st century and users leave more and more digital traces that are collected and evaluated by companies like Facebook or Google, as well as by intelligence services. In this seminar, we will look at techniques for protecting privacy that allow to process sensitive data under encryption without revealing the data itself. We will investigate both the theoretical background as well as practical issues of such solutions. Small groups of students choose a topic for which they get two or three publications that they will summarize in a written report and present in a talk. Possible topics include: - Privacy-preserving biometric identification - Privacy-preserving mobile applications, e.g., for location-based services - Privacy-preserving download of files, e.g., for medical or patent databases (Private Information Retrieval) - Privacy-preserving finding of common contacts or customers (Private Set Intersection) - Privacy-preserving checking for credit worthiness (Private Function Evaluation with linear complexity) - Representing functions as data (Universal Circuits) - Tools for privacy-preserving applications More Details: Weitere Details: http://encrypto.de/PRIVTECH
2	**Learning objectives** Students learn state-of-the-art and practical techniques for protecting privacy.
3	**Recommended prerequisites for participation** Basic knowledge in applied cryptography is required, e.g., by successfully completing the course "Introduction to Cryptography" and ideally also "Cryptographic Protocols (CRYPROT)".
4	**Form of examination** Course related exam: • [20-00-0935-se] (Study achievement, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-0935-se] (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik May be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**
9	**References**

Courses

	Course nr.	Course name		
	20-00-0935-se	Privacy-Preserving Technologies		
	Instructor		**Type**	**SWS**
	Dr.-Ing. Michael Kreutzer		Seminar	2

Module name IoT and wireless protocols in embedded systems					
Module nr. 20-00-1064	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language German			**Module owner** Prof. Dr. rer. nat. Eberhard Mühlhäuser		

1	**Teaching content** As part of the internship, students become acquainted with IoT and radio protocols and independently carry out a project with embedded hardware. In addition, aspects of IT security are also taken into account. The main focus is on Bluetooth LE, Bluetooth Mesh, LoRaWAN and communication via OOB channels. Depending on the selected project topic, hardware (microcontrollers, FPGAs, RF transceivers, software defined radio, etc.) as well as laboratory environment (logic analyzers, RF analyzers, oscilloscopes, etc.) are provided.
2	**Learning objectives** After successfully completing the module, students will be able to deal with complex specifications of radio protocols and transfer them into practice. Furthermore, the practical handling of embedded systems and laboratory equipment is taught.
3	**Recommended prerequisites for participation** Previous knowledge in computer networks (compulsory lecture "Computer Networks and Distributed Systems) and Embedded Systems (compulsory lectures Computer Organization and / or Data Engineering) Knowledge of the programming language C and basic knowledge of electrical engineering are helpful, as well as knowledge from relevant lectures in the field" Networks and Systems " Distributed systems "such as TK3, mobile networks or KN1.
4	**Form of examination** Course related exam: • [20-00-1064-pr] (Study achievement, Oral/written examination, Default RS) The form of the examination will be announced at the beginning of the course. One or a combination of max. two of the following forms is possible. Report (optional: including submission of source code), colloquium (optional: including presentation).
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-1064-pr] (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik May be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**
9	**References**

Courses

Course nr.	**Course name**		
20-00-1064-pr	IoT and wireless protocols in embedded systems		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Eberhard Mühlhäuser		Lab	4

Module name Advanced Topics in Statistical Signal Processing					
Module nr. 18-zo-2040	**Credit points** 8 CP	**Workload** 240 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Teaching content

The course covers the fundamentals of detection and estimation theory. These are extended by advanced topics in statistical signal processing. Applications are typically from the following areas: Detection in Radar Applications; Robust Estimation; Prediction, Filtering, and Tracking with the Kalman Filter; Sensor Array Signal Processing, Direction of Arrival Estimation, and Source Detection; Time-Frequency Analysis. Topics may change from semester to semester.

The course includes a series of lectures followed by a supervised research seminar over approximately 2 months. The main topics covered are:

- Estimation theory
- Detection theory
- Robust estimation theory
- Seminar projects: e.g., microphone arrays/beamforming, localization and tracking, radar/ultrasonic imaging, acoustic source localization, estimation of number of sources

2 Learning objectives

After completing the module, students will be able to work independently on advanced topics in signal processing and reproduce existing results. The students can present these results and discuss them scientifically.

3 Recommended prerequisites for participation

DSP, general interest in signal processing

4 Form of examination

Module exam:

- Module exam (Study achievement, Oral/written examination, Default RS)

Report and/or Presentation and/or Colloquium. The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Study achievement, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. MedTec, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

- 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.

Courses

Course nr.	**Course name**		
18-zo-2040-se	Advanced Topics in Statistical Signal Processing		
Instructor		**Type**	**SWS**
M.Sc. Pertami Kunz, Prof. Dr.-Ing. Abdelhak Zoubir		Seminar	4

Module name Signal Detection and Parameter Estimation					
Module nr. 18-zo-2050	**Credit points** 8 CP	**Workload** 240 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Teaching content

Signal detection and parameter estimation are fundamental signal processing tasks. In fact, they appear in many common engineering operations under a variety of names. In this course, the theory behind detection and estimation will be presented, allowing a better understanding of how (and why) to design "good" detection and estimation schemes.

These lectures will cover:

- Fundamentals of Detection and Estimation Theory
- Hypothesis Testing:
  - Bayesian/Ideal Observer/Neyman-Pearson Tests
  - Receiver Operating Characteristics
  - Uniformly Most Powerful Tests
  - Matched Filter
- Estimation Theory:
  - Types of Estimators
  - Maxmimum Likelihood Estimators
  - Sufficiency and the Fisher-Neyman/Factorisation Criterion
  - Unbiasedness and minimum variance
  - Fisher Information and the CRB
  - Asymptotic properties of the MLE

2 Learning objectives

After successful completion of the module, students know the basics of detection and estimation theory. They can design hypothesis tests and estimators for existing problems and implement them in Matlab on their own. In addition, students will be able to review existing work on detection and estimation independently. They can adequately present the methods and results from existing publications and discuss them scientifically.

3 Recommended prerequisites for participation

DSP, general interest in signal processing

4 Form of examination

Module exam:

- Module exam (Study achievement, Oral/written examination, Default RS)

Report and/or Presentation and/or Colloquium. The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Study achievement, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. MedTec, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9	**References** • 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.

Courses

	Course nr.	**Course name**		
	18-zo-2050-se	Signal Detection and Parameter Estimation		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Abdelhak Zoubir		Seminar	4

Module name Multimedia Communications Lab II					
Module nr. 18-sm-2070	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language German/English			**Module owner** Prof. Dr.-Ing. Ralf Steinmetz		

1 Teaching content

The course deals with cutting-edge development topics in the area of multimedia communication systems. Besides a general overview, it provides a deep insight into a special development topic. The topics are selected 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:

- Network planning and traffic analysis
- Performance evaluation of network applications
- Discrete event simulation for network services
- Protocols for mobile ad hoc networks / sensor networks
- Infrastructure networks for mobile communication / mesh networks
- Context-aware communication and services
- Peer-to-peer systems and architectures
- Content distribution and management systems for multimedia/e-learning
- Multimedia authoring and re-authoring tools
- Web service technologies and service-oriented architectures
- Adaptive educational technologies
- Natural language processing in education

The concrete list of topics can be found each semester on the corresponding teaching website of KOM.

2 Learning objectives

The ability to solve and evaluate problems in the area of design and development of future multimedia communication networks and applications shall be acquired. Acquired competences are:

- Design of complex communication applications and protocols
- Implementing and testing of software components for distributed systems
- Application of object-oriented analysis and design techniques
- Acquisition of project management techniques for small development teams
- Writing of software documentation and project reports
- Presentation of project advances and outcomes

3 Recommended prerequisites for participation

Keen interest to explore challenging topics which are cutting edge in technology and research. Further we expect:

- Solid experience in programming Java and/or C# (C/C++)
- Solid knowledge in object oriented analysis and design
- Solid knowledge in computer communication networks are recommended
- Lectures in Communication Networks I (II, III, or IV) are an additional plus

4 Form of examination

Module exam:

- Module exam (Study achievement, Oral/written examination, Default RS)

Report (including submission of programming code) and/or Presentation and/or Oral examination (25 minutes) and/or Colloquium (testate), but never more than two out of it. The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6	**Grading** Module exam: • Module exam (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** Each topic is covered by a selection of papers and articles. In addition we recommend reading of selected chapters from following books: • Andrew Tanenbaum: "Computer Networks". Prentice Hall PTR (ISBN 0130384887) • Christian Ullenboom: "Java ist auch eine Insel: Programmieren mit der Java Standard Edition Version 5 / 6" (ISBN-13: 978-3898428385) • Joshua Bloch: "Effective Java Programming Language Guide" (ISBN-13: 978-0201310054) • Erich Gamma, Richard Helm, Ralph E. Johnson: "Design Patterns: Objects of Reusable Object Oriented Software" (ISBN 0-201-63361-2) • Kent Beck: "Extreme Programming Explained - Embrace Changes" (ISBN-13: 978-0321278654)

Courses

Course nr.	Course name		
18-sm-2070-pr	Multimedia Communications Lab II		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Björn Scheuermann, Dr. Ing. Julian Zobel, M.Sc. Fridolin Siegmund, Prof. Dr.-Ing. Ralf Steinmetz		Lab	3

2.3 Communication Algorithms

2.3.1 Communication Algorithms - Lectures

Module name Information Theory I: Fundaments					
Module nr. 18-kp-1010	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr. techn. Heinz Köppl		

1	**Teaching content** This lecture course introduces the fundamentals of information theory, network information theory and coding theory. Outline: information, uncertainty, entropy, mutual information, capacity, differential entropy, typical sequences, Gaussian channels, basics of source and channel coding, linear block codes, Shannon's source coding theorem, Shannon's channel coding theorem, capacity of Gaussian channels, capacity of bandlimited channels, Shannon's bound, bandwidth efficiency, capacity of multiple parallel channels and waterfilling, Gaussian vector channel, Multiple Access Channel, Broadcast Channel, rate region.
2	**Learning objectives** Upon completion of the module, students will have an understanding of the fundamentals of classic information theory.
3	**Recommended prerequisites for participation** Basic knowledge of probability theory
4	**Form of examination** Module exam: • Module exam (Technical examination, Examination, Duration: 120 Min., Default RS)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. etit, M.Sc. CE, B.Sc. CE, M.Sc. iCE, B.Ed. etit, B.Sc. und M.Sc. iST, B.Sc. WI-etit, M.Sc. etit - CMEE
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.
Courses	

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

Module name Information Theory II: Networks					
Module nr. 18-pe-2010	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1 Teaching content

This 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 objectives

Upon completion of the module, students will have an understanding of the advanced concepts and strategies in network information theory.

3 Recommended prerequisites for participation

Knowledge of basic communication theory

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS)

The examination takes place in form of a written exam (duration: 120 minutes). If apparent that less than 10 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.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - CMEE, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

- Abbas El Gamal and Young-Han Kim, Network Information Theory, Cambrige, 2011.
- T.M. Cover and J.A. Thomas, Elements of Information Theory, Wiley Sons, 1991.
- D. Tse and P. Vishwanath, Fundamentals of Wireless Communications, Cambridge University Press, 2005.

Courses

Course nr.	**Course name**		
18-pe-2010-vl	Information Theory II: Networks		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Lecture	3

	Course nr. 18-pe-2010-ue	**Course name** Information Theory II: Networks		
	Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Practice	**SWS** 1

Module name MIMO - Communication and Space-Time-Coding					
Module nr. 18-ja-2010	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Vahid Kooshkghazi		

1 Teaching content

This lecture course introduces the principles of space-time and multiple-input multiple-output (MIMO) communications.

Outline: Motivation and background; overview of space-time and MIMO communications; fading MIMO channel models, MIMO information theory, receive and transmit diversity; channel estimation, MIMO detectors, Alamouti space-time block code, orthogonal space-time block codes; linear dispersion codes; coherent and non-coherent decoders, differential space-time block coding; MIMO with limited feedback, Multiantenna- and multiuser diversity, BER performance analysis, MIMO in moden wireless communication networks, multicell and multiuser MIMO (coordinated multipoint).

2 Learning objectives

Students will understand modern MIMO communications and existing space-time coding techniques.

3 Recommended prerequisites for participation

Knowledge of basic communication theory and basic information theory.

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS)

The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 10 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.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. MEC, M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

- A.B.Gershman and N.D.Sidiropoulos, Editors, Space-Time Processing for MIMO Communications, Wiley and Sons, 2005.
- E.G.Larsson and P.Stoica, Space-Time Block Coding for Wireless Communications, Cambridge University Press, 2003;
- A.Paulraj, R.Nabar, and D.Gore, Introduction to Space-Time Wireless Communications, Cambridge University Press, 2003.
- Lin Bai and Jinho Choi, Low Complexity MIMO detectors, Springer, 2012.
- Howard Huang, Constantinos B. Papadias, and Sivarama Venkatesan, MIMO Communication for Cellular Networks, Springer, 2012.

Courses

	Course nr. 18-ja-2010-vl	**Course name** MIMO - Communication and Space-Time-Coding		
	Instructor Prof. Dr.-Ing. Vahid Kooshkghazi		**Type** Lecture	**SWS** 2
	Course nr. 18-ja-2010-ue	**Course name** MIMO - Communication and Space-Time-Coding		
	Instructor Prof. Dr.-Ing. Vahid Kooshkghazi		**Type** Practice	**SWS** 1

Module name Sensor Array Processing and Adaptive Beamforming					
Module nr. 18-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. Dr.-Ing. Marius Pesavento		

1	**Teaching content** This lecture course introduces the principles of modern sensor array processing and adaptive beamforming. Outline: Motivation and background; applications, narrowband and wideband signal model Direction-of-arrival estimation (DoA): traditional methods based on beamforming, super resolution methods, Maximum-Likelihood methods, Subspace based methods, MUSIC, ESPRIT, MODE, root-MUSIC, multidimensional source localization, approximate Maximum Likelihood methods, Expectation Maximization (EM) algorithm, partial relaxation method, beamspace processing, array interpolation, partly calibrated arrays, wideband DOA estimation, spatial smoothing, forward-backward averaging, redundancy averaging, correlated sources, minimum redundancy arrays, compressed sensing and sparse reconstruction based DoA estimation, performance bounds Adaptive beamforming: Point-source model, covariance model, Wiener-Hopf equation, Minimum Variance Distortionless Response (MVDR) beamformer, Capon Beamformer, sample matrix inversion, signal self-nulling effect, robust adaptive beamforming, Hung-Turner projection beamformer, Generalized Sidelobe canceller beamformer, Eigenspace-based beamformer, non-stationary environments, modern convex optimization based beamforming, worst-case based beamforming, multiuser beamforming.
2	**Learning objectives** Upon completion of the module, students will have learned the application of theory and algorithms for processing Sensor-Arry and Tensor data.
3	**Recommended prerequisites for participation** Knowledge in linear algebra.
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS) The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 10 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.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. MEC, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, B.Sc. WI-etit, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References**

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.

Courses

Course nr.	**Course name**		
18-pe-2060-vl	Sensor Array Processing and Adaptive Beamforming		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Lecture	2

Course nr.	**Course name**		
18-pe-2060-ue	Sensor Array Processing and Adaptive Beamforming		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Practice	1

Module name
Graph Signal Processing, Learning and Optimization

Module nr.	Credit points	Workload	Self-study	Module duration	Module cycle
18-pe-2080	6 CP	180 h	120 h	1 Term	Winter term

Language	Module owner
English	Prof. Dr.-Ing. 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
  - Pearson product-moment correlation
  - Causality, Partial correlation
  - Conditional independence graph
  - Gaussian Markov Random Fields
  - Graphical LASSO, Graphical LASSO with Laplacian constraint
  - Applications
- Graph analysis
  - Subgraph identification
  - Cliques identification
- Optimization over graphs
  - Average consensus, diffusion, exact diffusion
  - Gradient tracking, push-sum algorithm, etc.
  - Applications
- Graph neuronal (convolutional) network

2 Learning objectives

Graph signal processing (i.e., the processing of signals defined over graphs) and network analysis form an interdisciplinary research field with numerous and diverse applications. Upon completion of the module, students will have gained systematic knowledge in graph signal processing theory, graph network analysis, graph topology learning, optimization in graph networks, and learning using graph neural networks. They have learned essential concepts, algorithms and application areas of graph signal processing.

3 Recommended prerequisites for participation

Basic knowledge in linear algebra and matrix analysis.

4 Form of examination

	Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS) In general, the examination takes place in form of a written exam (duration: 120 minutes). If up to 20 students register in semesters in which the lecture does not take place, there will will be an oral examination (duration: 20 min.). The type of examination will be announced within one working weeks after the end of the examination registration phase.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - CMEE, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** • Lecture notes and slides can be downloaded here: – www.nts.tu-darmstadt.de – moodle • Further reading: – Petar M. Djuric, Cédric Richard, Cooperative and Graph Signal Processing, Academic Press, 2018, ISBN 9780128136775.

Courses

Course nr. 18-pe-2080-vl	**Course name** Graph signal processing, learning and optimization		
Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lecture	**SWS** 3
Course nr. 18-pe-2080-ue	**Course name** Graph signal processing, learning and optimization		
Instructor Prof. Dr.-Ing. Marius Pesavento, M.Sc. Yufan Fan		**Type** Practice	**SWS** 1

Module name Adaptive Filters					
Module nr. 18-zo-2010	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language German/English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Teaching content

Theory:

1. Derivation of optimal filters for stochastic processes, e.g. Wiener filter or linear prediction filter based on suitable cost functions.
2. Elaboration of adaptive procedures, which allow to iteratively approach the optimal solution for non-stationary signals in non-stationary environments. Here, the adaptive procedures such as NLMS adaptation, affine projection, and the RLS algorithm are derived and extensively analysed.
3. Analysis of the adaptation behaviour and control procedures of adaptive filters based on the NLMS procedure.
4. Derivation and analysis of the Kalman filter as optimal filter for non-stationary input signals.
5. Procedures for the decomposition of signals into sub-bands for the realization of optimal filters in the frequency domain, e.g. noise reduction procedures.

Applications:

Parallel to the theory, practical applications are explained. As an example for the Weiner filter, the acoustic noise reduction procedures are explained. Acoustic echo cancellation and feedback cancellation are given as examples for adaptive filters. Furthermore beamforming approaches are introduced.

It is planned to offer an excursion to Siemens Audiology Engineering Group in Erlangen.
In the 4 to 5 exercises, some content of the lecture will be implemented in MATLAB which allows the students to get familiar with practical realizations of the theoretical procedures.

2 Learning objectives

Upon completion of the module, students were taught the fundamentals of adaptive filters. The necessary algorithms are derived, interpreted and applied to examples of speech, audio and video processing. Based on the content of the lecture you are able to apply adaptive filters to real practical applications.
For the admission to the exam you give a talk about a topic in the domain of adaptive filters chosen by you. This will allow you to acquire the know-how to read and understand scientific literature, familiarize yourself 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 Recommended prerequisites for participation

Digital Signal Processing

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS)

The examination takes place in form of a written exam (duration: 90 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.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

	M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** Slides of the lecture. Literature: • E. Hänsler, G. Schmidt: Acoustic Echo and Noise Control, Wiley, 2004 (Textbook of this course); • S. Haykin: Adaptive Filter Theory, Prentice Hall, 2002; • A. Sayed: Fundamentals of Adaptive Filtering, Wiley, 2004; • P. Vary, U. Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 1998 (in German)

Courses

Course nr. 18-zo-2010-vl	**Course name** Adaptive Filters		
Instructor Prof. Dr.-Ing. Henning Puder		**Type** Lecture	**SWS** 3
Course nr. 18-zo-2010-ue	**Course name** Adaptive Filters		
Instructor Prof. Dr.-Ing. Henning Puder		**Type** Practice	**SWS** 1

Module name Speech and Audio Signal Processing					
Module nr. 18-zo-2070	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language German			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1	**Teaching content** Algorithms of speech and audio signal processing: Introduction to the models of speech and audio signals and basic methods of audio signal processing. Procedures of codebook based processing and audio coding. Beamforming for spatial filtering and noise reduction for spectral filtering. Cepstral filtering and fundamental frequency estimation. Mel-filterind cepstral coefficients (MFCCs) as basis for speaker detection and speech recognition. Classification methods based on GMM (Gaussian mixture models) and speech recognition with HMM (Hidden markov models). Introduction to the methods of music signal processing, e.g. Shazam-App or beat detection.
2	**Learning objectives** Based on the module you acquire an advanced knowledge of digital audio signal processing mainly with the help 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	**Recommended prerequisites for participation** Knowlegde about satistical signal processing (lecture „Digital Signal Processing“). Desired - but not mandatory - is knowledge about adaptive filters.
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS) Seminar presentation: Scientific talk about a topic in the field of “Speech and Audio Signal Processing”, single (duration 10-15 min) or in groups of two students (15-20 min) or in a group of 20 students and more a written exam (duration 90 min)
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. MedTec, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** Slides (for further details see homepage of the lecture)
Courses	

	Course nr. 18-zo-2070-vl	**Course name** Speech and Audio Signal Processing		
	Instructor Prof. Dr.-Ing. Henning Puder		**Type** Lecture	**SWS** 2
	Course nr. 18-zo-2070-ue	**Course name** Speech and Audio Signal Processing		
	Instructor Prof. Dr.-Ing. Henning Puder		**Type** Practice	**SWS** 1
	Course nr. 18-zo-2070-se	**Course name** Sprach- und Audiosignalverarbeitung		
	Instructor Prof. Dr.-Ing. Henning Puder		**Type** Seminar	**SWS** 1

Module name Introduction to Cryptography					
Module nr. 20-00-0085	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language German			**Module owner** Dr.-Ing. Michael Kreutzer		

1 Teaching content

Mathematical basic principles:

- Calculations in congruence and residue class rings

Basic principles of encryption:

- Symmetric vs. asymmetric cryptosystems
- Block and stream ciphers, AES, DES
- Cryptanalysis
- Probability and perfect security
- Public-key encryption
- RSA, Diffie-Hellman, ElGamal
- Factoring large numbers
- Discrete logarithms
- Cryptographic hash functions
- Digital signatures
- Identification

2 Learning objectives

After successful completion of the module students

- understood the mathematical foundations of cryptography such as calculations in congruence and residue class rings, factoring large numbers, probability theory and perfect security
- understood the principles of public and secret key encryption and relevant schemes including their security and efficiency
- understood the principles of digital signatures and the relevant schemes including their security and efficiency

3 Recommended prerequisites for participation

Recommended:

- Linear Algebra for Computer Science
- Funktionale und Objektorientierte Programmierkonzepte

4 Form of examination

Course related exam:

- [20-00-0085-iv] (Technical examination, Oral/written examination, Default RS)

The form of the examination will be announced at the beginning of the course. One or a combination of max. two of the following forms is possible.

Written exam (duration 60 or 90 or 120 minutes), oral exam (duration 15 or 30 minutes), homework (optional: including tests).

5 Prerequisite for the award of credit points

Pass exam (100%)

6 Grading

Course related exam:

- [20-00-0085-iv] (Technical examination, Oral/written examination, Weighting: 100 %)

7	**Usability of the module** B. Sc. Informatik M. Sc. Informatik M. Sc. IT Sicherheit M.Sc. IT Security May be used in other degree programs.
8	**Grade bonus compliant to §25 (2)** 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** • Johannes Buchmann: Einführung in die Kryptographie, 5. Auflage, Springer-Verlag, 2010, 278 p. ISBN: 978-3-642-11185-3 • Johannes Buchmann: Cryptographic Protocols. Vorlesungsskript (u.a. Undeniable, Fail-Stop und Blind Signatures) • Neal Koblitz:A Course in Number Theory and Cryptography, Springer Verlag, 1994 • Alfred J. Menezes, Paul C. van Oorschot, Scot A. Vanstone: Handbook of Applied Cryptography, CRC Press, 1997 (erhältlich als PDF) • Bruce Schneier: Applied Cryptography, John Wiley & Sons, Inc., 1994 • Douglas R. Stinson: Cryptography - Theory and Practice, CRC Press, 1995 • Gustavus J. Simmons: Contemporary Cryptology - The Science of Information Integrity, IEEE Press, 1992

Courses

	Course nr.	**Course name**		
	20-00-0085-iv	Introduction to Cryptography		
	Instructor		**Type**	**SWS**
			Integrated course	4

Module name Ubiquitous computing in business processes					
Module nr. 20-00-0121	**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** Prof. Dr. rer. nat. Eberhard Mühlhäuser		

1	**Teaching content** - Learning how state-of-the-art ubiquitous computing technologies can be utilized in enterprise business processes and in the context of smart city services - Identifying technologies' economic potential for business processes and in the context of smart cities - Understanding underlying technologies, their benefits, challenges, and corresponding business cases - Technologies considered will be RFID technology and its integration with business processes, other smart items (e.g., smart shelfs), etc. - Demonstration of how integration works between the real world and the virtual world as it is represented in enterprise software systems today - Hands-on experience and live demonstrations
2	**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 concepts.
3	**Recommended prerequisites for participation**
4	**Form of examination** Course related exam: • [20-00-0121-vl] (Technical examination, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-0121-vl] (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik M.Sc. Sportwissenschaft und Informatik May be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**
9	**References**

- 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 name**		
20-00-0121-vl	Ubiquitous computing in business processes		
Instructor		**Type**	**SWS**
		Lecture	2

Module name Computer Vision I					
Module nr. 20-00-0157	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language English			**Module owner** Prof. Dr. Bernt Schiele		

1	**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	**Learning objectives** After successfully attending the course, students are familiar with the basics of computer vision. They understand fundamental techniques for the analysis of images and videos, can name their assumptions and mathematical formulations, as well as describe the resulting algorithms. They are able to implement these techniques in order to solve basic image analysis tasks on realistic imagery.
3	**Recommended prerequisites for participation** Particiation of lecture Visual Computing is recommended.
4	**Form of examination** Course related exam: • [20-00-0157-iv] (Technical examination, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-0157-iv] (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik B.Sc. Computational Engineering M.Sc. Computational Engineering M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik M.Sc. Sportwissenschaft und Informatik May be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**
9	**References**

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

Courses

Course nr.	**Course name**		
20-00-0157-iv	Computer Vision		
Instructor		**Type**	**SWS**
		Integrated course	4

Module name Data Science I					
Module nr. 18-zo-2110	**Credit points** 5 CP	**Workload** 150 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak 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 Learning objectives

This module offers an introduction to the topic of Data Science with a strong practical orientation. Students gain knowledge about all parts of a Data Science processing: From storage/data acquisition over inferential statistics to visualization.

3 Recommended prerequisites for participation

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS)

The examination takes place in form of a written exam (duration: 90 minutes). If one can estimate that less than 16 students register, the examination will be an oral examination (duration: 45 min.). The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

Yes

9 References

- Lecture notes and slides can be downloaded here:
  - http://www.spg.tu-darmstadt.de
  - moodle
- 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

Course nr.	**Course name**		
18-zo-2110-vl	Data Science I		
Instructor		**Type**	**SWS**
Dr.-Ing. Christian Debes		Lecture	2

Course nr.	**Course name**		
18-zo-2110-ue	Data Science I		
Instructor		**Type**	**SWS**
Dr.-Ing. Christian Debes		Practice	2

Module name Robot Learning					
Module nr. 20-00-0629	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language English			**Module owner**		

1	**Teaching content** - Foundations from robotics and machine learning for robot learning - Learning of forward models - Representation of a policy, hierarchical abstraction wiith movement primitives - Imitation learning - Optimal control with learned forward models - Reinforcement learning and policy search - Inverse reinforcement learning
2	**Learning objectives** 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	**Recommended prerequisites for participation** Good programming in Matlab Lecture Machine Learning 1 - Statistical Approaches is helpful but not mandatory.
4	**Form of examination** Course related exam: • [20-00-0629-vl] (Technical examination, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-0629-vl] (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik B.Sc. Computational Engineering M.Sc. Computational Engineering M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik M.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**

	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** Deisenroth, M. P.; Neumann, G.; Peters, J. (2013). A Survey on Policy Search for Robotics, Foundations and Trends in Robotics Kober, J; Bagnell, D.; Peters, J. (2013). Reinforcement Learning in Robotics: A Survey, International Journal of Robotics Research C.M. Bishop, Pattern Recognition and Machine Learning (2006), R. Sutton, A. Barto. Reinforcement Learning - an Introduction Nguyen-Tuong, D.; Peters, J. (2011). Model Learning in Robotics: a Survey

Courses

	Course nr.	**Course name**		
	20-00-0629-vl	Robot Learning		
	Instructor		**Type**	**SWS**
			Lecture	4

Module name Combinatorial Optimization					
Module nr. 04-10-0588	**Credit points** 5 CP	**Workload** 150 h	**Self-study** 150 h	**Module duration** 1 Term	**Module cycle** Every 9. Semester
Language English			**Module owner** Prof. Dr. Yann Disser		

1	**Teaching content** shortest paths (advanced), maximum flows (advanced), min-cost maximum flows, maximum matchings, complexity
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	**Recommended prerequisites for participation** Recommended: Introduction to Optimization, ADM
4	**Form of examination** Module exam: • 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.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M. Sc. Mathematik and Mathematics, B Sc. Mathematik (3rd year)
8	**Grade bonus compliant to §25 (2)**
9	**References** Korte, Vygen. Combinatorial Optimization. Springer, 2012.

Courses

Course nr. 04-10-0588-vu	**Course name** Combinatorial Optimization		
Instructor		**Type** Lecture and practice	**SWS** 0

Module name Statistical Relational Artificial Intelligence: Logic, Probability, and Computation					
Module nr. 20-00-1011	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language English			**Module owner** Prof. Dr. techn. Johannes Fürnkranz		

1	**Teaching content** + Logic programming + Inductive logic programming, i.e., learning logical programs from data + Probabilistic graphical models: Inference and Learning + Statistical relational models such as ProbLog and Markov logic networks + Inference within statistical relational models + Learning statistical relational models from data + Relational linear and quadratic programs
2	**Learning objectives** The lecture provides a systematic introduction to the foundations and methods of statistical relational learning and AI: the study and design of intelligent agents that act in worlds composed of individuals (objects, things), where there can be complex relations among the individuals, where the agents can be uncertain about what properties individuals have, what relations are true, what individuals exist, whether different terms denote the same individual, and the dynamics of the world. After the successful completion of the course, students understand the basic concepts and methods of statistical relational AI. They understand the basic challenges posed by relational domains and know the current state of the art to meet tem. They are able to apply the acquired toolbox to novel problems.
3	**Recommended prerequisites for participation** The successful completion of “Statistical Machine Learning” and of “Probabilistic Graphical Models” is recommended but not required.
4	**Form of examination** Course related exam: • [20-00-1011-iv] (Technical examination, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-1011-iv] (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik May be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**
9	**References** Pointers to literature will be updated regularly and include: Luc De Raedt, Kristian Kersting, Sriraam Natarajan, David Poole (2016): Statistical Relational Artificial Intelligence: Logic, Probability, and Computation. Synthesis Lectures on Artificial Intelligence and Machine Learning, Morgan & Claypool Publishers, ISBN: 9781627058414.
Courses	

	Course nr.	Course name		
	20-00-1011-iv	Statistical Relational Artificial Intelligence: Logic, Probability, and Computation		
	Instructor		**Type**	**SWS**
	Prof. Dr. techn. Johannes Fürnkranz		Integrated course	4

Module name Scalable Data Management Systems					
Module nr. 20-00-1017	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language English			**Module owner** Prof. Dr. techn. Johannes Fürnkranz		

1	**Teaching content** This course introduces the fundamental concepts and computational paradigms of scalable data management systems. The focus of this course is on the systems-oriented aspects and internals of such systems for storing, updating, querying, and analyzing large datasets. Topics include: Database Architectures Parallel and Distributed Databases Data Warehousing MapReduce and Hadoop Spark and its Ecosystem Optional: NoSQL Databases, Stream Processing, Graph Databases, Scalable Machine Learning
2	**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 examination** Course related exam: • [20-00-1017-iv] (Technical examination, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-1017-iv] (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik May be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**
9	**References**

Courses

	Course nr.	Course name		
	20-00-1017-iv	Scalable Data Management Systems		
	Instructor		**Type**	**SWS**
	Prof. Dr. techn. Johannes Fürnkranz		Integrated course	4

Module name Introduction to Artificial Intelligence					
Module nr. 20-00-1058	**Credit points** 5 CP	**Workload** 150 h	**Self-study** 105 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language German			**Module owner** Prof. Dr. techn. Johannes Fürnkranz		

1 Teaching content

Artificial Intelligence (AI) is concerned with algorithms for solving problems, whose solution is generally assumed to require intelligence. While research in the early days was oriented on results about human thinking, the field has since developed towards solutions that try to exploit the strengths of the computer. In the course of this lecture we will give a brief survey over key topics of this core discipline of computer science, with a particular focus on the topics search, planning, learning, and reasoning. Historical and philosophical foundations will also be considered.

- Foundations
- Introduction, History of AI (RN chapter 1)
- Intelligent Agents (RN chapter 2)
- Search
- Uninformed Search (RN chapters 3.1 - 3.4)
- Heuristic Search (RN chapters 3.5, 3.6)
- Local Search (RN chapter 4)
- Constraint Satisfaction Problems (RN chapter 6)
- Games: Adversarial Search (RN chapter 5)
- Planning
- Planning in State Space (RN chapter 10)
- Planning in Plan Space (RN chapter 11)
- Decisions under Uncertainty
- Uncertainty and Probabilities (RN chapter 13)
- Bayesian Networks (RN chapter 14)
- Decision Making (RN chapter 16)
- Machine Learning
- Neural Networks (RN chapters 18.1,18.2,18.7)
- Reinforcement Learning (RN chapter 21)
- Philosophical Foundations

2 Learning objectives

After a successful completion of this module, students are in a position to

- understand and explain fundemental techniques of artificial intelligence
- participate in a discussion about the possibility of an artificial intelligence with well-founded arguments
- critically judge new developments in this area

3 Recommended prerequisites for participation

4 Form of examination

Course related exam:

- [20-00-1058-iv] (Technical examination, Oral/written examination, Default RS)

Written Exam (90 min.)

5 Prerequisite for the award of credit points

Pass exam (100%)

6 Grading

	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	**Grade bonus compliant to §25 (2)**
9	**References**

Courses

	Course nr.	**Course name**		
	20-00-1058-iv	Introduction to Artificial Intelligence		
	Instructor		**Type**	**SWS**
	Prof. Dr. techn. Johannes Fürnkranz		Integrated course	3

Module name Matrix Analysis and Computations					
Module nr. 18-pe-2070	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

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	**Learning objectives** Students will have learned advanced topics in matrix analysis and related algorithms at an advanced level upon completion of the module.
3	**Recommended prerequisites for participation** Basic knowledge in linear algebra.
4	**Form of examination** Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS) The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 10 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.
5	**Prerequisite for the award of credit points** Pass module final exam.
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. etit, M.Sc. MEC, M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. etit - AUT, M.Sc. iCE, B.Ed. etit, B.Sc. und M.Sc. iST, B.Sc. WI-etit, M.Sc. etit - CMEE
8	**Grade bonus 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

Course nr.	**Course name**		
18-pe-2070-vl	Matrix Analysis and Computations		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Lecture	3

Course nr.	**Course name**		
18-pe-2070-ue	Matrix Analysis and Computations		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Practice	1

Module name Data-driven Modeling - Machine Learning					
Module nr. 18-kp-2110	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr. techn. Heinz Köppl		

1 Teaching content

The module provides an introduction to the emerging field of machine learning from an engineering perspective. Important models and learning methods are presented and exemplified through problems from information and communication technology.

- Fundamentals of probability theory and multivariate statistics
- Taxonomy of machine learning problems and models (supervised, unsupervised, generative, discriminative)
- Regression and classification: theory, methods and ICT applications
- Dimensionality reduction, clustering and big data analytics: methods and application in communications and signal processing
- Probabilistic graphical models: categories, inference and parameter estimation
- Fundamentals of Bayesian inference, Monte Carlo methods, Bayesian non-parametrics
- Fundamentals of convex optimization: Solution methods and application in communications
- Approximate algorithms for scalable Bayesian inference; application in signal processing and information theory (e.g. decoding of LDPC codes)
- Hidden Markov models (HMM): Theory, Algorithms and ICT applications (e.g. Viterbi decoding of convolutional codes)
- High-dimensional statistics (“large p small n” setting), learning dependency structure in high-dimensional data, learning causality relations from observational data.
- Sparse estimation, random projections, compressive sensing: Theory and applications in signal processing
- Deep neural networks (deep learning): Models, learning algorithms, libraries and ICT applications

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.

They are able to implement all necessary algorithms from scratch, but they are also familiar with the state-of-the-art libraries in machine learning.

They are able to determine the involved computational complexity of a method and choose an appropriate solution algorithms based on application constraints.

They are able to apply the acquired methods to other domains, such as data analysis in biomedical engineering, analysis of social network data, etc.

3 Recommended prerequisites for participation

Good command of Matlab (for instance knowledge from course 18-st-2030 Matlab Grundkurs) and engineering mathematics

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS)

The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 10 students register, the examination will be an oral examination (duration: 30 min.). The type of examination will be announced in the beginning of the lecture.

5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, B.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST, B.Sc. WI-etit, M.Sc. etit - CMEE, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** • Kevin P. Murphy. Machine Learning - A probabilistic perspective, MIT Press, 2012 • Christopher M. Bishop. Pattern recognition and Machine Learning, Springer, 2006 • Peter Bühlmann und Sara van de Geer. Statistics of high-dimensional data - Methods, theory and applications, Springer, 2011

Courses

Course nr. 18-kp-2110-vl	**Course name** Data-driven Modeling - Machine Learning		
Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein		**Type** Lecture	**SWS** 2
Course nr. 18-kp-2110-ue	**Course name** Data-driven Modeling - Machine Learning		
Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein		**Type** Practice	**SWS** 1
Course nr. 18-kp-2110-pr	**Course name** Data-driven Modeling - Machine Learning Lab		
Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein		**Type** Lab	**SWS** 1

Module name Computer Vision in Engineering					
Module nr. 18-ad-2090	**Credit points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Module duration** 1 Term	**Module cycle** Winter term
Language German			**Module owner** Prof. Dr.-Ing. Jürgen Adamy		

1 Teaching content

A Basics

- Scene Representation 2D and 3D Geomtery
- Image Acquisition
  - Geometric Projections Camera Calibration
- Objective and Illumination
- Discrete 2D signals
  - Separability, Sampling
  - Transformation, Interpolation
  - Convolution, Correlation
  - Discrete Fourier Transformation

B Basics of Image Analysis

- Filtering
  - Basics2D Filter Design
  - Linear Filtering
  - Nichtlinear Filtering
- Image Decompositions
  - Multi-scale Representation
  - Pyramids
  - Filter Banks
- Image Features
  - Structure
  - Moments, Histograms

2 Learning objectives

After successful completion, the module teaches mathematical basics needed to solve computer vision problems in the field of engineering. The focus is on methods that are relevant for measuring and control tasks. Applications range from visual quality inspection, visual robotics, photogrammetry, visual odometry up to visually guided driver assistance etc.

The students should obtain a good understanding for the relations between the three-dimensional world and its two-dimensional projection onto the image plane of a camera. They also should learn about methods that exist to infer knowledge from the world given image data. They should develop some feeling for the different kinds of problems that arise in computer vision and how to choose an efficient solution in terms of algorithms.

3 Recommended prerequisites for participation

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS)

The examination takes place in form of a written exam (duration: 90 minutes). If one can estimate that less than 10 students register, the examination will be an oral examination (duration: 30 min.). The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

	Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. MEC, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - AUT, M.Sc. MedTec, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** References / Textbooks: Lecture slides, exercise sheets and matlab-code. Further reading 1. Yi Ma, Stefano Soatto, Jana Kosecka und Shankar S. Sastry, An Invitation to 3-D Vision - From Images to Geometric Models, Springer, 2003. 2. Richard Hartley and Andrew Zisserman, Multiple View Geometry in Computer Vision, Second Edition, Cambridge University Press, 2004. 3. Karl Kraus, Photogrammetrie, Band 1 Geometrische Informationen aus Photographien und Laserscanner-aufnahmen 7. Auflage, de Gruyter Lehrbuch, 2004. 4. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer 2006. 5. Bernd Jähne, Digital Image Processing, 6. Auflage, 2005.

Courses

	Course nr.	**Course name**		
	18-ad-2090-vl	Computer Vision in Engineering		
	Instructor		**Type**	**SWS**
	Dr.-Ing. Thomas Guthier, M.Sc. Frank Ziegler		Lecture	2

Module name Convex Optimization in Signal Processing and Communications					
Module nr. 18-pe-2020	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1 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 compuation, applications.

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 processing and mobile communication systems.

3 Recommended prerequisites for participation

Knowledge in linear algebra and the basic concepts of signal processing and communications.

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 120 Min., Default RS)

The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 14 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.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Ed. etit, B.Sc. und M.Sc. iST, B.Sc. WI-etit, M.Sc. etit - CMEE, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

- S. Boyd and L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004. (online Verfügbar:http://www.stanford.edu/ boyd/cvxbook/)
- D. P. Bertsekas, Nonlinear Programming, Athena Scientific, Belmont, Massachusetts, 2nd Ed., 1999.
- Daniel P. Palomar and Yonina C. Eldar, Convex Optimization in Signal Processing and Communications, Cambridge University Press, 2009.

Courses

	Course nr. 18-pe-2020-vl	**Course name** Convex Optimization in Signal Processing and Communications		
	Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lecture	**SWS** 2
	Course nr. 18-pe-2020-ue	**Course name** Convex Optimization in Signal Processing and Communications		
	Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Practice	**SWS** 1
	Course nr. 18-pe-2020-pr	**Course name** Convex Optimization in Signal Processing and Communications Lab		
	Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lab	**SWS** 1

Module name Mobile Communications					
Module nr. 18-kl-2020	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Anja Klein		

1 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

2 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

3 Recommended prerequisites for participation

Deterministic Signals and Systems, Communication Technology I, Mathematics I to III, Statistics/Probability Theory, Scientific Computing

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

	will be announced in the lecture			
Courses				
	Course nr. 18-kl-2020-vl	**Course name** Mobile Communications		
	Instructor Prof. Dr.-Ing. Anja Klein, Dr.-Ing. Lin Xiang		**Type** Lecture	**SWS** 3
	Course nr. 18-kl-2020-ue	**Course name** Mobile Communications		
	Instructor Prof. Dr.-Ing. Anja Klein, Dr.-Ing. Lin Xiang		**Type** Practice	**SWS** 1

Module name Network, Traffic and Quality Management for Internet Services					
Module nr. 20-00-0056	**Credit points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language English			**Module owner** Prof. Dr. rer. nat. Eberhard Mühlhäuser		

1 Teaching content

Introduction into management of Internet service provider (ISP-)networks for integrating IP service platforms with their quality and traffic profiles.

2 Learning objectives

Course Content:

Requirements and measures to ensure Quality-of-Service (QoS)

- criteria from the application & user perspective (QoE: Quality of Experience).
- QoS Architecture in IP Networks: Differentiated & Integrated Services
- QoS support & impact per application in IP traffic mix (video streaming, VoIP, web browsing, downloads, social networking etc.)

Quality Assurance for Internet Services in ISP Network Infrastructures

- Network and Transport Layer Impact: Routing (OSPF, BGP), Multiprotocol Label Switching (MPLS), TCP with protection against errors and failures.
- measurement, monitoring, optimization of IP traffic regarding QoS

Quality assurance in service overlays and at application level

- Content Delivery Networks (CDN), Clouds and Peer-to-Peer Networks (P2P) incl. distributed caches, transport path optimization, scalability
- -IETF Standardization (CDN Interconnection, ALTO: Appl. Layer Traffic Opt.)

3 Recommended prerequisites for participation

Recommended:

Prerequisites: Basic knowledge in computer science and Internet applications is required. The courses on Kommunikationsnetze I and II are recommended.

4 Form of examination

Course related exam:

- [20-00-0056-vl] (Technical examination, Oral/written examination, Default RS)

The form of the examination will be announced at the beginning of the course. One or a combination of max. two of the following forms is possible.

Written exam (duration 60 or 90 or 120 minutes), oral exam (duration 15 or 30 minutes), homework (optional: including tests).

5 Prerequisite for the award of credit points

Pass exam (100%)

6 Grading

Course related exam:

- [20-00-0056-vl] (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

B.Sc. Informatik

M.Sc. Informatik

Maybe used in other degree programs.

8 Grade bonus compliant to §25 (2)

9	**References** Will be given in lecture.			
Courses				
	Course nr. 20-00-0056-vl	**Course name** Network, traffic and quality management for Internet services		
	Instructor		**Type** Lecture	**SWS** 2

Module name Software Defined Networking					
Module nr. 18-sm-2280	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language German/English			**Module owner** Prof. Dr.-Ing. Ralf Steinmetz		

1 Teaching content

The course deals with topics in the area of software defined networking:

- SDN Data Plane
- SDN Control Plane
- SDN Application Plane
- Network Function Virtualization
- Network Virtualization and Slicing
- QoS and QoE in Software Defined Networks

2 Learning objectives

Upon completion of the module, students will have gained in-depth insights into Software Defined Networking, as well as basic technologies and applications.

3 Recommended prerequisites for participation

Basic courses of the first 4 semesters are required. Knowledge of lectures Communication Networks I and II are recommended.

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS)

The examination takes place in form of a written exam (duration: 90 minutes). If one can estimate that less than 15 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.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, B.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST

8 Grade bonus compliant to §25 (2)

9 References

Textbooks as indicated.
Slides and paper copies as necessary.

Courses

Course nr.	**Course name**		
18-sm-2280-vl	Software Defined Networking		
Instructor		**Type**	**SWS**
Dr.-Ing. Ralf Kundel, M.Sc. Chengbo Zhou, M.Ed. Benjamin Becker		Lecture	2

	Course nr. 18-sm-2280-ue	**Course name** Software Defined Networking		
	Instructor Dr.-Ing. Ralf Kundel, M.Sc. Chengbo Zhou, M.Ed. Benjamin Becker		**Type** Practice	**SWS** 2

Module name Communication Networks II					
Module nr. 18-sm-2010	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Ralf Steinmetz		

1 Teaching content

The course Communication Networks II covers the principles and practice of computer networking and telecommunications with emphasis on the Internet. Starting with the history, the course discusses past, current and future aspects of communication networks. In addition to the basics including well known protocols and technologies, recent developments in the area of multimedia communication (e.g., Video Streaming, P2P, IP-Telephony, Cloud Computing and Service-oriented Architectures) will be examined thoroughly. The course is designed as follow-up to Communication Networks I.

Topics are:

- Basics and History of Communication Networks (Telegraphy vs. Telephony, Reference Models, ...)
- Transport Layer (Addressing, Flow Control, Connection Management, Error Detection, Congestion Control, ...)
- Transport Protocols (TCP, SCTP)
- Interactive Protocols (Telnet, SSH, FTP, ...)
- Electronic Mail (SMTP, POP3, IMAP, MIME, ...)
- World Wide Web (HTML, URL, HTTP, DNS, ...)
- Distributed Programming (RPC, Web Services, Event-based Communication)
- SOA (WSDL, SOAP, REST, UDDI, ...)
- Cloud Computing (SaaS, PaaS, IaaS, Virtualization, ...)
- Overlay Networks (Unstructured P2P, DHT Systems, Application Layer Multicast, ...)
- Video Streaming (HTTP Streaming, Flash Streaming, RTP/RTSP, P2P Streaming, ...)
- VoIP and Instant Messaging (SIP, H.323)

2 Learning objectives

Upon successful completion, the module provides students with an understanding of the principles and practice of computer networking and telecommunications with emphasis on the Internet. Starting with the history, the course discusses past, current and future aspects of communication networks. In addition to the basics including well known protocols and technologies, recent developments in the area of multimedia communication (e.g., Video Streaming, P2P, IP-Telephony, Cloud Computing and Service-oriented Architectures) will be examined thoroughly. The course is designed as follow-up to Communication Networks I.

3 Recommended prerequisites for participation

Basic courses of first 4 semesters are required. Knowledge in the topics covered by the course Communication Networks I is recommended. Theoretical knowledge obtained in the course Communication Networks II will be strengthened in practical programming exercises. So, basic programming skills are beneficial.

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 120 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

	M.Sc. MEC, M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, B.Sc. CE, M.Sc. MedTec, M.Sc. iCE, M.Sc. iST, 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 improvemnet 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

Courses

	Course nr. 18-sm-2010-vl	**Course name** Communication Networks II		
	Instructor Dr.-Ing. Tobias Meuser, M.Sc. Christoph Gärtner, Prof. Dr.-Ing. Ralf Steinmetz, M.Sc. Pratyush Agnihotri		**Type** Lecture	**SWS** 3
	Course nr. 18-sm-2010-ue	**Course name** Communication Networks II		
	Instructor Dr.-Ing. Tobias Meuser, M.Sc. Christoph Gärtner, Prof. Dr.-Ing. Ralf Steinmetz, M.Sc. Pratyush Agnihotri		**Type** Practice	**SWS** 1

Module name Digital Signal Processing					
Module nr. 18-zo-2060	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Teaching content

1) Discrete-Time Signals and Linear Systems - Sampling and Reconstruction of Analog Signals
2) Digital Filter Design - Filter Design Principles; Linear Phase Filters; Finite Impulse Response Filters; Infinite Impulse Response Filters; Implementations
3) Digital Spectral Analysis - Random Signals; Nonparametric Methods for Spectrum Estimation; Parametric Spectrum Estimation; Applications;
4) Kalman Filter

2 Learning objectives

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 Recommended prerequisites for participation

Deterministic signals and systems theory

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 180 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

M.Sc. MEC, M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. MedTec, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

Course manuscript
Additional References:

- A. Oppenheim, W. Schafer: Discrete-time Signal Processing, 2nd ed.
- J.F. Böhme: Stochastische Signale, Teubner Studienbücher, 1998

Courses

Course nr.	**Course name**		
18-zo-2060-vl	Digital Signal Processing		
Instructor		**Type**	**SWS**
M.Sc. Christian Schroth, M.Sc. Christian Eckrich, Prof. Dr.-Ing. Abdelhak Zoubir		Lecture	3

	Course nr. 18-zo-2060-ue	**Course name** Digital Signal Processing		
	Instructor M.Sc. Christian Schroth, M.Sc. Christian Eckrich, Prof. Dr.-Ing. Abdelhak Zoubir		**Type** Practice	**SWS** 1

Module name Fundamentals of Reinforcement Learning					
Module nr. 18-kl-2070	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 75 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Anja Klein		

1 Teaching content

- Review of Probability Theory
- Markov Property and Markov Decision Processes
- The Multi-Armed Bandit Problem vs. the Full Reinforcement Learning Problem
- Taxonomy of Multi-Armed Bandit Problems (e.g., Stochastic vs. Adversarial Rewards, Contextual MAB)
- Algorithms for Multi-Armed Bandit Problems (e.g., Upper Confidence Interval (UCB), Epsilon-Greedy, SoftMax, LinUCB) and their Application to Cyber-Physical Networking
- Fundamentals of Dynamic Programming and Bellman Equations
- Taxonomy of Approaches for the Full Reinforcement Learning Problem (e.g., Temporal-Difference Learning, Policy Gradient and Actor-Critic)
- Algorithms for the Full Reinforcement Learning Problem (e.g., Q-Learning, SARSA, Policy Gradient, Actor-Critic) and their Application to Cyber-Physical Networking
- Linear Function Approximation
- Non-linear Function Approximation

2 Learning objectives

The students are able to

- define the Markov property and identify the elements that constitute a Markov decision process. They will be able to use these concepts to model decision-making problems in Cyber-Physical Networking.
- determine the characteristics of the Multi-Armed Bandit (MAB) Problem and compare them to the characteristics of the Full Reinforcement Learning (RL) Problem.
- determine under which conditions the MAB or the full RL formulation should be used to solve decision-making problems.
- differentiate the main MAB strategies, e.g., Upper Confidence Interval (UCB), Epsilon-Greedy and Softmax.
- choose appropriate MAB strategies for the solution of MAB problems.
- formulate and solve Contextual-MAB problems.
- determine under which conditions Dynamic Programming can be used to solve decision-making problems.
- explain the difference between Dynamic Programming and RL methods.
- differentiate between Temporal-Difference, Policy Gradient and Actor-Critic RL techniques.
- identify the limitations of MAB and full RL problems.
- explain the need for generalization in MAB and full RL problems.
- choose appropriate approximation techniques and use them in combination with MAB and full RL strategies.
- apply algorithmic techniques to solve MAB and full RL problems and obtain valid solutions.
- judge the reasonableness and consistency of the obtained solutions.

3 Recommended prerequisites for participation

- Python or Matlab: basic knowledge
- Engineering mathematics and probability theory

4 Form of examination

	Module exam: • Module exam (Technical examination, Oral/written examination, Duration: 60 Min., Default RS) 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.
5	**Prerequisite for the award of credit points** Passing the final module examination
6	**Grading** Module exam: • Module exam (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. MEC, M.Sc. WI-etit, M.Sc. etit - KTS, M.Sc. etit - AUT, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS
8	**Grade bonus compliant to §25 (2)**
9	**References** • Richard S. Sutton and Andrew G. Barto, “Reinforcement Learning: An Introduction”, A Bradford Book, Cambridge, MA, USA, 2018. • Aleksandrs Slivkins, "Introduction to Multi-Armed Bandits", Foundations and Trends in Machine Learning, Vol. 12: No. 1-2, 2019.

Courses

	Course nr. 18-kl-2070-vl	**Course name** Fundamentals of Reinforcement Learning		
	Instructor Dr.-Ing. Andrea Jimenez, Dr. rer. nat. Sabrina Klos		**Type** Lecture	**SWS** 2
	Course nr. 18-kl-2070-ue	**Course name** Fundamentals of Reinforcement Learning		
	Instructor		**Type** Practice	**SWS** 1

Module name Serious Games					
Module nr. 18-de-2050	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language German/English			**Module owner** PD Dr.-Ing. Stefan Göbel		

1 Teaching content

Introduction to the topic of ""Serious Games"": scientific and technical foundations, application areas and trends. Individual lectures include:

- Introduction to Serious Games
- Game Development, Game Design
- Game Technology, Tools and Engines
- Personalization and Adaptation
- Interactive Digital Storytelling
- Authoring and Content Generation
- Multiplayer Games
- Game Interfaces and Sensor Technology
- Effects, Affects and User Experience
- Mobile Games
- Serious Games Application Domains and Best Practice Examples

The exercise consists of theoretical and practical parts. Students are taught how to use a Game Engine.

2 Learning objectives

After successfully completing this course the students are able to explain the concept of “Serious Games” and can transfer it to different application domains (like education or health). They can describe the general approach for developing computer games and can apply basic principles of game design, personalisation / adaptation and interactive digital storytelling. Aside from that students are able to sketch out other current research questions regarding Serious Games as well as their solutions.

3 Recommended prerequisites for participation

4 Form of examination

Module exam:

- Module exam (Technical examination, Oral/written examination, Duration: 90 Min., Default RS)

The examination takes place in form of a written exam (duration: 90 minutes). If one can estimate that less than 8 students register, the examination will be an oral examination (duration: 30 min.). The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Pass exam (100%)

6 Grading

Module exam:

- Module exam (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. etit - DT, M.Sc. CE, B.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST, B.Sc. WI-etit

8 Grade bonus compliant to §25 (2)

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

	Will be given in lecture.

Courses				
	Course nr. 18-de-2050-vl	**Course name** Serious Games		
	Instructor PD Dr.-Ing. Stefan Göbel		**Type** Lecture	**SWS** 3
	Course nr. 18-de-2050-ue	**Course name** Serious Games		
	Instructor PD Dr.-Ing. Stefan Göbel		**Type** Practice	**SWS** 1

Module name Network Security					
Module nr. 20-00-0512	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language English			**Module owner** Dr.-Ing. Michael Kreutzer		

1 Teaching content

The integrated course Network Security covers the principles and practice of computer and telecommunication network security with particular emphasis on Internet security. After transferring the fundamentals of IT security and cryptography to the networking domain, we follow a top-down approach to network security. Starting with the application layer, the course provides a detailed discussion of network security principles and protocols. In addition to well known mechanisms, selected recent developments in the area of network security will be examined.

Course contents:
- Network security: introduction, motivation, and challenges
- Fundamentals: a reference model for network security, security standards for networks and the Internet, security threats, attacks, services, and mechanisms
- Cryptographic foundations for networking security: symmetric crypto and its use in networks, public-key crypto and its use in networks, support functions to implement network security
- Application layer security
- Transport layer security
- Network layer security
- Link layer security
- Physical layer security and physical security
- Operational network security: firewalls, intrusion detection systems
- Selected topics in network security

2 Learning objectives

After successfully attending the course, students have aquired an in-deep knowledge in the domain of communication network security with emphasis on Internet security. Students are able to apply and transfer the most important fundamentals from IT security and cryptography to the field of communication networks. Students are able to distinguish the most important basic techniques for securing communication networks. They have a thorough understanding of security mechanisms on the different network layers (application layer, transport layer, network layer, link layer, physical layer). As a result, they are able to thoroughly discuss the characteristics and principles in the area of network security and exhibit detailed theoretical and practical knowledge in this field. Additionally, students are able to describe recent developments in the area of network security (e.g. peer-to-peer security, mobile network security, etc.). The exercise deepens the theoretical foundations by means of exercises, which consist of literature, calculation as well as practical implementation/application examples.

3 Recommended prerequisites for participation

Knowledge in the area IT Security, Introduction to Cryptography and Communication Networks

4 Form of examination

Course related exam:
- [20-00-0512-iv] (Technical examination, Oral/written examination, Default RS)

5 Prerequisite for the award of credit points

Pass exam (100%)

6 Grading

Course related exam:
- [20-00-0512-iv] (Technical examination, Oral/written examination, Weighting: 100 %)

7 Usability of the module

	B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
8	**Grade bonus compliant to §25 (2)** 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** Charlie Kaufman, Radia Perlman, Mike Speciner: Network Security - Private Communication in a Public World, 2nd Edition, Prentice Hall, 2002, ISBN: 978-0-14-046019-6; additional texts may be announced

Courses

	Course nr.	**Course name**		
	20-00-0512-iv	Network Security		
	Instructor		**Type**	**SWS**
	Dr.-Ing. Michael Kreutzer		Integrated course	4

Module name TK3: Ubiquitous / Mobile Computing					
Module nr. 20-00-0120	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Summer term
Language German			**Module owner** Prof. Dr. rer. nat. Eberhard Mühlhäuser		

1	**Teaching content** Objectives: - Knowledge of technical basics of the mobile communication - Knowledge of important challenges of the Ubiquitous Computing - Methodic knowledge about current approaches to these challenges Course Content: - Introduction to Ubiquitous Computing - Mobile Communication - Internet of Things: RFID and Smart Items - Service Discovery & Cloudlets - Context- and Location-aware Computing - Human Computer Interaction - Privacy and Trust in Ubiquitous Computing
2	**Learning objectives** After successfully attending the course, students are familiar with the technical basis of mobile communication. They understand the fundamental challenge of ubiquitous computing. They know current approaches to solve these challenges. They are able to apply their knowledge to build ubiquitous computing systems.
3	**Recommended prerequisites for participation** Computer Netzwerke and Distributed Systems
4	**Form of examination** Course related exam: • [20-00-0120-iv] (Technical examination, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-0120-iv] (Technical examination, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik M.Sc. Sportwissenschaft und Informatik May be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**

	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** 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: 1. F. Adelstein, S. Gupta et al.: Fundamentals of Mobile & Pervasive Computing McGraw Hill 2004, 2. Stefan Poslad: Ubiquitous Computing, Wiley 2009, ISBN 978-0-470-03560-3 3. Kapitel Mobilkommunikation: M. Sauter: Grundkurs Mobile Kommunikationssysteme: UMTS, HSDPA und LTE, GSM, GPRS und Wireless LAN; Vieweg-Teubner Studium 2010 4. J. Krumm (Ed.): Ubiquitous Computing Fundamentals, CRC Press 2010 D. Cook, S. Das (Ed.): Smart Environments, Wiley 2005

Courses

	Course nr.	**Course name**		
	20-00-0120-iv	TK3: Ubiquitous / Mobile Computing		
	Instructor		**Type** Integrated course	**SWS** 4

Module name Automated Driving					
Module nr. 18-ad-2110	**Credit points** 3 CP	**Workload** 90 h	**Self-study** 60 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Jürgen Adamy		

1 Teaching content

- History of Automated Driving
- Terminology and Paths towards Automated Driving
- Architectures, Building Blocks, and Components
- Perception & Environment Models
- Data Fusion & State Estimation
  - Deep Dive: Target Tracking & Traffic Participant Fusion
  - Deep Dive: Grid Fusion & Free Space Estimation
  - Deep Dive: Road Model Fusion
- Localization, Digital Maps, and Vehicle-To-X Communication
- Situation Understanding, Prediction, and Criticality Assessment
  - Deep Dive: Probabilistic Driving Maneuver Detection
- Behavior & Trajectory Planning, Decision Making
- Automated Driving Software Development & Test
- Open Challenges & State-of-the-Art Research Topics

2 Learning objectives

Upon successful completion of the module, students will be able to:

- is familiar with the history and terminology of automated driving systems,
- knows important architectures, building blocks, and components of automated vehicles,
- understands different perception, environment model, and data fusion approaches,
- has an idea about relevant methods (e.g. Bayesian Inference & Probabilistic Graphical Models, State Estimation, Deep Learning, Dempster-Shafer Theory) and knows how they can be beneficially applied in different of automated driving areas (e.g. detection, target tracking & traffic participant fusion, grid fusion, road model fusion, localization),
- is familiar with the challenges of situation understanding, prediction, and criticality assessment and knows exemplary methods to tackle the problem,
- is aware of exemplary behavior & trajectory planning approaches,
- knows best practices about automated driving software development & test (e.g. continuous integration, verification & validation, test-driven development, key performance indicators), and
- is familiar with open challenges and research topics.

3 Recommended prerequisites for participation

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 90 Min., Default RS)

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

	Module exam: • Module exam (Technical examination, Examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. MEC, M.Sc. WI-etit, M.Sc. etit - AUT, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** Own lecture slides are distributed in advance of any lecture. For more detailed insights into the topic area, the following books can be recommended: • Eskandarian, A.: Handbook of Intelligent Vehicles. Springer, London, 2012. • Siciliano, B.; Khatib, O.: Springer Handbook of Robotics. 2nd Edition, Springer, Berlin Heidelberg 2016. • Thrun, S.; Burgard, W.; Fox, D.: Probabilistic Robotics. Intelligent Robotics and Autonomous Agents. The MIT Press, Cambridge, 2006. • Watzenig, D.; Horn, M.: Automated Driving. Safer and More Efficient Future Driving. Springer, Switzerland, 2017. • Winner, H. et al.: Handbook of Driver Assistance Systems. Basic Information, Components and Systems for Active Safety and Comfort. Springer, Switzerland, 2016.

Courses

Course nr.	**Course name**		
18-ad-2110-vl	Automated Driving		
Instructor		**Type**	**SWS**
Dr.-Ing. Matthias Schreier		Lecture	2

Module name Robust Data Science With Biomedical Applications					
Module nr. 18-mu-2010	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. 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 implement the lecture contents are available to the students.

2 Learning objectives

Students understand the basics of robust signal processing and data science and are able to apply them to a variety of problems. They are familiar with various biomedical applications and know the causes of artifacts, outliers and impulsive noise. They can apply algorithms for robust regression, cluster analysis, classification and spectral analysis.

3 Recommended prerequisites for participation

Fundamental knowledge of statistical signal processing

4 Form of examination

Module exam:

- Module exam (Technical examination, Examination, Duration: 180 Min., Default RS)

5 Prerequisite for the award of credit points

Pass module final exam

6 Grading

Module exam:

- Module exam (Technical examination, Examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. MedTec, M.Sc. iCE, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

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

Course nr.	**Course name**		
18-mu-2010-vl	Robust Signal Processing With Biomedical Applications		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Michael Muma		Lecture	3
Course nr.	**Course name**		
18-mu-2010-ue	Robust Data Science With Biomedical Applications		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Michael Muma		Practice	1

2.3.2 Communication Algorithms - Labs and Projects

Module name Digital Signal Processing Lab					
Module nr. 18-zo-2030	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Teaching content

1. Introduction to MATLAB
2. Discrete-Time Signals and Systems
3. Frequency-Domain Analysis using the DFT
4. Digital FIR Filter Design
5. IIR Filter Design using Analog Prototypes
6. Nonparametric Spectrum Estimation
7. Parametric Spectrum Estimation.

2 Learning objectives

The students are able to apply skills acquired in the course Digital Signal Processing. These include the design of digital FIR and IIR filters as well as non-parametric and parametric spectrum estimation. Students learn how MATLAB is used to apply theoretical concepts and to demonstrate signal processing techniques by using hands-on application examples.

3 Recommended prerequisites for participation

Fundamentals of Signal Processing

4 Form of examination

Module exam:

- Module exam (Study achievement, Written examination, Duration: 120 Min., Default RS)

Exam (Duration: 120 min) and a Report (Lab Reports), Details will be announced at the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Study achievement, Written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

Lab manual

Courses

Course nr.	**Course name**		
18-zo-2030-pr	Digital Signal Processing Lab		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Abdelhak Zoubir		Lab	3

Module name Advanced Topics in Statistical Signal Processing					
Module nr. 18-zo-2040	**Credit points** 8 CP	**Workload** 240 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Teaching content

The course covers the fundamentals of detection and estimation theory. These are extended by advanced topics in statistical signal processing. Applications are typically from the following areas: Detection in Radar Applications; Robust Estimation; Prediction, Filtering, and Tracking with the Kalman Filter; Sensor Array Signal Processing, Direction of Arrival Estimation, and Source Detection; Time-Frequency Analysis. Topics may change from semester to semester.

The course includes a series of lectures followed by a supervised research seminar over approximately 2 months. The main topics covered are:

- Estimation theory
- Detection theory
- Robust estimation theory
- Seminar projects: e.g., microphone arrays/beamforming, localization and tracking, radar/ultrasonic imaging, acoustic source localization, estimation of number of sources

2 Learning objectives

After completing the module, students will be able to work independently on advanced topics in signal processing and reproduce existing results. The students can present these results and discuss them scientifically.

3 Recommended prerequisites for participation

DSP, general interest in signal processing

4 Form of examination

Module exam:

- Module exam (Study achievement, Oral/written examination, Default RS)

Report and/or Presentation and/or Colloquium. The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Study achievement, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. MedTec, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

- 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.

Courses

Course nr.	**Course name**		
18-zo-2040-se	Advanced Topics in Statistical Signal Processing		
Instructor		**Type**	**SWS**
M.Sc. Pertami Kunz, Prof. Dr.-Ing. Abdelhak Zoubir		Seminar	4

Module name Signal Detection and Parameter Estimation					
Module nr. 18-zo-2050	**Credit points** 8 CP	**Workload** 240 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Summer term
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Teaching content

Signal detection and parameter estimation are fundamental signal processing tasks. In fact, they appear in many common engineering operations under a variety of names. In this course, the theory behind detection and estimation will be presented, allowing a better understanding of how (and why) to design "good" detection and estimation schemes.

These lectures will cover:

- Fundamentals of Detection and Estimation Theory
- Hypothesis Testing:
  - Bayesian/Ideal Observer/Neyman-Pearson Tests
  - Receiver Operating Characteristics
  - Uniformly Most Powerful Tests
  - Matched Filter
- Estimation Theory:
  - Types of Estimators
  - Maxmimum Likelihood Estimators
  - Sufficiency and the Fisher-Neyman/Factorisation Criterion
  - Unbiasedness and minimum variance
  - Fisher Information and the CRB
  - Asymptotic properties of the MLE

2 Learning objectives

After successful completion of the module, students know the basics of detection and estimation theory. They can design hypothesis tests and estimators for existing problems and implement them in Matlab on their own. In addition, students will be able to review existing work on detection and estimation independently. They can adequately present the methods and results from existing publications and discuss them scientifically.

3 Recommended prerequisites for participation

DSP, general interest in signal processing

4 Form of examination

Module exam:

- Module exam (Study achievement, Oral/written examination, Default RS)

Report and/or Presentation and/or Colloquium. The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Study achievement, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. MedTec, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9	**References** • 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.

Courses

	Course nr.	**Course name**		
	18-zo-2050-se	Signal Detection and Parameter Estimation		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Abdelhak Zoubir		Seminar	4

Module name Visual Computing Lab					
Module nr. 20-00-0418	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language German/English			**Module owner** Prof. Dr. Bernt Schiele		

1	**Teaching content** 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	**Learning objectives** 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	**Form of examination** Course related exam: • [20-00-0418-pr] (Study achievement, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-0418-pr] (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik B.Sc. Computational Engineering M.Sc. Computational Engineering M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik M.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**
9	**References** Will be announced in course.

Courses

Course nr.	**Course name**		
20-00-0418-pr	Lab Visual Computing		
Instructor		**Type** Lab	**SWS** 4

Module name Protection in Infrastructures and Networks					
Module nr. 20-00-1022	**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** Prof. Dr. techn. Stefan Katzenbeisser		

1	**Teaching content** The Seminar on Protection in Infrastructures and Networks is a cycle of seminars where students are given the chance to read, analyze and summarize current scientific publications. The topics are related to the areas of: - Trust - Privacy - Resilience in the domain of infrastructures and networks.
2	**Learning objectives** Students participating in the seminar will have the opportunity to learn and conduct research in the direction of these topics. Your task will be to understand state-of-the-art scientific publications in order to explain their contributions. Furthermore, you are expected to write a survey in relation to the topic 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 examination** Course related exam: • [20-00-1022-se] (Study achievement, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-1022-se] (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik May be used in other degree programss
8	**Grade bonus compliant to §25 (2)**
9	**References**

Courses

Course nr. 20-00-1022-se	**Course name** Protection in Infrastructures and Networks		
Instructor Prof. Dr. techn. Stefan Katzenbeisser		**Type** Seminar	**SWS** 2

Module name Project on Secure Mobile Networking					
Module nr. 20-00-0553	**Credit points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language German/English			**Module owner** Prof. Dr. rer. nat. Karsten Weihe		

1 Teaching content

The Project on Secure Mobile Networking covers the applied software development as well as hardware-software development. Topic areas covered are communication networks, IT security, mobile netwokrs and wireless communications as well as the combination of these. Goal is to independently carry out a development project in a team.

Course contents:
- Independent solving of a development project in the area of communication networks, IT security, mobile netwokrs and wireless communications
- Project planning and project management
- Survey on solution alternatives and discussion of pros and cons
- Conception of a software architecture or a combined hardware-software architecture
- Software/hardware design for the target platform
- Prototypical realization on the target platform
- Evaluation of the system with respect to performance aspects
- Documentation of the implemented solution as well as extensive documentation of the project management

2 Learning objectives

After successfully attending the course, students have aquired the ability to solve complex problems in the area of secure mobile networking using software technology. To this end, the students are able to independently define, manage and carrry out a project.
The students have gained insight into the design/implementation of complex protocols or applications in one/multiple of the areas of communication networks, IT security, mobile netwokrs and wireless communications. They are able to implement the chosen protocols and application, and to test the functionality as well as to evaluate the performance. The students are able to document the project planning and management, the developed software artefacts and to present the project progress and outcomes.

3 Recommended prerequisites for participation

Successfull participation of an lecture of SEEMOO.

4 Form of examination

Course related exam:
- [20-00-0553-pp] (Study achievement, Oral/written examination, Default RS)

5 Prerequisite for the award of credit points

Pass exam (100%)

6 Grading

Course related exam:
- [20-00-0553-pp] (Study achievement, Oral/written examination, Weighting: 100 %)

7 Usability of the module

	B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**
9	**References** Will be given in project.

Courses

	Course nr.	**Course name**		
	20-00-0553-pp	Secure Mobile Networking Project		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Matthias Hollick		Lab	6

Module name Multimedia Communications Seminar II					
Module nr. 18-sm-2090	**Credit points** 4 CP	**Workload** 120 h	**Self-study** 90 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language German/English			**Module owner** Prof. Dr.-Ing. Ralf Steinmetz		

1 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.
Some potential topics are:

- Knowledge & Educational Technologies
- Self organizing Systems & Overlay Communication
- Mobile Systems & Sensor Networking
- Service-oriented Computing
- Multimedia Technologies & Serious Games

2 Learning objectives

Students shall acquire profound knowledge from current scientific publications, standards and literature on multimedia communication systems and applications which will build the future Internet. In so doing, the students will develop the following competencies:

- Search for and review relevant scientific literature.
- Analyse and evaluate complex technical and scientific information.
- Write technical and scientific abstracts and summary reports.
- Present technical and scientific information.

3 Recommended prerequisites for participation

Solid knowledge in computer communication networks. Lectures in Communication Networks I and II are recommended.

4 Form of examination

Module exam:

- Module exam (Study achievement, Oral/written examination, Default RS)

Report and/or Presentation and/or Colloquium. The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Study achievement, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST

8 Grade bonus compliant to §25 (2)

9 References

Depending on specific topic (selected articles of journals, magazines, and conferences).

Courses

	Course nr.	Course name		
	18-sm-2090-se	Multimedia Communications Seminar II		
	Instructor		**Type**	**SWS**
	Prof. Dr. rer. nat. Björn Scheuermann, Dr. Ing. Julian Zobel, M.Sc. Fridolin Siegmund, Prof. Dr.-Ing. Ralf Steinmetz		Seminar	2

Module name Multimedia Communications Lab II					
Module nr. 18-sm-2070	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 135 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language German/English			**Module owner** Prof. Dr.-Ing. Ralf Steinmetz		

1 Teaching content

The course deals with cutting-edge development topics in the area of multimedia communication systems. Besides a general overview, it provides a deep insight into a special development topic. The topics are selected 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:

- Network planning and traffic analysis
- Performance evaluation of network applications
- Discrete event simulation for network services
- Protocols for mobile ad hoc networks / sensor networks
- Infrastructure networks for mobile communication / mesh networks
- Context-aware communication and services
- Peer-to-peer systems and architectures
- Content distribution and management systems for multimedia/e-learning
- Multimedia authoring and re-authoring tools
- Web service technologies and service-oriented architectures
- Adaptive educational technologies
- Natural language processing in education

The concrete list of topics can be found each semester on the corresponding teaching website of KOM.

2 Learning objectives

The ability to solve and evaluate problems in the area of design and development of future multimedia communication networks and applications shall be acquired. Acquired competences are:

- Design of complex communication applications and protocols
- Implementing and testing of software components for distributed systems
- Application of object-oriented analysis and design techniques
- Acquisition of project management techniques for small development teams
- Writing of software documentation and project reports
- Presentation of project advances and outcomes

3 Recommended prerequisites for participation

Keen interest to explore challenging topics which are cutting edge in technology and research. Further we expect:

- Solid experience in programming Java and/or C# (C/C++)
- Solid knowledge in object oriented analysis and design
- Solid knowledge in computer communication networks are recommended
- Lectures in Communication Networks I (II, III, or IV) are an additional plus

4 Form of examination

Module exam:

- Module exam (Study achievement, Oral/written examination, Default RS)

Report (including submission of programming code) and/or Presentation and/or Oral examination (25 minutes) and/or Colloquium (testate), but never more than two out of it. The type of examination will be announced in the beginning of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6	**Grading** Module exam: • Module exam (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** M.Sc. etit - DT, M.Sc. WI-etit, M.Sc. CE, M.Sc. iCE, B.Sc. und M.Sc. iST
8	**Grade bonus compliant to §25 (2)**
9	**References** Each topic is covered by a selection of papers and articles. In addition we recommend reading of selected chapters from following books: • Andrew Tanenbaum: "Computer Networks". Prentice Hall PTR (ISBN 0130384887) • Christian Ullenboom: "Java ist auch eine Insel: Programmieren mit der Java Standard Edition Version 5 / 6" (ISBN-13: 978-3898428385) • Joshua Bloch: "Effective Java Programming Language Guide" (ISBN-13: 978-0201310054) • Erich Gamma, Richard Helm, Ralph E. Johnson: "Design Patterns: Objects of Reusable Object Oriented Software" (ISBN 0-201-63361-2) • Kent Beck: "Extreme Programming Explained - Embrace Changes" (ISBN-13: 978-0321278654)

Courses

Course nr.	Course name		
18-sm-2070-pr	Multimedia Communications Lab II		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Björn Scheuermann, Dr. Ing. Julian Zobel, M.Sc. Fridolin Siegmund, Prof. Dr.-Ing. Ralf Steinmetz		Lab	3

Module name Lab Exercise on Secure Mobile Networking					
Module nr. 20-00-0552	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language German/English			**Module owner** Prof. Dr. rer. nat. Karsten Weihe		

1	**Teaching content** The Lab Exercise on Secure Mobile Networking covers the applied software development as well as hardware-software development. Topic areas covered are communication networks, IT security, mobile networks and wireless communications as well as the combination of these. Goal is the solving of a given problem by implementation in software or hardware/software in a team. Course contents: - Solving of a problem in the area of communication networks, IT security, mobile networks and wireless communications - Survey on solution alternatives and discussion of pros and cons - Conception of a software architecture or a combined hardware-software architecture - Software/hardware design for the target platform - Prototypical realization on the target platform - Evaluation of the system with respect to performance aspects - Documentation of the implemented solution
2	**Learning objectives** After successfully attending the course, students have aquired the ability to solve problems in the area of secure mobile networking using software technology. The students have gained insight into the design/implementation of complex protocols or applications in one/multiple of the areas of communication networks, IT security, mobile netwokrs and wireless communications. They are able to implement the chosen protocols and application, and to test the functionality as well as to evaluate the performance. Students are able to document the developed software artefacts and to present the project progress and outcomes.
3	**Recommended prerequisites for participation** Successfull participation in an lecture of SEEMOO.
4	**Form of examination** Course related exam: • [20-00-0552-pr] (Study achievement, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-0552-pr] (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**

9	**References** Will be given in lab.

Courses

Course nr. 20-00-0552-pr	**Course name** Secure Mobile Networking Lab		
Instructor Prof. Dr.-Ing. Matthias Hollick		**Type** Lab	**SWS** 4

Module name Multimedia Communications Project II					
Module nr. 18-sm-2130	**Credit points** 9 CP	**Workload** 270 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Every Semester
Language German/English			**Module owner** Prof. Dr.-Ing. Ralf Steinmetz		

1 Teaching content

The course deals with cutting edge scientific and development topics in the area of multimedia communication systems. Besides a general overview it provides a deep insight into a special scientific topic. The topics are selected according to the specific working areas of the participating researchers and convey technical and scientific competences in one or more of the following topics:

- Network planning and traffic analysis
- Performance evaluation of network applications
- Discrete event simulation for network services
- Protocols for mobile ad hoc networks / sensor networks
- Infrastructure networks for mobile communication / mesh networks
- Context-aware communication and services
- Peer-to-peer systems and architectures
- Content distribution and management systems for multimedia / e-learning
- Multimedia authoring and re-authoring tools
- Web service technologies and service-oriented architectures
- Resource-based Learning

2 Learning objectives

The ability to solve and evaluate technical and scientific problems in the area of design and development of future multimedia communication networks and applications using state of the art scientific methods shall be acquired. Acquired competences are:

- Searching and reading of project relevant literature
- Design of complex communication applications and protocols
- Implementing and testing of software components for distributed systems
- Application of object-oriented analysis and design techniques
- Acquisition of project management techniques for small development teams
- Systematic evaluation and analyzing of technical and scientific experiments
- Writing of software documentation and project reports
- Presentation of project advances and outcomes

3 Recommended prerequisites for participation

Keen interest to develop and explore challenging solutions and applications in cutting edge multimedia communications systems using scientific methods. Further we expect:

- Solid experience in programming Java and/or C# (C/C++).
- Solid knowledge in object oriented analysis and design.
- Basic knowledge of design patterns, refactoring and project management.
- Solid knowledge in computer communication networks is recommended.
- Lectures in “Communication Networks I” and “Communication Networks II” are recommended

4 Form of examination

Module exam:

- Module exam (Study achievement, Oral/written examination, Default RS)

Report (including submission of programming code) and/or Presentation and/or Oral examination and/or Colloquium (testate), but never more than two out of it. The type of examination will be announced in the beginning of the lecture.

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

Courses

Course nr.	Course name		
18-sm-2130-pr	Multimedia Communications Project Lab		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Björn Scheuermann, Dr. Ing. Julian Zobel, M.Sc. Fridolin Siegmund, Prof. Dr.-Ing. Ralf Steinmetz		Lab	6

Module name Visual Computing Lab					
Module nr. 20-00-0418	**Credit points** 6 CP	**Workload** 180 h	**Self-study** 120 h	**Module duration** 1 Term	**Module cycle** Every 2. Semester
Language German/English			**Module owner** Prof. Dr. Bernt Schiele		

1	**Teaching content** 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	**Learning objectives** 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	**Form of examination** Course related exam: • [20-00-0418-pr] (Study achievement, Oral/written examination, Default RS)
5	**Prerequisite for the award of credit points** Pass exam (100%)
6	**Grading** Course related exam: • [20-00-0418-pr] (Study achievement, Oral/written examination, Weighting: 100 %)
7	**Usability of the module** B.Sc. Informatik M.Sc. Informatik B.Sc. Computational Engineering M.Sc. Computational Engineering M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik M.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
8	**Grade bonus compliant to §25 (2)**
9	**References** Will be announced in course.

Courses

Course nr. 20-00-0418-pr	**Course name** Lab Visual Computing	
Instructor	**Type** Lab	**SWS** 4

Module name Data Science II					
Module nr. 18-zo-2120	**Credit points** 8 CP	**Workload** 240 h	**Self-study** 180 h	**Module duration** 1 Term	**Module cycle** Winter term
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Teaching content

The course covers the following topics:

- Data Science Advanced Methods
- Data Management + Big data frameworks
- Statistical Learning
  - Recommender Systems
  - Deep Learning
  - Unsupervised Learning
  - Text data analysis
- Final application project. Flexibility to choose from list of projects or come up with own project. Examples:
  - Sound classification
  - Heart rate analysis
  - Activity recognition with acceleration data
  - Hyperspectral data
  - Image classification
  - Health survey

2 Learning objectives

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 Form of examination

Module exam:

- 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 of the lecture.

5 Prerequisite for the award of credit points

Passing the final module examination

6 Grading

Module exam:

- Module exam (Study achievement, Oral/written examination, Weighting: 100 %)

7 Usability of the module

M.Sc. etit - SAE, M.Sc. WI-etit, M.Sc. CE, M.Sc. etit - KTS, M.Sc. iCE, B.Sc. und M.Sc. iST, M.Sc. etit - VAS

8 Grade bonus compliant to §25 (2)

9 References

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

Courses

Course nr.	**Course name**		
18-zo-2120-se	Data Science II		
Instructor		**Type**	**SWS**
Dr.-Ing. Christian Debes		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