List of Modules

Master Computer Science

(Study Foci Embedded Systems and Visual Computing)

Department of Electrical Engineering and Computer Science

University of Siegen

Date: 17.03.21

Important note: Modules and text paragraphs in red are under construction and may not reflect the current state.

Module name	**Advanced Semiconductor and Microelectronics I**
Module level	Master
Abbreviation (if any)	FHME I
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. Choubey
Lecturer	Prof. Dr. Choubey
Module type	Specialization module
Module duration (semester)	1
Frequency	Summer semester
Recommended semester	ab 3.
Language	English
Teaching forms	Lecture with exercise
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	The course is based on the knowledge of the contents of the courses Semiconductor Electronics I, semiconductor electronics II as well as microelectronics I and microelectronics II.
Contents	The Advanced Semiconductor and Microelectronics course deals with various current developments in the fields of semiconductor and microelectronics. The aim is to focus on topics that could not be covered or only briefly covered in the lectures Semiconductor Electronics and Microelectronics due to lack of time. The course FHME is divided into two parts: Laboratory internship with accompanying preparations and/or exercises and lecture with accompanying seminars and/or exercises. The content of the lecture FHME is not fixed, but changes with each new lecture series. Possible topics include MOS technology, memory technology, AD converters, microsensor technology, optoelectronics, bipolar technology, semiconductor components for power electronics, semiconductor components for high-frequency and microwave technology, photovoltaic, thin-film technologies or display technology. The event is held by the students in the form of a lecture series. Under the guidance of a supervisor, each student works on a topic for which a lecture of about 20 minutes will be held.
Intended learning results / competences	In small groups of 3-4 students, the students work with the supervision of the institute to develop a basic understanding of common working methods for the manufacture of semiconductor devices. Depending on the interests of the

	students, current topics in the field of semiconductor and microelectronics are available. The students learn to create a script and to give a lecture, which forms the conclusion of the meeting. For the preparation and execution of the lecture and the following discussion the students learn the acquired knowledge and authority, which go beyond the technical contents and include for example team ability and techniques of the knowledge transfer to convert. The students acquire a fundamental physical understanding of the theoretical processes in semiconductors. The students are familiar with the process technologies required to manufacture the semiconductor device up to the design of special integrated circuits. The acquired knowledge and competences enable the students to work in a team in the microelectronics industry and its environment or at scientific institutions with a high degree of independence, especially in the areas of research and development, production, production development.
Examination type	Oral
Requirement for awarding credit points	Presentation
Literature	

Module name	**Advanced Semiconductor and Microelectronics II**
Module level	Master
Abbreviation (if any)	FHME II
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. Choubey
Lecturer	Prof. Dr. Choubey
Module type	Specialization module
Module duration (semester)	1
Frequency	Winter semester
Recommended semester	after 3rd semester
Language	English
Teaching forms	Lecture and exercise
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	The course requires knowledge of the contents of the Courses Semiconductor Electronics I, Semiconductor Electronics II and Microelectronics I and Microelectronics II.
Contents	The Advanced Semiconductor and Microelectronics course deals with various current developments in the fields of semiconductor and microelectronics. Microelectronics. The aim is to focus on topics that could not or only briefly be covered in the lectures Semiconductor Electronics and Microelectronics due to lack of time. The FHuME course is divided into two parts: Laboratory internship with accompanying preparations and/or exercises and lecture with accompanying seminars and/or exercises. The content of the lecture FHuME is not fixed, but changes with each new lecture series. Possible topics include MOS technology, storage technologies, AD converters, microsensors, optoelectronics, bipolar technology, semiconductor components for power electronics, semiconductor components for high-frequency and microwave technology, photovoltaics, thin-film technologies or display technology. The event is held by the students in the form of a lecture series. Each student works on a topic under the guidance of a supervisor. A lecture of about 20 minutes will be held.
Intended learning results / competences	The goal of the Advanced Semiconductor and Microelectronics II course is to give students an insight into the production of semiconductor devices and microelectronic circuits. For this purpose the students manufacture a semiconductor

	component or a circuit in a team of 2-4 students in the technology line of the institute and under the supervision of at least one very experienced technologist. Typical projects range from the manufacture of a solar cell array to the manufacture of a simple operational amplifier in MOS technology with integrated optical detector. Students learn the processes used in semiconductor manufacturing through hands-on experience, including the use of expensive and complex production equipment. The spectrum of techniques taught ranges from basic cleaning procedures, lithography procedures, doping and deposition procedures to testing the self-manufactured component. The acquired knowledge and competences, which go beyond technical contents, e.g. semiconductor process technology, and for example include team skills, techniques of knowledge transfer, questions of occupational safety and the handling of hazardous substances, should enable the student to work in a team in the microelectronics industry and its environment or at scientific institutions with a high degree of independence, in particular in the areas of research and development, production, product development.
Examination type	Oral
Requirement for awarding credit points	Presentation
Literature	

Module name	**Algorithms I**
Module level	Master
Abbreviation (if any)	
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Markus Lohrey
Lecturer	Markus Lohrey
Module type	Core module
Module duration (semester)	1
Frequency	every winter semester
Recommended semester	starting from first semester of master course
Language	English
Teaching forms	lecture and tutorials
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	none
Requirements for participa-tion with regard to content	Discrete Mathematics for Computer Scientists, Foundations of Theoretical Computer Science
Contents	divide-and-conquer algorithms, greedy algorithms, dynamic programming, algorithms on strings, trees and graphs, sorting algorithms, basic data structures (e.g. search trees)
Intended learning results / competences	The students know basic techniques for the analysis of algorithms and algorithmic design principles and are able to apply these to concrete problems.
Examination type	oral exam to the content of the lecture
Requirement for awarding credit points	successful passing of the exam
Literature	Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein, Introduction to Algorithms (third edition). MIT Press 2009 Thomas Ottmann, Peter Widmayer, Algorithmen und Datenstrukturen (fifth edition). Springer 2012 Uwe Schöning, Algorithmik. Spektrum Akademischer Verlag 2001

Module name	**Communications Engineering / ANT**
Module level	Master
Abbreviation (if any)	ANT (I)
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. O. Loffeld
Lecturer	Prof. Dr. O. Loffeld / scientific Assistants
Module type	Specialization module
Module duration (semester)	1
Frequency	Winter semester
Recommended semester	starting from first semester of master course
Language	German/English
Teaching forms	Lecture (2 SWS) and Seminar (2 SWS)
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	none
Requirements for participa-tion with regard to content	*Basics of communications engineering for computer scientists (strongly recommended) *Basics of signal and system theory (strongly recommended) *Contents: signals and signal characteristics, periodic signals and their analysis, linear systems, convolutional integral and Fourier transform, signal transmission via linear systems
Contents	1. Determined signals in linear time-variant systems 2. Fourier transformation 3. Sampling theorems 4. Correlation functions of determinate signals 5. System and signal theory of low-pass and bandpass signals and systems
Intended learning results / competences	Provision of mathematical and telecommunications fundamentals, skills and abilities. Proficiency: * The term 'signal' * Periodic and non-periodic signals * Linear and non-linear systems * Time variant and time invariant systems * Sampling in time and frequency domain * Folding and correlation * Modulation procedures Skills: * Description of signals in time and frequency domain

	* Description of linear time-invariant systems in the time and frequency domain * Understanding the relationships between time-continuous and time-discrete signals and systems on the basis of sampling theory * Understanding the relationships between periodic and non-periodic signals by sampling in the frequency domain * Measurement of the similarity of signals by minimizing a quadratic distance measure (correlation, correlation by convolution) * Matched filter reception * Lowpass and bandpass systems and signals (understanding and description forms) Competences: *Application of linear system theory for the development of processing algorithms in one- and multidimensional signal processing (coding theory, image processing, image analysis)
Examination type	Written exam (2 hours)
Requirement for awarding credit points	Participation in the seminar or exercise, examination
Literature	Recording of slides and annotations as pdf-file, recording and archiving of the lecture as real media stream, archiving of all documents with the e-learning system Moodle, interactive tests in the Moodle system, Java applets for self-study. The same applies to the seminar. Lecture notes, web contents are updated every semester and referenced in the lecture. Textbooks: * Lüke, Ohm. Signalübertragung. Springer Lehrbuch. * Puente, Leaon, Kiencke, Jäkel. Signale und Systeme. Olderbourg Verlag München

Module name	**Computer Architecture II**
Module level	Master
Abbreviation (if any)	CA II
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Dr. Michael Wahl
Lecturer	Dr. Michael Wahl
Module type	Core module
Module duration (semester)	1
Frequency	Winter semester
Recommended semester	
Language	German/English
Teaching forms	Lecture (2 SWS) and Exercises (2 SWS)
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	none
Requirements for participa-tion with regard to content	Digital logic design, basics of computer architecture
Contents	CA II requires basic knowledge in Computer Architecture, e.g.from the class CA I, which is part of the Bachelor program. The first section of the class shows the development of the architectures over time, based on selected architectures. Driver is the technology, allowing to increase the number of memory levels and interfaces. The focus is set on the IBM Power, but also DEC, Intel Itanium, SPARC and of course the Intel IA86 are presented. In the second section of the class, a set of means for increasing the performance is presented, such as cache management, memory management, and parallelism on the various levels. The third part is dedicated to special processors: digital signal processors, graphic processors, and processors for automotive applications.
Intended learning results / competences	* Development of architectures * Means for improving performance * Specific architectures for specific requirements
Examination type	Oral examination
Requirement for awarding credit points	Term paper / Examination The successful completion of the term paper is a prerequisite for admission to the examination.
Literature	Basic books on Computer architecture, e.g. by Hennessy & Patterson or Andrew Tanenbaum

Module name	**Computer Graphics II**
Module level	Master
Abbreviation (if any)	CG 2
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. A. Kolb
Lecturer	Prof. Dr. A. Kolb
Module type	Core module
Module duration (semester)	1
Frequency	Summer semester
Recommended semester	starting from 4th semester in bachelor course starting from 1st semester in master course
Language	German/English
Teaching forms	Lecture 2 SWS, lab 2 SWS
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	Mathematics for Visual Computing, Computer Graphics I
Contents	Mediation of the extended fundamentals of generative 3D computer graphics with the focus on modeling complex geometries and animation. * Free-form curves and - surfaces * Polygon-meshes, winged-edge and half-edge representations * Modeling techniques * Sub-division surfaces * Keyframe animation, spline-based animation * Polynomial models, inverse kinematics * Procedural animation
Intended learning results / competences	* Students know different ways of describing geometrical forms and are skilled in handling them * Students can reproduce elementary algorithms of computer animation * Students can evaluate animation techniques and utilize them for specific assignments * Students can describe modeling techniques * Students know the main advantages and disadvantages of different modeling techniques and can evaluate and implement them for simple problems * Students can apply mathematical concepts practically
Examination type	Written exam (2 hours)

Requirement for awarding credit points	Examination; successful processing of exercises (50% of points) is prerequisite for the examination
Literature	*Foley, van Dam, Feiner & Hughes. Computer Graphics. Addison Wesley, 1993 *Encarnacao, Strasser & Klein. Graphische Datenverarbeitung. Oldenbourg 1996 *Watt. 3D Computer Graphics. Addison Wesley 2000 *Shirley. Fundamentals of Computer Graphics. AK Peters 2005 *Bungartz, Griebel & Zenger. Einführung in die Computergraphik. Vieweg 1996

Module name	**Computer Graphics III**
Module level	Master
Abbreviation (if any)	CG 3
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Dr. Martin Lambers
Lecturer	Dr. Martin Lambers
Module type	Specialization module
Module duration (semester)	1
Frequency	Winter semester
Recommended semester	starting with the 1st semester
Language	German / English
Teaching forms	Lecture 2 SWS, lab 1 SWS
Courses/labs (hours)	45
Self-studies (hours)	105
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	Basic knowledge from B. CG-VC, Mathematics for VC, Computer Graphics I
Contents	This course imparts enhanced knowledge of Computer Graphics. The focus is on hardware acceleration and shading, realtime-rendering and photo realism. Topics covered in detail include: * Complex material models, BRDFs * Global illumination * Procedural texturing and modeling * Image based rendering, light fields * Point based rendering
Intended learning results / competences	* Students know the different concepts and specific algorithms of photo realistic image synthesis, and are able to choose and apply in practice adequate techniques, in simple contexts * Students know the basic principles of image based rendering, and know how to differentiate them against classical techniques of model based graphics. * Students know basic principles of global illumination calculation and know how to implement them in simple contexts in practice * Students can develop simple GPU-programs for the creation of special graphic effects
Examination type	Oral exam
Requirement for awarding credit points	Examination; successful final project is prerequisite for the examination

Literature	*Eberly. 3D Game Engine Design. Morgan Kaufman, 2006 *Ebert, Musgrave, Peachey, Perlin and Worley. Texturing and Modeling. Morgan Kaufman 2003 *Möller, Haines. Real-Time Rendering. AK Peters, 2008

Module name	**Computer Graphics IV**
Module level	Master
Abbreviation (if any)	CG 4
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Dr. Martin Lambers
Lecturer	Dr. Martin Lambers
Module type	Specialization module
Module duration (semester)	1
Frequency	Summer semester
Recommended semester	starting with the 2nd semester
Language	German / English
Teaching forms	Lecture 2 SWS, lab 1 SWS
Courses/labs (hours)	45
Self-studies (hours)	105
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	
Contents	Subject of this course is the programmnig of highly parallel processors, specifically graphic processors (GPUs), by means of graphic independent interfaces. No graphic knowledge is required. * General Purpose Computations on Graphics Processing Units (GPGPU) * Graphics independent interfaces for programming graphics processing units (CUDA, OpenGL, OpenACC) * Selected algorithms for highly parallel processors
Intended learning results / competences	Students know the principles of graphic independent usage of graphic processors (GPUs) as well as the properties of the necessary interfaces * Students can develop highly parallelized solutions for general problems on graphic processors * Students know the storage and processing concepts for modern GPUs * Students are able to develop simple programs in CUDA
Examination type	Oral exam
Requirement for awarding credit points	Examination; successful final project is prerequisite for the examination
Literature	*Möller, Haines, Hoffman. Real-Time Rendering. AK Peters, 2008 *Ausgewählte aktuelle Forschungspublikationen

Module name	**Convex Optimization for Computer Vision**
Module level	Master
Abbreviation (if any)	
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Michael Möller
Lecturer	Prof. Michael Möller
Module type	Specialization module
Module duration (semester)	1
Frequency	Summer semester
Recommended semester	1-3
Language	English
Teaching forms	Lecture with projector and black board, interactive elements, exercises
Courses/labs (hours)	90
Self-studies (hours)	210
Workload (hours)	300
Credit points	10
Formal requirements for participation	Master studies computer science (visual computing or theoretical informatics) or master studies mathematics
Requirements for participa-tion with regard to content	Solid knowledge of basic mathematics (analysis and linear algebra)
Contents	The following topics will be covered in this module: Convex analysis as the theoretical basis for all algorithms: - Convexity - Existence and uniqueness of minimizers - Subdifferentials - Convex conjugates - Saddle point problems and duality Numerical methods: - Gradient Descent - Proximal Gradient Descent - Proximal point algorithm - Primal-dual hybrid gradient method - Augmented Lagrangian methods - Acceleration schemes, adaptive step sizes, and heavy ball methods for the aforementioned methods Example applications in computer vision and signal processing problems: - Denoising, deblurring, image reconstruction - Depth reconstruction - Implementation of the above numerical methods for the example applications in Matlab

Intended learning results / competences	Upon completion of this module, students will be proficient in the practically relevant aspects of convex analysis. They are able to understand, apply and implement different numerical methods for convex optimization problems involving constraints and non-differentiable functions. The students are also able to reformulate energy minimization problems in a saddle-point and dual form. They will understand the convergence analysis of the proximal point algorithm and can apply the result to several other algorithms by deriving their proximal point form. Students will be able to solve convex optimization arising from standard computer vision problems on their own.
Examination type	Oral exam
Requirement for awarding credit points	Reaching at least 50% of the points on the homework sheets is a requirement for being admitted to the oral exam
Literature	- Lecture notes. - Stephen Boyd, Lieven Vandenberghe. Convex Optimization. Cambridge University Press. 2003. - R. Tyrrell Rockafellar. Convex analysis. Princeton University Press. 1970. - Jean-Baptiste Hiriart-Urruty, Claude Lemaréchal. Fundamentals of convex analysis. Springer. 2004. - Yurii Nesterov. Introductory lectures on convex optimization. Kluwer-Academic. 2003. - Convex Analysis and Monotone Operator Theory in Hilbert Spaces. H. H. Bauschke and P. L. Combettes. 2011. - Jorge Nocedal, Stephen J. Wright. Numerical optimization. - Dimitri Bertsekas. Nonlinear programming. Athena Scientific. 1999. Further references to recent literature will be given in the lecture.

Module name	**Deep Learning**
Module level	Master
Abbreviation (if any)	
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Michael Möller
Lecturer	Prof. Michael Möller
Module type	Specialization course
Module duration (semester)	1
Frequency	Winter semester[1]
Recommended semester	
Language	English
Teaching forms	Lecture and exercise
Courses/labs (hours)	45
Self-studies (hours)	105
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	Previous knowledge in programming and mathematical basics
Contents	- Supervised machine learning as an interpolation problem - Simple network architectures: Fully connected layers, rectified linear units, sigmoids, softmax - Gradient descent for nested functions: The chain rule and it's implementation via backpropagation - Stochastic gradient descent on large data sets, acceleration via momentum and ADAM - Capacity, overfitting and underfitting of neural networks - Training, testing, and validation data sets - Improving generalization: data augmentation, dropout, early stopping - Working with images: Convolutions and pooling layers. Computing derivatives and adjoint linear operators - Getting the network to train: Data preprocessing, weight initialization schemes, and batch normalization - Applications and state-of-the-art architectures for image classification, segmentation, and denoising - Architecture designs: Encoder-decoder idea, unrolled algorithms, skip connections + residual learning, recurrent neural networks

[1] Can also be studied in the summer term, but exclusively in self-study via online material provided in moodle; no further support for the lecture and exercise is given. It is strongly recommended to take the module in the winter semester.

	- Implementations in NumPy and PyTorch: Hands-on practical experience by implementing gradient descent on a fully connected network in NumPy. Introduction to the deep learning framework PyTorch for training complex models on GPUs
Intended learning results / competences	Upon completion of this module, students understand the basic concepts of deep learning. They can analyze the chain rule for nested functions with several variables and are able to implement the gradient descent algorithm for simple networks from scratch. Students are familiar with a deep learning framework and can implement architectures for regression and classification problems on their own. Students are familiar with different design patterns for the architecture of neural networks, and can explains crucial steps for the successful training and generalization of neural networks.
Examination type	Written exam (1.5 hours)
Requirement for awarding credit points	Reaching 50% of the points on the exercises / homework is mandatory for being admitted to the written exam.
Literature	- "Deep Learning" by Ian Goodfellow, Yoshua Bengio and Aaron Courville (available at http://www.deeplearningbook.org/) - Introduction to Python, e.g. at https://github.com/jrjohansson/scientific-python-lectures - Coursera course "Machine Learning" by Andrew Ng

Module name	**Development of the Embedded Systems with FPGAs**
Module level	Master
Abbreviation (if any)	ES_FPGA
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Hamidreza Ahmadian
Lecturer	Hamidreza Ahmadian
Module type	Specialization module
Module duration (semester)	1
Frequency	Winter semester
Recommended semester	starting from 4th semester in bachelor course starting from 1st semester in master course
Language	English
Teaching forms	Lecture 2 SWS, lab 2 SWS
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	none
Requirements for participa-tion with regard to content	*Digital Design *Computer Architecture I
Contents	Embedded system design using Vivado is the central topic of this course. This course gives the students the ability to learn the necessary skills to develop complex embedded systems using the Vivado design suite; understand and utilize advanced development techniques of embedded systems design for architecting a complex system in an All Programmable System on a Chip (SoC). Additionally, this course provides the necessary skills to develop ARM-based SoCs from high level functional specifications to design, implementation and testing on real FPGA hardware using standard hardware description and software programming languages. The particular topics to be covered are: • Introduction to Embedded System Design using Zynq • Zynq Architecture • Implementing Embedded Systems using Programmable Logic • Adding Your Own IP Peripheral • Software Development Environment and Debugging • System Debugging using Vivado Logic Analyzer and SDK • Memory Interfacing • Interrupts

	• Processor Configuration and Bootloader • Programming a Microblaze Processor
Intended learning results / competences	* Students know SoC architectures such as ZYNQ * Students know how to utilize the Hardware platform using development tools (e.g., Vivado) * Students know how to utilize the software platform (Software Development Kit) * Students get familiar with Zedboard and ZYBO Boards. * Students can apply hardware and software concepts practically at the end of the course.
Examination type	Oral exam
Requirement for awarding credit points	Examination; successful processing of exercises is prerequisite for the examination
Literature	* The zynq Book, Louise, Ross, Martin, Bob and David, August 2015 *Xilinx Tuturials, labs and data sheets.

Module name	**Digital Communication Technology I**
Module level	Master
Abbreviation (if any)	DKT I
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. Ch. Ruland
Lecturer	Prof. Dr. Ch. Ruland
Module type	Specialization module
Module duration (semester)	1
Frequency	Winter semester
Recommended semester	starting from 1st semester in master course
Language	German
Teaching forms	Lecture 2 SWS, Exercises 2 SWS
Courses/labs (hours)	45
Self-studies (hours)	105
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	Grundlagen der Nachrichtentechnik (Bachelor)
Contents	* Transmission in baseband * Shannon limit * Modulation procedures * Line coding * Multiplexing (FDMA, WDMA, TDMA, CDMA, PDH, SDH) * Channel coding (block codes, cyclic codes, especially Reed Solomon, convolutional codes, turbo codes, soft input – soft output) * Cross-layer techniques
Intended learning results / competences	The students are able to understand the technologies, algorithms and methods used in modern wired wire-bonded and wireless communication systems. They have all the prerequisites required to subsequently complete master's theses in the field of digital communication systems or to continue research. They have special knowledge in the field of error detecting and correcting codes and can use it not only in communication systems, but also in storage systems and other applications.
Examination type	Oral exam
Requirement for awarding credit points	examination

Literature	* J. Lindner: Informationsübertragung, Springer Verlag * U. Freyer: Nachrichtenübertragungstechnik, Hanser Verlag * J. Ohm, H.D. Lüke: Signalübertragung, Springer Verlag * D. Lochmann: Digitale Nachrichtentechnik, Verlag Technik * K.D. Kammeyer: Nachrichtenübertragung, Vieweg+Teubner Verlag * M. Bossert: Kanalcodierung, Teubner-Verlag * S. Lin, D. Costello: Error Control Coding, Prentice Hall * T. Moon: Error Correction Coding, Wiley

Module name	**Digital Communication Technology II**
Module level	Master
Abbreviation (if any)	DKT II
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. Ch. Ruland
Lecturer	Prof. Dr. Ch. Ruland
Module type	Specialization module
Module duration (semester)	1
Frequency	Summer semester
Recommended semester	starting from 2nd semester in master course
Language	German
Teaching forms	Lecture 2 SWS, practical course 2 SWS
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	none
Requirements for participa-tion with regard to content	DKT I, GNT
Contents	* MAC protocols (wired and wireless) * Switching techniques * Queueing theory for packet switching * Blocking rates for circuit switching/switching node * Quality of Service (IntServ/DiffServ) * Routing procedures * Internet protocols (up to layer 4, VoIP, RTP) * PCM technology, analog/digital conversion * Data compression methods (V. 42bis, arithmetic encoding, lossless, lossy, JPEG-x, MPEG-y) * Source coding
Intended learning results / competences	In Part II, students will be able to understand problems and solutions that arise in the communication of many simultaneous participants. They know what happens in local networks, and how network access in local networks and wireless networks (broadcast-based systems) is carried out. They are able to use queueing theory to formulate requirements to routers, and can design switching nodes for circuit switched connections. They can also apply these techniques for similar applications, e. g. Multi-SIM/Multi ME. Also they master analog to digital conversions, and in general procedures for source coding can adapt them for other applications, if needed.
Examination type	Oral exam

Requirement for awarding credit points	examination
Literature	* J. Lindner: Informationsübertragung, Springer Verlag * U. Freyer: Nachrichtenübertragungstechnik, Hanser Verlag * J. Ohm, H.D. Lüke: Signalübertragung, Springer Verlag * D. Lochmann: Digitale Nachrichtentechnik, Verlag Technik * K.D. Kammeyer: Nachrichtenübertragung, Vieweg+Teubner Verlag * M. Bossert: Kanalcodierung, Teubner-Verlag * S. Lin, D. Costello: Error Control Coding, Prentice Hall * T. Moon: Error Correction Coding, Wiley

Module name	**Distributed Systems**
Module level	Master
Abbreviation (if any)	VS
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. R. Wismüller
Lecturer	Prof. Dr. R. Wismüller
Module type	Specialization course
Module duration (semester)	1
Frequency	Summer semester
Recommended semester	
Language	German/English
Teaching forms	Lecture and exercise
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	Operating Systems I, Algorithms and Data Structures, Object Orientation and Functional Programming
Contents	The course covers the basics of distributed systems, middleware and distributed programming. The topics in detail are: * Definition of terms, hardware and software architectures of distributed systems * Middleware: tasks, programming models, services * Distributed programming with Java RMI * Name services * Process management * Time and state in distributed systems * Coordination and synchronization * Replication and consistency * Distributed file systems * Distributed shared memory
Intended learning results / competences	Students will be able to explain the characteristics of distributed systems, in particular the effects of the lack of global time, and identify the resulting problems in synchronizing and ensuring the consistency of replicated data. They can explain relevant distributed algorithms and use them to solve corresponding problems. They can differentiate between the different architecture models for distributed systems and the different types and tasks of middleware. In

	addition, they are able to develop simple distributed applications using Java RMI.
Examination type	Oral
Requirement for awarding credit points	
Literature	* Andrew S. Tanenbaum, Marten van Steen. Distributed Systems, Principles and Paradigms. Pearson Education, 2016 *George Coulouris, Jean Dollimore, Tim Kindberg, Gordon Blair. Distributed Systems, Concepts and Design. Pearson Education, 2012 *Ulrike Hammerschall. Verteilte Systeme und Anwendungen. Pearson Studium, 2005 *Robert Orfali, Dan Harkey. Client/Server-Programming with Java and Corba. John Wiley & Sons, 1998 *Cay S. Horstmann, Gary Cornell. Core Java 2, Volume 2 – Advanced Features. Sun Microsystems Press / Prentice Hall, 2008 *Torsten Langner. Verteilte Anwendungen mit Java. Markt+Technik, 2002

Module name	**Embedded Control**
Module level	Master
Abbreviation (if any)	EC
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. Roman Obermaisser
Lecturer	Prof. Dr. Roman Obermaisser
Module type	Specialization module
Module duration (semester)	1
Frequency	Winter semester
Recommended semester	starting from 1st semester in master course
Language	English
Teaching forms	Lecture 2 SWS, lab 2 SWS
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	None
Requirements for participa-tion with regard to content	*Fundamentals of Control Theory *Electronics *Basic Digital Electronics *Programming Languages *Modeling and Simulation
Contents	Content: 1. Modeling and Mathematical Descriptions of Dynamic Systems * Discrete Dynamics * Hybrid Systems * Composition of State Machines * Concurrent Models of Computation 2. Design of Embedded Control Systems * Embedded Processors * Memory Architectures * Input and Output * Multitasking * Scheduling 3. Analysis and Verification * Invariants and Temporal Logic * Equivalence, Refinement, Simulations * Reachability Analysis and Model Checking * Quantitative Analysis 4. State-of-the-Art Tools for Embedded Controller Development * Scilab/Xcos

Intended learning results / competences	The purposes of the course are to * become acquainted with application fields of embedded control systems * understand working methods to develop embedded control systems * understand models of embedded control systems and comprehend the interplay of software and hardware with the physical environment * work with state-of-the-art development tools (e.g., Scilab/Xcos) * provide background knowledge to understand the functionality of these development tools. * finally bridge the gap from theory to practical implementing by performing a practical experiment in the lab.
Examination type	Written exam (2 hours)
Requirement for awarding credit points	Examination; successful processing of exercises is prerequisite for the examination
Literature	*E. A. Lee and S. A. Seshia, Introduction to Embedded Systems - A Cyber-Physical Systems Approach, LeeSeshia.org, 2011 *Peter Marwedel. Embedded System Design, Embedded Systems Foundations of Cyber-Physical Systems. 2nd Edition. 2011 *L. Gomes, J.M. Fernandes. Behavioral Modeling for Embedded Systems and Technologies: Applications for Design and Implementation. Information Science Reference. 2009 *P.J. Mosterman. Model-Based Design for Embedded Systems. CRC Press. 2010

Module name	**Embedded Systems**
Module level	Master
Abbreviation (if any)	ES
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. Roman Obermaisser
Lecturer	Prof. Dr. Roman Obermaisser
Module type	Core module
Module duration (semester)	1
Frequency	Winter semester
Recommended semester	starting from 2nd semester in master course
Language	English
Teaching forms	Lecture 2 SWS, lab 2 SWS
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	None
Requirements for participation with regard to content	*Digital Design *Computer Architecture I *Operating Systems I
Contents	The module focuses on system aspects of distributed embedded real-time systems and conveys the central requirements (e.g., real time, determinism, reliability, composability) as well as suitable methods for supporting them. Students learn about different paradigms and design principles for embedded systems. A focus area is coping with contradicting system requirements (e.g., flexibility vs. composability, open system vs. temporal guarantees) and competence for using the most appropriate design principles and methods in a given problem scenario. The course conveys information about new developments (e.g., Internet of things) in addition to basic knowledge (e.g., global time, scheduling), thereby providing the foundation for research in the area of embedded real-time systems. The theoretical knowledge is complemented by case studies and system architectures from different domains (e.g., automotive, avionics). The lab provides further insight and offers practical experience based on the content of the lecture (e.g., programming of embedded systems with microcontrollers, scheduling, timing analysis). Overview of contents: * Context and requirements of embedded real-time systems * Modelling of embedded real-time systems * Global time and temporal relations

	* Reliability * Real-time communication * Real-time operating systems * Real-time Scheduling * Interaction with the environment * Design of embedded systems * Validation * Internet of things * Examples of system architectures
Intended learning results / competences	One objective of the module is that students can describe requirements, paradigms, concepts, platforms and models of embedded systems. In particular, students can explain non functional requirements of embedded systems. They can also describe and apply concepts and methods for real time and fault tolerance. Students will become familiar with different components and design principles in order to apply them in concrete problem scenarios. Students can evaluate different development approaches (e.g., time-triggered and event-triggered control) und map them to application scenarios. Furthermore, students can evaluate platform technologies such as communication protocols, processors and operating systems with respect to their suitability for real-time, safety and reliability requirements.
Examination type	Oral exam
Requirement for awarding credit points	Successful processing of exercises and Examination
Literature	*E. A. Lee and S. A. Seshia, Introduction to Embedded Systems - A Cyber-Physical Systems Approach, LeeSeshia.org, 2011 *Peter Marwedel. Embedded System Design, Embedded Systems Foundations of Cyber-Physical Systems. 2nd Edition. 2011 *L. Gomes, J.M. Fernandes. Behavioral Modeling for Embedded Systems and Technologies: Applications for Design and Implementation. Information Science Reference. 2009 *P.J. Mosterman. Model-Based Design for Embedded Systems. CRC Press. 2010

Module name	**Estimation Theory**
Module level	Master
Abbreviation (if any)	Est
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. O. Loffeld
Lecturer	Prof. Dr. O. Loffeld, scientific assistants
Module type	Specialization module
Module duration (semester)	1
Frequency	Summer semester
Recommended semester	starting from 2nd semester in master course
Language	English
Teaching forms	Lecture 2 SWS, lab 2 SWS
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	None
Requirements for participation with regard to content	*Stochastic Models (strongly recommended), Content wise: *Linear dynamic and stochastic models *probability and random variables (in depth)
Contents	Stochastic Processes *Stochastic processes in continuous and discrete time *description of stochastic processes *classes of stochastic processes *processes with indepependent increments *Brownian motion *continuity and differentialability of stochastic processes *white noise *modeling with additive noise processes *integration of stochastic processes *Wiener's stochastic integral *Markovian processes *Gauss Markov Processes *linear models with white Gaussian noise Estimation Approaches for Stochastic Processes *Kalman filter and different formulations *different approaches to the derivation of Kalman filters Applications *State Space Modelling and Optimal Estimation by Examples
Intended learning results / competences	Provision of mathematical and estimation theory basics, skills and abilities: Proficiency:

	* Stochastic processes * linear dynamic models with stochastic input * optimal estimation principles for dynamic problems Skills: * Modelling dynamic stochastic problems and estimation of time varying unknown states with optimal recursive estimation approaches. competences: * Given a stochastic observation problem of an dynamically changing unknown state, find the optimal estimation solution to determine the unknown state from the noisy observations.
Examination type	Oral exam
Requirement for awarding credit points	Participation in the seminar or exercise, examination
Literature	Recording of slides and annotations as pdf-file, recording and archiving of the lecture as real media stream, archiving of all documents with the e-learning system Moodle, interactive tests in the Moodle system, Java applets for self-study. The same applies to the seminar. Lecture notes, web contents are updated every semester and referenced in the lecture. Textbooks: O. Loffeld. Estimation theory II. Oldenbourg Publishing House Munich *P.S. Maybeck. Stochastic Models Estimation and Control I, II. Academic Press *B.D.O. Anderson, J. B. More. Optimal filtering. Prentice Hall

Module name	**Introduction to Artificial Intelligence**
Module level	
Abbreviation (if any)	
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Roth
Lecturer	Prof. Roth
Module type	Specialization course
Module duration (semester)	1
Frequency	Summer semester
Recommended semester	
Language	English
Teaching forms	Lecture and exercises
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	Basic knowledge of controller systems, Basic knowledge in programming, MatLab
Contents	Fuzzy Logic(FL): - Fuzzy Sets, Membership functions, Expert Systems, Rule-based systems, Fuzzy inference, Mamdani-style inference, Sugenostyle inference - Design of PID-like Fuzzy controllers Artificial Neural Networks (ANN): - Types of ANN, Perceptron, Teaching an ANN, Delta Rule, Multilayer Neural Networks, Back Propagation - Recurrent Networks, Hopfield Network, Bidirectional Associative Memory Genetic Algorithms (GA): - Evolutionary Computation: Evolutionary Strategy & Programming, Genetic Algorithm - GA problem forming, Multi-variable GA, Practical case studies
Intended learning results / competences	Scientific component: - What are FL,ANN,GA and which methods do they use? - Which approach is best for which problems? - When should I use which approach? - How do I model a problem so that my approach can solve it? Competence Students know the basic systems for automated information processing. They will be able to analyze problems and

	determine which methods should be used to find the best solution to the problem.
Examination type	Oral
Requirement for awarding credit points	Examination; exercise project successfully completed
Literature	"Artificial Intelligence, A Guide to Intelligence Systems", M. Negnevitsky “Introduction to Fuzzy Logic using MATLAB”, S. N. Sivanandam, S. Sumathi and S. N. Deepa “Artificial Intelligence A Modern Approach - 2nd Edition”, Russel, Norvig “An Introduction to Genetic Algorithms” , Melanie Mitchell

Module name	**Logic II**
Module level	Master
Abbreviation (if any)	Log II
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Markus Lohrey
Lecturer	Markus Lohrey
Module type	Specialization module
Module duration (semester)	1
Frequency	every summer semester
Recommended semester	starting from first semester of master course
Language	English
Teaching forms	lecture and tutorials
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	none
Requirements for participa-tion with regard to content	Discrete Mathematics for Computer Scientists Fundamentals of Theoretical Computer Science Logic I
Contents	*Undecidability of satisfiability in predicate logic (theorem of Church) * Theorem of Trakhtenbrot on finite satisfiability * Undecidability of arithmetic * Gödel's incompleteness theorem * Automatic structures * Decidability of the Presburger arithmetic * Decidability of real arithmetic * Monadic logic of 2nd order (MSO) * Theorem of Büchi (equivalence of finite automata and MSO)
Intended learning results / competences	The students * know the basic limits of formal methods * master basic techniques for deciding logical theories, * know the connection between logic and automats
Examination type	oral exam to the content of the lecture
Requirement for awarding credit points	successful passing of the exam
Literature	* lecture notes * Ebbinghaus, Flum, Thomas. Einführung in die mathematische Logik. Spektrum Verlag, 1996 * Schöning. Logik für Informatiker, Spektrum Verlag, 2000

Module name	**Machine Vision**
Module level	Master
Abbreviation (if any)	MaS
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. V. Blanz
Lecturer	Prof. Dr. V. Blanz
Module type	Specialization module
Module duration (semester)	1
Frequency	Every second summer semester
Recommended semester	starting from first semester of master course
Language	English
Teaching forms	Lecture and exercise
Courses/labs (hours)	45
Self-studies (hours)	105
Workload (hours)	150
Credit points	5
Formal requirements for participation	none
Requirements for participa-tion with regard to content	Linear Algebra
Contents	Camera Models (perspective projection, homogeneous coordinates), camera calibration, 3D depth reconstruction (trianglulation-based methods, structured light, phase-shift methods, spece-time-analysis), stereo vision (correspondence problem, auto-stereograms, triangulation from disparity, epipolar geometry, fundamental matrix, constrained stereo), multi-view geometry, reconstruction of objects with assumptions on parallel and orthogonal lines, image rectification, 3D face reconstruction using a morphable model, singular value decomposition and Moore-Penrose Pseudoinverse, Foundations of biometry and face recognition, Eigenfaces, PCA, Active Shape and Appearance Models, 2D and 3D Morphable Models, Evaluation techniques (error types, ROC)
Intended learning results / competences	Understanding the challenges of machine vision, judgement on which problems are easy to solve and which are hard or still unsolved, familiarity with some classical problems of machine vision and approaches to solve them, including a historical perspective of the development since the 80s, Knowledge of the theoretical foundations (camera models, projective geometry, image statistics), understanding of the most important techniques and ability to implement them
Examination type	Oral exam
Requirement for awarding credit points	successful passing of the exam
Literature	

Module name	**Master Thesis**
Module level	Master
Abbreviation (if any)	MA
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Department ETI
Lecturer	Department ETI
Module type	Specialization module
Module duration (semester)	1
Frequency	Winter and summer semester
Recommended semester	starting from first semester of master course
Language	English
Teaching forms	Master thesis
Courses/labs (hours)	-
Self-studies (hours)	-
Workload (hours)	900
Credit points	30
Formal requirements for participation	see "Uniform Rules for Examinations" in the Courses of Study of the Department of Electrical Engineering and Computer Science of the Faculty of Science and Technology" §36 para. (4)
Requirements for participa-tion with regard to content	Knowledge in the respective subject area according to the first 3 semesters of Master studies.
Contents	In-depth and special topics of the respective subject area of the problem domain. Key qualifications: 1. most assignments involve extensive system development work; the related planning/organizational skills are acquired 2. the ability to use literature resources and other sources to collect and structure material on the given topic 3. If applicable, the ability to read and understand demanding original English professional literature 4. the ability to draft a lecture on a non-trivial scientific topic in front of a specialist audience (i.e. also to design it didactically correctly) and to present it using standard media 5. the ability to write texts of approx. 60 - 120 pages, usually to explain the corresponding scientific content.
Intended learning results / competences	In the final thesis, the candidate must independently work on a problem in his or her field of study using scientific methods within a specified period of time.
Examination type	MA
Requirement for awarding credit points	1. solving the subject-specific problem, usually connected with extensive development work, 2. writing a report about the work, 3. giving a lecture about the results of the work
Literature	Individually specified for each thesis

Module name	**Microelectronics 1**
Module level	Master
Abbreviation (if any)	ME I
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. Choubey
Lecturer	Prof. Dr. Choubey
Module type	Specialization course
Module duration (semester)	1
Frequency	Winter semester
Recommended semester	starting from first semester of master course
Language	English
Teaching forms	Lecture and exercise
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	
Contents	MOS device: Fabrication, I-V Characteristics, Deep Sub-Micron effects, Subthreshold device operation, CMOS scaling; CMOS Digital Circuits: Inverter and complex gates, Schmitt trigger inputs, Tri-state outputs, Transmission gates ; Digital characteristics: Speed – propagation times, Fan-out, set-up and hold times clock skew, power consumption mechanisms, capacitance charging, leakage, short-circuit currents; Memory: Architectures, Circuits and Sense amplifiers, Tunnelling and flash memories; Signal integrity and high speed readouts
Intended learning results / competences	The learning course of the course are to provide the student with an ability to a) Understand Metal Oxide Semiconductor devices as building blocks for large scale CMOS digital circuits. b) Explain the physics of MOSFET devices in very small dimensions c) Design simple digital circuits like inverters and gates. d) Explain the electrical characteristics of these circuits e) Analyse the speed, timing and power dissipation of digital circuits f) Explain different types of memory modules used in electronic designs, their electrical characteristics and design simple memory cells
Examination type	Written exam (2 hours)
Requirement for awarding credit points	successful passing of the exam

Literature	1) Integrated Circuit Design, by Neil H.E. Weste and David M. Harris, Pearson [also sold as CMOS VLSI Design: A Circuits and Systems Perspective] 2) CMOS Digital Integrated Circuits, Sung-Mo Kang, Yusuf Leblebici and Chulwoo Kim, McGraw Hill 3) Physics of Semiconductor Devices by Sze, Wiley

Module name	**Numerical Methods for Visual Computing**
Module level	Master
Abbreviation (if any)	
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Univ.-Prof. Dr. Michael Möller
Lecturer	Univ.-Prof. Dr. Michael Möller
Module type	Specialization module
Module duration (semester)	1
Frequency	Winter semester
Recommended semester	first semester
Language	English
Teaching forms	Lecture and exercise
Courses/labs (hours)	45
Self-studies (hours)	105
Workload (hours)	150
Credit points	5
Formal requirements for participation	None
Requirements for participation with regard to content	None
Contents	The following topics will be covered in this module: - Error analysis, rounding errors, error amplification, catastrophic cancellation - Linear equations, Gaussian normal equation, minimal-norm solutions > Exact solution via Gaussian elimination (with pivoting) > Iterative methods: Richardson, Jacobi, Gauß-Seidel, Conjugate-Gradient - Numerical methods for computing eigenvectors and eigenvalues, power-method, QR-algorithm - Fixed-point iterations for solving nonlinear equations: Newton's method and gradient descent - Interpolation problems: Polynomial interpolation, Chebyshev roots, best approximations, splines - Numerical integration: Trapezoidal rule, volume and line integrals - Implementation of the above numerical methods for the example applications in Matlab
Intended learning results / competences	Upon completion of this module, students understand are are able to apply and implement numerical methods for basic tasks arising in data sciences including solving linear equations exactly and approximately, computing eigenvalues and -vectors, solving nonlinear equations using Newton's method, and being able to interpolate and integrate functions numerically. They will understand sources of errors in their

	computations and are aware of the condition of algorithms as well as operations that are prone to be unstable. Students will be able to solve visual computing problems that reduce to the above more abstract problem classes on their own using Matlab.
Examination type	Oral
Requirement for awarding credit points	Examination; successful processing of exercises (50% of points) is prerequisite for the examination
Literature	- Lecture notes, - W. Dahmen and A. Reusken, "Numerik für Ingenieure und Naturwissenschaftler", Springer 2008, (in German) - Frank Wübbeling, Skript zur numerischen linearen Algebra, https://www.uni-muenster.de/AMM/num/Vorlesungen/NumerischeLA_WS13/skript.pdf (in German) Further references to recent literature will be given in the lecture.

Module name	**Parallel Computing**
Module level	Master
Abbreviation (if any)	PV
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. Roland Wismüller
Lecturer	Prof. Dr. Roland Wismüller
Module type	Core module
Module duration (semester)	1
Frequency	Winter Semester
Recommended semester	starting from 1st semester in master course
Language	German/English
Teaching forms	Lecture (2 SWS) and practical exercises (2 SWS)
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	none
Requirements for participation with regard to content	Programming skills in C/C++ or Java; Knowledge of basic Operating System concepts, esp. threads and synchronisation
Contents	Parallel processing is a basic technique to increase the performance and throughput of both hardware and software. This course communicates theoretical and practical knowledge of different techniques for parallel processing with a focus on practical applications. The module comprises a lab, where participants will autonomously parallelise small programs with different techniques. The lecture covers the following topics: * Basics: parallelism, architecture of parallel computers, strategies for parallelisation, data dependences * Parallel programming with shared memory: threads, OpenMP, parallel libraries and languages * Parallel programming with message passing: MPI * Performance estimation and optimization
Intended learning results / competences	Students can apply different techniques of parallel processing and can judge their specific strengths and weaknesses. They can solve practical problems with relevant standards, libraries and tools. For a given application, they can assess whether a parallelisation makes sense and if so, which techniques should be used. They can identify those parts of a given sequential program, which can be parallelised and can construct code for these parts. The students can apply relevant methods when designing parallel programs, especially during performance estimation, problem decomposition and the actual parallelisation.

Examination type	Oral examination
Requirement for awarding credit points	Examination; successful participation in the practical lab is required for being admitted to the exam
Literature	*Barry Wilkinson, Michael Allen. Parallel Programming, internat. ed., 2. ed. Pearson Education international, 2005 *A. Grama, A. Gupta, G. Karypis, V. Kumar. Introduction to Parallel Computing, 2. ed. Pearson Education, 2003 *Thomas Rauber, Gudula Rünger. Parallele und verteilte Programmierung. Springer, 2000 *Theo Ungerer. Parallelrechner und parallele Programmierung. Spektrum, Akad. Verl., 1997 *Ian Foster:. Designing and Building Parallel Programs. Addison-Wesley, 1995 *Seyed Roosta. Parallel Processing and Parallel Algorithms. Springer, 2000

Module name	**Project Group**
Module level	Master
Abbreviation (if any)	PG20
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Department ETI
Lecturer	Department ETI
Module type	Practical course
Module duration (semester)	2
Frequency	Regularly
Recommended semester	2nd semester
Language	German/English
Teaching forms	
Courses/labs (hours)	600
Self-studies (hours)	
Workload (hours)	600
Credit points	20
Formal requirements for participation	
Requirements for participa-tion with regard to content	
Contents	The participants in a project group work in a team on a complex task that is relevant to their course of study. The problem is described concretely by the organizer in a project group description which is handed out to the participants before the start of the project group. In the project group description, the minimum goal to be achieved for a successful completion of the project group must be specified. With regard to the motivation of the participants, the problem should be as realistic as possible; interdisciplinary topics are permitted; an external product or deadline constraint should be ruled out.
Intended learning results / competences	Factual knowledge *Deepened and specific technical topics of the respective subject area of the task Key skills *Ability to work in a team; The task of a project group can usually only be fulfilled by sharing the work. The group must divide up the work on its own responsibility, regularly monitor and discuss the progress of the work, plan the next steps, draw up appropriate protocols and organisational techniques, recognise and rectify any faults and problems that may arise.

	*Communication with users: in many cases the task is to implement a system for real users who are not engineers, who do not know the relevant technical terms and cannot assess the technologies. *the ability to access material on a given topic from literature databases and other sources *If applicable, the ability to read and understand demanding original English literature. *the ability to design a lecture on a non-trivial scientific topic in front of a specialist audience (i.e. to design it didactically correctly) and to give it using standard media *the ability to write a report of approximately 50 - 200 pages in a group, presenting the results of the work of the project group
Examination type	Practicum (Final report and presentation)
Requirement for awarding credit points	
Literature	

Module name	**Recent Advances in Machine Learning**
Module level	Master
Abbreviation (if any)	
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Michael Möller
Lecturer	Department ETI
Module type	Specilization course
Module duration (semester)	1
Frequency	Summer semester
Recommended semester	1-2
Language	Englisch
Teaching forms	Lecture and exercise
Courses/labs (hours)	45
Self-studies (hours)	105
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	Prior knowledge in programming, mathematics and machine learning, where the latter can be acquired through various modules such as statistical learning theory, artificial intelligence or deep learning.
Contents	This module will present recent advances in machine learning in different fields of data sciences including imaging, vision, graphics, mechatronics, and sensorics. It addresses advanced techniques in the fields of machine learning, deep learning and artificial intelligence, with a particular focus on recent research papers, novel application areas and open questions in the aforementioned fields. Based on basic prior knowledge gained in other courses, this module specifically focuses on the state-of-the-art in machine learning by introducing recent publications from the leading international conferences on machine learning (e.g. NeurIPS, ICML, ICLR), computer vision (e.g. CVPR, ICCV, ECCV), or their application in fields like computer graphics, 3d reconstruction, robotics, navigation, medicine, or body-worn sensorics. After covering the theory of such works, a project phase will ask every student to implement and apply one of the discussed techniques on their own in one of the leading machine learning frameworks. The results of the project phase need to be presented to the class.
Intended learning results / competences	Upon completion of this module, students have an understanding of some exemplary state-of-the-art research papers on machine learning. They are able to explain their main ideas and concepts. Students are familiar with at least

	one machine learning framework and are able to implement machine learning problems on their own. Additionally, each student specializes in one research paper for which she/he is able to understand, explain, analyse and evaluate the discussed technique. The students are able to run practical experiments for the studied method, and can apply it to new problems or data.
Examination type	Written report
Requirement for awarding credit points	Working on a mini-project, including (re-)implementing or executing project-related code, conducting numerical experiments and preparing a report as well as giving a presentation in the class.
Literature	- Course notes - "Deep Learning" von Ian Goodfellow, Yoshua Bengio und Aaron Courville (frei verfügbar unter http://www.deeplearningbook.org/) - Einführung in Python, z.B. unter https://github.com/jrjohansson/scientific-python-lectures - Coursera-Kurs "Machine Learning" von Andrew Ng

Module name	**Robotics II**
Module level	Master
Abbreviation (if any)	Rob-II
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. Roth
Lecturer	Prof. Dr. Roth
Module type	Specialization course
Module duration (semester)	1
Frequency	Summer semester
Recommended semester	
Language	English
Teaching forms	Lecture and exercise
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	Robotics I
Contents	Based on the basics of robotics from the event "Robotics I", this event will give an introduction into further chapters. A selection will be made from the areas of simulation systems and techniques with which the behavior of a robot can be safely investigated in virtual worlds. In mobile robotics, the topics "locomotion", "sensor technology", "simultaneous localization and mapping" are dealt with.
Intended learning results / competences	* Assessment and application of simulation systems for planning and programming robot systems * Analyzing collision detection methods * Assessment and categorization of locomotion principles of mobile robots * Differentiation and classification of sensors for the localization of autonomous robots * Evaluation of algorithms for path planning * Evaluation of sensors for navigation
Examination type	Oral
Requirement for awarding credit points	

Literature	* Course material * R. Siegwart, I. R. Nourbakhsh: Autonomous Mobile Robots * A. Nüchter: 3D Robotic Mapping * J. L. Jones, A.M. Flynn: Mobile Roboter * J. Altenburg, U. Altenburg: Mobile Roboter

Module name	**Scientific Visualization**
Module level	Master
Abbreviation (if any)	VIS
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. A. Kolb
Lecturer	Prof. Dr. A. Kolb
Module type	Specialization module
Module duration (semester)	1
Frequency	Winter Semester
Recommended semester	starting from 1st semester in master course
Language	German / English
Teaching forms	Lecture: 2 SWS; Lab: 1 SWS
Courses/labs (hours)	45
Self-studies (hours)	105
Workload (hours)	150
Credit points	5
Formal requirements for participation	none
Requirements for participa-tion with regard to content	Basic knowledge of B. Inf-VC; mathematics for VC, Computer Graphics I
Contents	The Visualization lecture treats the visual representation of spatial scientific simulation and measuring data of medicine, natural science and technology. The focus is on interactive illustration techniques of abstract data fields on displayable geometries. The following topics are covered in depth: * Grid types and interpolation * 2D scalar fields * Vector field topology and particle paths * 2D and 3D flow visualization * Direct and indirect volume visualization
Intended learning results / competences	* Students know the various concepts and specific algorithms of scientific visualization * Students are able to practically implement and apply selected visualization techniques * Students can choose and apply appropriate visualization techniques for a given problem in simple situations
Examination type	Oral exam
Requirement for awarding credit points	Examination; successful final project is prerequisite for the examination
Literature	*C. Hansen, C. Johnson. The Visualization Handbook. Elsevier Academic Press, 2005 *K. Engel, M. Hadwiger, J. Kniss, R. Rezk-Salama, D. Weiskopf. Real-Time Volume Graphics. AK Peters, 2006 *Proceedings IEEE Visualization. www.ieee.org

Module name	**Semiconductor Electronics I**
Module level	Master
Abbreviation (if any)	HE-I
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Choubey
Lecturer	Prof. Choubey
Module type	Specialization course
Module duration (semester)	1
Frequency	Winter semester
Recommended semester	
Language	English
Teaching forms	Lecture and exercise
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	The course requires previous knowledge of mathematics. for Electrical Engineers I-III, Basics of the semiconductor physics and physics for electrical engineers.
Contents	In the course Semiconductor electronics the elementary physical processes in the semiconductor. and the properties of the most important semiconductor components. The exercises include practical calculation exercises as a supplement to the more theoretical lecture. The course also includes a laboratory internship in which various semiconductor materials and components are investigated and characteristic curves are recorded.
Intended learning results / competences	The aim of the course Semiconductor Electronics I is to impart basic knowledge of solid-state electronics at a demanding level, which should enable the participant to apply the physical models underlying the description of semiconductor devices (e.g. band model, semiconductor equation system) to problems as they occur in the development and optimization of modern semiconductor devices in science, research and application in industry and academia. The acquired knowledge is applied exemplarily to the pn-junction, which is treated on a high level and under inclusion of different extensions beyond Shockley's basic model. With the taught contents the student should be able to work with a high degree of independence in the field of

	semiconductor device development in the semiconductor industry.
Examination type	Written exam (2 hours)
Requirement for awarding credit points	Examination
Literature	

Module name	**Semiconductor Electronics II**
Module level	Master
Abbreviation (if any)	HE-I
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Choubey
Lecturer	Prof. Choubey
Module type	Specialization course
Module duration (semester)	1
Frequency	Winter semester
Recommended semester	
Language	English
Teaching forms	Lecture and exercise
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	The course requires previous knowledge of mathematics. for Electrical Engineers I-III, Basics of the semiconductor physics and physics for electrical engineers.
Contents	The course Semiconductor Electronics examines the elementary physical processes in semiconductors and derives the properties of the most important semiconductor components. The exercises include practical calculation exercises as a supplement to the more theoretical lecture. The course also includes a laboratory internship in which different semiconductor materials and components are investigated and characteristic curves are recorded.
Intended learning results / competences	The aim of the course Semiconductor Electronics II is the Mediation of knowledge in the field of semiconductor devices at a high level under application of basic solid-state physical models. The exemplary and In-depth treatment of basic components such as Bipolar transistor and MOS field effect transistor for the purpose of Description of the performance data of these components as Function of semi-conductor, technological and geometric parameter should enable the students to to work on similar problems, as they are used, for example, in the development and optimization of modern semiconductor devices in science, research and development. application in industry and academia. The the students should be able to use the knowledge they have acquired in the in the microelectronics industry and its environment. or to scientific

	institutions with a high degree of to become active in self-employment, in particular in the research and development, production, Product development.
Examination type	Written exam (2 hours)
Requirement for awarding credit points	Examination
Literature	

Module name	**Seminar**
Module level	Master
Abbreviation (if any)	
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Department ETI
Lecturer	Department ETI
Module type	Compulsory course
Module duration (semester)	1
Frequency	Every semester
Recommended semester	2^{nd} or 3^{rd} semester
Language	German/English
Teaching forms	
Courses/labs (hours)	30
Self-studies (hours)	120
Workload (hours)	150
Credit points	5
Formal requirements for participation	
Requirements for participa-tion with regard to content	
Contents	Seminars deal with changing technical topics, which are based on the subjects taught in the previous semesters. The topics can deepen already existing professional interests and emphases.
Intended learning results / competences	factual knowledge *The technical contents are secondary to the desired methodological competencies and key qualifications and may supplement a focus chosen in the elective area. Key qualifications *the ability to access material on a given topic from literature databases and other sources * the ability to read, understand and prepare English original literature *the ability to design a lecture on a more complex scientific topic in front of a specialist audience (i.e. to design it didactically correctly) and to give it using standard media *the ability to contribute to discussions in a scientific lecture *the ability to write texts of approx. 10 - 20 pages, usually to explain technical / scientific matters
Examination type	Seminar
Requirement for awarding credit points	Written seminar paper and presentation; regular participation
Literature	

Module name	**Statistical Learning Theory**
Module level	Master
Abbreviation (if any)	StL
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. V. Blanz
Lecturer	Prof. Dr. V. Blanz
Module type	Specialization module
Module duration (semester)	1
Frequency	Summer semester
Recommended semester	starting from 1st semester in master course
Language	English
Teaching forms	Lecture and exercise
Courses/labs (hours)	45
Self-studies (hours)	105
Workload (hours)	150
Credit points	5
Formal requirements for participation	none
Requirements for participa-tion with regard to content	Linear Algebra, Machine Vision
Contents	Definition of the Problem of Learning, Induction, Foundations of Stochastics and Statistics (Conditional Probability, Bayes Theorem, Expectation Values, Variance, Normal Distribution, arithmetic mean, maximum a posteriori methods), linear regression, artificial intelligence and neural networks, principal component analysis, fishers linear discriminant, Support Vector Machines (VC dimension, structural risk minimization, linear soft-margin classifiers, constrained optimization with Lagrange multipliers, kernel methods, non-linear SVM, kernel-PCA)
Intended learning results / competences	Make students familiar with state-of-the-art methods in statistical learning as versatile tools for their career in research and development. The focus is to teach the fundamental problem settings, the benefits and challenges of different approaches, so students are able to recognize potential applications of machine learning and to choose appropriate methods. An in-depth knowledge of approaches such as neural networks and Support Vector Machines that would allow students to implement these algorithms from scratch are desired, but not the primary task of the course.
Examination type	Oral exam
Requirement for awarding credit points	Examination

Literature	*V. Vapnik. The Nature of Statistical Learning Theory. Springer 1999 *Duda, Hart, Stork. Pattern Clasification, 2ed. Wiley 2001 *B. Schölkopf, A. J. Smola. Learning with Kernels. MIT Press, 2002.

Module name	**Stochastic Models**
Module level	Master
Abbreviation (if any)	STM
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. O. Loffeld
Lecturer	Prof. Dr. O. Loffeld, scientific assistants
Module type	Specialization module
Module duration (semester)	1
Frequency	Winter semester
Recommended semester	starting from 2nd semester in master course
Language	English
Teaching forms	Lecture and seminar
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	None
Requirements for participa-tion with regard to content	Communications Engineering (strongly recommended), Grundlagen der Regelungstechnik (GRT) Content wise: * Basics of modern control theory, state space techniques * Basics and foundations of communication and signal theory
Contents	Linear dynamic state space descriptions * Differential and difference equation systems * vectorial formulations * observability * reachability * controllability * stability issues Probability and Static Models * Probability and relative frequency * event space; events; elementary events * sigma algebra * Borel fields * probability axioms * random variables and random vectors * probability distribution and probability distriburgion density * probability distribution and - density of random vectors * multivariate distributions and densities * joint densities * relations between random vectors and variables mapping of random variables and vectors; joint densities and conditional densities; induced densities moments and expectations of random vectors and functions of random vectors, mean,

	correlation and covariance * Gaussian distributions * central limit theorem * conditional expectations of jointly normal random vectors Optimal Estimation Principles * Conditional mean estimation * minimum variance estimation * Bayesian estimation * Kalman Filter for Static Problems * Relations between estimation principles
Intended learning results / competences	Provision of mathematical and estimation theory basics, skills and abilities: Proficiency: * Dynamic Linear Models and State Space Description * Probability and Random Variables Skills: * Modeling linear dynamic systems in state space * solution of state space differential equations * formulation of discrete time equivalent systems * optimal estimation for static stochastic problems * Bayesian estimation * conditional mean estimation * maximum likelihood estimation * recurisve minimum varaince estimation * static Kalman filter Competences: *Given a stochastic observation problem of an static unknown state, find the optimal estimation solution to determine the unknown state from the noisy observations
Examination type	Oral exam
Requirement for awarding credit points	Participation in the seminar or exercise, examination
Literature	Recording of slides and annotations as pdf-file, recording and archiving of the lecture as real media stream, archiving of all documents with the e-learning system Moodle, interactive tests in the Moodle system, Java applets for self-study. The same applies to the seminar. Lecture notes, web contents are updated every semester and referenced in the lecture. Textbooks: *O. Loffeld. Estimationstheorie I. Oldenbourg Verlag München *W.B. Davenport. Probability and Random Variables. Mc Graw-Hill *P.S. Maybeck. Stochastic Models Estimation and Control. Academic Press * B.D.O. Anderson, J.B. More. Optimal Filtering. Prentice Hall

Module name	**Storage Technologies**
Module level	Master
Abbreviation (if any)	SPTE
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Dr. Michael Wahl
Lecturer	Dr. Michael Wahl
Module type	Specialization module
Module duration (semester)	1
Frequency	Summer semester
Recommended semester	starting from 1st semester in master course
Language	German/English
Teaching forms	Lecture (2 SWS) and Exercises (2 SWS)
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	none
Requirements for participa-tion with regard to content	Digital Design, Computer Architecture I
Contents	The lecture is divided into two parts. The first part of the lecture deals with rotating storage media, i. e. on the one hand with the different types of polycarbonate media (CD, DVD, BluRay) and on the other hand with hard disks. The underlying technology is presented and the limits that are currently foreseeable. Students will also learn about new technologies such as patterned media, shingeled writing and heat-assied writing. The second part deals with semiconductor memory. The main focus is on the technologies used to store one bit. Classical cells are SRAM and DRAM as well as EEPROM for the non-volatile memory. There are a whole range of technologies based on different physical principles. Based on the cells, the architecture of a memory is then developed with its hierarchy of sense amplifiers. Finally, the interfaces are of extreme importance for the performance that can actually be achieved.
Intended learning results / competences	Upon completion of the module * students know the memory pyramid from registers, cache, main memory and mass storage to archive systems, * have gained an overview of the different methods of storage on rotating media, with a view to the future being essential, * have understood where the limits of storage density on hard disks are, * are able to explain volatile and non-volatile memory and explain the technologies; and

	* have learned to distinguish well between the values that are possible in the ideal case and those that occur in practice, e. g. in the case of interfaces.
Examination type	Oral examination
Requirement for awarding credit points	Examination
Literature	* William D .Brown, Joe E. Brewer: Nonvolatile Semiconductor Memory Technology. Wiley, 1997 * Tegze P. Haraszti. CMOS Memory Circuits. Kluwer Academic Press, 2000 * Alan B. Marchant: Optical recording. Addison Wesley, 1990 * Ulf Troppens, Rainer Erkens, Wolfgang Müller: Speichernetze. dpunkt, 2008 * Sakhrat Khizroev, Dmitri Litvinow_ Perpendicular Magnetic Recording. Kluwer Academic Publishers, 2004 * E. W. Williams: The CD-ROM and optical disc recording systems. Oxford Science Press, 1996 * Current publications on the topic

Module name	**Telematics Multimedia**
Module level	Master
Abbreviation (if any)	TE MM
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Dr. Kai Hahn (Fak. V)
Lecturer	Kai Hahn
Module type	Specialization module
Module duration (semester)	1
Frequency	Winter semester
Recommended semester	starting from 1st semester in master course
Language	English
Teaching forms	Lecture (2 SWS) with practical exercises (1 SWS)
Courses/labs (hours)	45
Self-studies (hours)	105
Workload (hours)	150
Credit points	5
Formal requirements for participation	none
Requirements for participa-tion with regard to content	Basic knowledge of network technology (Computer Networks) and digital technology e.g. Lecture: Digital technology
Contents	The lecture content deals initially with the physiological and psychological abilities of humans and the resulting constraints for coding the multimedia data. At the beginning there is a summary of the communication bases. The historical foundations of multimedia data include inter alia typographic basics, fonts etc. Basics of vision and color reception are preparing for the raster image data formats. The human ability to hear and psychoacoustics form the audio basics. Building on that audio data formats and compression methods are discussed. The classical (analog) video technology is the initial consideration for digital video compression. MPEG, multimedia encryption standards, as well as the transfer of media content with digital wideband audio / video transmission methods such as DVB. The media law and media economics illuminate the social and economic implications of telematics in the multimedia field
Intended learning results / competences	Knowing the History of Multimedia Deriving needs for media data formats from human senses abilities Assessing the capabilities of multimedia data Applying basic compression ideas on different media types Understanding lossy compression with regard to psycho-acoustics and psycho-optics
Examination type	Written exam (1 hour)

Requirement for awarding credit points	examination
Literature	Peter Henning. Taschenbuch Multimedia. Hanser-Verlag, 2007

Module name	**Telematics Technologies and Applications**
Module level	Master
Abbreviation (if any)	TE TuA
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Rainer Brück
Lecturer	Kai Hahn
Module type	Specialization module
Module duration (semester)	1
Frequency	Summer semester
Recommended semester	starting from 1st semester in master course
Language	German/English
Teaching forms	Lecture (2 SWS) with practical exercises (1 SWS)
Courses/labs (hours)	45
Self-studies (hours)	105
Workload (hours)	150
Credit points	5
Formal requirements for participation	none
Requirements for participa-tion with regard to content	Basic knowledge of network technology (Computer Networks) and digital technology e.g. Lecture: Digital technology
Contents	Telematic technologies part include * Modelling of telecommunication systems * Internet, mobile communications, satellite services * Public telecommunications networks, standardization process * Telematics hardware, medical sensor * Physiological and psychological basics the subsequent Telematics Applications part include: * E-Commerce, Electronic Markets / Marketing, Technical Infrastructure, M-Commerce, payment systems, security, Legal framework, logistics - RFID for trade issues, * Traffic telematics applications Individual traffic, technologies (GPS, DAB ..) * Tele surgery, clinical information systems, electronic medical card * Multimedia Electronic Patient Record, data cards in healthcare, network-based services * Telemedicine in medical care, public health information for consumers and patients * Cost / Benefit Ratio for the doctor and patient, Technological framework Legal framework

Intended learning results / competences	Knowing the History of Telecommunication Understanding the layer model of communication systems Assessing the capabilities of tethered an radio-based communication means Applying basic ideas to areas like e-Commerce, traffic, and medicine Understanding opportunities and limitations of current and future telecommunication
Examination type	Written exam (1 hour)
Requirement for awarding credit points	examination
Literature	Gerhard Krüger, Dietrich Reschke (eds.): Lehr- und Übungsbuch Telematik: Netze - Dienste - Protokolle, Hanser-Verlag, 2004.

Module name	**Ubiquitous Computing**
Module level	Master
Abbreviation (if any)	UC
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. Kristof Van Laerhoven
Lecturer	Prof. Dr. Kristof Van Laerhoven
Module type	Specialization module
Module duration (semester)	1
Frequency	Every Semester
Recommended semester	starting from 1st semester in master course
Language	German/English
Teaching forms	Lecture (2 SWS) with practical exercises (2 SWS)
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	None
Requirements for participation with regard to content	None
Contents	This lecture gives an overview on relevant concepts and technologies (such as the history of ubiquitous computing and underlying visions, embedded systems and cyber-physical systems, mobile computing, wearable computing, and wireless sensor networks). It will also deal with more specific subjects (e.g., context awareness, activity recognition, privacy and security issues, research methods in this emerging field). Case studies will also be given during breaks to give more insights in current developments and the lessons and pitfalls that researchers and engineers have met while deploying such novel systems.
Intended learning results / competences	After following this course, students will be able to orient themselves in research and development projects that involve novel computing systems such as wireless sensor networks and wearables. The exercises will make the students familiar with the latest tools and methods to prototype and develop software for these systems, as well as experiment and set up user studies.
Examination type	Written exam (1 hours)
Requirement for awarding credit points	Examination
Literature	lecture slides plus: Mark Weiser, The computer for the 21st century

Module name	**Ubiquitous Systems**
Module level	Master
Abbreviation (if any)	
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. Kristof Van Laerhoven
Lecturer	Florian Wolling
Module type	Specialization module
Module duration (semester)	1
Frequency	Every Semester
Recommended semester	starting from 1st semester in master course
Language	German/English
Teaching forms	Lab course
Courses/labs (hours)	60
Self-studies (hours)	90
Workload (hours)	150
Credit points	5
Formal requirements for participation	None
Requirements for participa-tion with regard to content	Basic knowledge in technical computer science and programming in C
Contents	During the lab course, the low-level programming of energy-efficient microcontrollers is taught, as they are often utilized in wearable and ubiquitous applications. The practical exercises are based on the modern ultra-low-power microcontrollers MSP430 of Texas Instruments and are coded in C. During the exercises the handling of microcontrollers and their datasheets as well as the structured and low-level programming is trained. The skills will be intensified in a final project, the "Coin Cell Challenge". The lab course is executed individually.
Intended learning results / competences	- A thorough understanding of energy-efficiency - design and development of efficient software on micro-controllers - structured programming for microcontrollers - interpreting datasheets - documentation of software
Examination type	Practicum - Graded exercise sheets (60%) [8 weeks] - Final project (40%) [4-5 weeks]
Requirement for awarding credit points	
Literature	

Module name	**Virtual Reality**
Module level	Master
Abbreviation (if any)	VR
Subtitle (if any)	
Courses (if appropriate)	
Responsible person	Prof. Dr. A. Kolb
Lecturer	Prof. Dr. A. Kolb
Module type	Specialization module
Module duration (semester)	1
Frequency	Summer semester
Recommended semester	starting with semester 2 of the master course
Language	German/English
Teaching forms	Lecture and Lab/Exercise
Courses/labs (hours)	45
Self-studies (hours)	105
Workload (hours)	150
Credit points	5
Formal requirements for participation	none
Requirements for participa-tion with regard to content	Basic knowledge of B. Inf-VC; mathematics for VC, Computer Graphics I
Contents	Virtual Reality is an area which finds application in the human-technology interaction. Participants will be enabled to apply the field of Computer Graphics in the application area VR, and to create problem specific hardware configurations. * Basics, particularly immersion, control flow, components of a VR application * Human perception, eye, ear, sensory perception * VR-hardware: Display devices, motion capturing, input devices, feedback, acoustic feedback * Special aspects of Computer Graphics: Stereo projection, mesh streaming and reduction, LODs * Interaction, rigid-body simulation and collision recognition * Special VR-software environments
Intended learning results / competences	* Students know the important properties of human perception and the particular challenges presented by the creation of sensory stimuli in VR environments. (Image, sound) * Students know the various hardware concepts in the area of display and interaction and are able to choose appropriate software components for simple problems * Students know software concepts and specific algorithms, which are of particular importance in the area of Virtual Reality (particularly stereo-image-creation, LODs) and are able to implement and apply them in programming. * Students know the software packages which are used as

	examples in the VR-Lab of the University of Siegen, and can begin to create simple extensions.
Examination type	Oral exam
Requirement for awarding credit points	Examination; successful final project is prerequisite for the examination
Literature	*D. Eberly. 3D Game Engine Design. Morgan Kaufman, 2001 *A. Watt, F. Policarpo. 3D Games. AddisonWelsley, 2001 *J. Vince. Introduction to Virtual Reality. Springer London, 2004 *G. Burdea und Ph. Coiffet. Virtual Reality Technology. Wiley, 2003