Electrical Engineering and Embedded Systems (Master)

Master of Engineering

Module Manual

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Valid from: SoSe22

Content Modules

Master studies

Program Objectives

The aim of the Master's degree programme "Electrical Engineering and Embedded Systems" is to train young people with a versatile interest in technology who have the basic knowledge (the Bachelor's degree is a prerequisite) to familiarise themselves with special areas in the subject area of electrical engineering and embedded systems. The education includes the teaching of specialised knowledge, but also the development of social skills that make working in groups productive. In addition, the degree programme teaches methods for familiarising oneself with complex contexts and for systematic problem solving. The graduates' field of activity ranges from research, industry and the service sector to public service.
The requirements for engineers in electrical engineering and embedded systems are very diverse. The degree programme therefore aims to convey the subject-specific technical skills in the required breadth and depth. Key qualifications such as language skills, knowledge of project management as well as communication skills and time management are to be taught.

Interrelationship of the modules of the degree programme
The subject-specific and methodical mathematical fundamentals are taught in the first semester. In the degree programme "Electrical Engineering and Embedded Systems", special emphasis is placed on a well-founded and broad-based basic education in mathematics (beyond the Bachelor's level). This comprises the Mathematics module.
The degree programme has two profiles: Autonomous Driving and Internet of Things (IoT), which are covered by the common subjects and specialisations.
The embedded systems essentially consist of computing with Circuit & Systems 1 and Computer Architecture (profile IoT) as well as signal processing (after the sensors) with Signalprocessing 1 and Signalprocessing 2 (as an elective), communication with the environment or system internally with Communication 1 and Communication 2, as well as control engineering with Advanced Control Systems and Embedded Control and finally the calculation and control of the system with Embedded Computing.
The two specialisations Autonomous Driving and IoT allow a deeper insight into the respective areas. The curriculum is rounded off by the project work and the Master's thesis with associated seminar. These modules enable a further individual focus and promote the acquisition of key competences such as teamwork, self-organisation and project management.
Through its modules, the degree programme thus provides an appropriate education in terms of breadth and depth for the demanding professional fields of graduates with an M. Eng. degree in Electrical Engineering and Embedded Systems.

COURSE CONTENTS

ELECTRICAL ENGINEERING AND EMBEDDED SYSTEMS

SEM.	MODULE OVERVIEW						ECTS
1	Mathematics 10		Communication 1 5	Circuit & Systems 1 5	Signalprocessing 1 5	Embedded Computing 5	**30**
2	Communication 2 5	Circuit & Systems 2 5	Signalprocessing 2 5	Advanced Control Systems 5	Embedded Computing 5	Optional Module 5	**30**
3	Master-Thesis incl. Colloquium 25					Embedded Control 5	**30**

■ Lecture subjects ■ Thesis

Advanced Mathematics

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM01
Modul title:	Advanced Mathematics
Module responsible:	Prof. Dr. rer. nat. Wolfgang Ertel
Typ of module:	Mandatory module
Module Content:	1 Linear Algebra (Repetition) - Video Lectures (Gilbert Strang) 2 Computer Algebra - Gnuplot, a professional Plotting Software - Short Introduction to GNU Octave / MATLAB, Python 3 Calculus - Selected Topics (Repetition) - Sequences and Convergence; - Series; - Continuity - Taylor Series - Differential Calculus in many Variables 4 Statistics and Probability (Repetition) - Statistical Parameters - Probability Theory - Distributions - Random Numbers - Principal Component Analysis - Estimators 5 Numerical Mathematics Fundamentals - Arithmetics on the Computer - Numerics of Linear Systems of Equations - Roots of Nonlinear Equations 6 Function Approximation - Polynomial Interpolation - Spline interpolation - Method of Least Squares and Pseudoinverse - Singular Value Decomposition (SVD) 7 Numerical Integration and Solution of Ordinary Differential Equations - Numerical Integration - Numerical Solution of Ordinary Differential Equations - Linear Differential Equations with Constant Coefficients
Courses:	Advanced Mathematics for Engineers Advanced Mathematics for Engineers - Lab

Teaching and learning forms:	Lecture/Practical training
Prerequisites for participation:	Undergraduate Mathematics, e.g. Calculus (multidimensional), Linear Algebra, Statistics, Programming
Applicability of the module:	Mechatronics Electrical Engineering and Embedded Systems Informatik
Prerequisites allocation ECTS:	Portfolio with 80% weight of the written examination (K90) and 20% weight of the laboratory results (P).
ECTS credits:	10
Grading:	benotet
Workload:	30h / 1 ECTS
Duration of the module:	one semester
Frequency of offering:	Winter semester only
Literature:	] W. Cheney and D. Kincaid. Numerical mathematics and computing. Thomson Brooks/Cole, 2007. J. Nocedal and S.J. Wright. Numerical optimization. Springer Verlag, 1999. S.M. Ross. Introduction to probability and statistics for engineers and scientists. Academic Press, 2009. G. Strang. Introduction to linear algebra. Wellesley Cambridge Press, 3rd edition, 2003. H. Schwarz: Numerische Mathematik, Teubner Verlag. M. Brill.: Mathematik für Informatiker. Hanser Verlag, 2001. W. Nehrlich: Diskrete Mathematik, Fachbuchverlag Leipzig.
Compulsory attendance:	no

Competence dimensions Advanced Mathematics

Knowledge and understanding: Deepening of individual components of knowledge

After successfully attending this course the graduates is able to solve mathematical problems arising in typical engineering tasks. Primary focus is on numerically solving on linear problems and on the statistical interpretation of results from measurements. In numerical mathematics, the focus is put on methods for function approximation from data, solution of equations, integration and solution of differential equations. Generation and test of random numbers are essential foundations of simulation and cryptography.

Use, application and generation of knowledge/art: Use and transfer

The graduates have broadened their knowledge in the following fields and are capable of reproducing this knowledge: High level programming languages with built in mathematical functions like Octave or Python will be used for the practical assignments (e.g. programming of algorithms).

Communication and cooperation

Scientific / artistic self-image and professionalism

Communication 1

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM02
Modul title:	Communication 1
Module responsible:	Prof. Dr.-Ing. Frank Fechter
Typ of module:	Mandatory module
Module Content:	Introduction Part A. Channel models for wireless communications 1 Wave propagation (1.1 Free Space propagation, 1.2 Physical propagation models, 1.3 Statistical models of propagation, 1.4 Wideband channels) 2. Noise and Interference (2.1 Noise, 2.2 Interference, 2.3 Link Budget) 3 Spectrum issues Part B. Key technologies of modern wireless systems 4. Code Division Multiple Access (CDMA) 5 Frequency-Division Multiplex 6. Scheduling and rate control 7 Diversity 8. Multi-Hop Networks 9. Network Coding 10. Cognitive radio Part C. Wireless Systems 11. Universal Mobile Telecommunications System (UMTS) 12. Long Term Evolution and System Architecture Evolution 13. Beyond LTE and the path to 5G (13.1 Enhanced Mobile Broadband, 13.2 Massive machine-type communications, 13.3 Ultra-reliable and low-latency communications)
Courses:	Wireless Communication
Teaching and learning forms:	Lecture, exercise, self-study
Prerequisites for participation:	Basics of Communication (Bachelor)
Applicability of the module:	Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	K90
ECTS credits:	5
Grading:	graded
Workload:	150h
Duration of the module:	one semester
Frequency of offering:	Every semester

Literature:	Dahlman, E. et al:4G: LTE/LTE-Advanced for Mobile Broadband. Academic Press, 2014 Dahlman, E. et al:4G: LTE-Advanced Pro and the road to 5G Academic Press, 2016. Molisch, A. F.: Wireless Communications. John Wiley & Sons, 2011 Holma H.; Toskala, A.: WCDMA for UMTS: HSPA Evolution and LTE. John Wiley & Sons, 2006 Holma H.; Toskala, A.: LTE for UMTS: HSPA Evolution to LTE-Advanced. John Wiley & Sons, 2011 Haykin, S.; Moher, M.: Modern Wireless Communications. Pearson Prentice Hall, 2005 Lescuyer, P.; Lucidarme, T.: Evolved Packet System (EPS) – The LTE and SAE Evolution of 3G UMTS. Wiley 2008. Larmo A. et al: The Link-Layer Design. IEEE Communications Magazine. April 2009 Wannstrom J.: LTE-Advanced. www.3gpp.org/technologies/keywords-acromyms/97-lte-advanced.
Compulsory attendance:	no

Competence dimensions Communication 1

Knowledge and understanding: Broadening of prior knowledge

The graduates have broadened their knowledge in the following fields and are capable of reproducing this knowledge: Describe construction and functionality of modern mobile communication systems. They have understood the basic technologies, the architecture and protocols of selected wireless communication systems and they are be able to describe it with his/her own words.

Use, application and generation of knowledge/art: Use and transfer

The graduates are capable of applying the knowledge they have acquired in the following fields: Mathematical methods for planning and optimization of communication systems.
The students are able to calculate mathematically selected problems of wireless communications, e.g. the range of radio transmission systems, diversity gain by multi-antenna systems and channel capacity of channels with relay nodes.

Communication and cooperation

The students work together in groups cooperative and responsible.

Scientific / artistic self-image and professionalism

The students know their own strength and weaknesses with respect to their study achievements.

Communication 2

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM03
Modul title:	Communication 2
Module responsible:	Prof. Dr.-Ing. Andreas Siggelkow
Typ of module:	Mandatory module
Module Content:	Basics of Nearfield Communication Transmission standards Protocols Applications
Courses:	Nearfield Communication
Teaching and learning forms:	Lecture and Project
Prerequisites for participation:	Basics of Communication (Bachelor)
Applicability of the module:	Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	K90
ECTS credits:	5
Grading:	benotet
Workload:	Es wird von einem Workload von 30 Stunden je ECTS ausgegangen.
Duration of the module:	one semester
Frequency of offering:	Every semester
Literature:	Coscun et. al.: Near Field Communication (NFC): From Theory to Practice Wiley, 2012 Hendry :Near Field Communications Technology and Applications. Cambridge University Press, 2014
Compulsory attendance:	no

Competence dimensions Communication 2

Knowledge and understanding: Broadening of prior knowledge

The graduates have deepened their existing knowledge in the following areas and are capable of not only reproducing the corresponding contents but also of explaining them. They understand the underlying principles, the whys and wherefores: - describe the function of NFC systems with own words

Use, application and generation of knowledge/art: Scientific innovation

The graduates are capable of applying the knowledge they have acquired in the following fields and, additionally, of assessing their own approach to the theory-praxis-transfer and the result thereof: - evaluate and optimize NFC systems. The graduates can not only apply their knowledge and assess the application methods and / or results, they can also independently develop further research questions in the following fields: - create applications.

Communication and cooperation

Scientific / artistic self-image and professionalism

Circuit & Systems 1

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM04
Modul title:	Circuit & Systems 1
Module responsible:	Prof. Dr.-Ing. Andreas Siggelkow
Typ of module:	Mandatory module
Module Content:	- ASIC-Design - Bus-Systems - Peripherals in a System-on-Chip (SoC) - Test and Debug of SoC - Principles of Micro-controller - MMU - Parallel Architectures
Courses:	System-on-Chip
Teaching and learning forms:	Lecture and Project
Prerequisites for participation:	Knowledge of computer architectures from Bachelor courses
Applicability of the module:	Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	PF (50% P, 50% K60)
ECTS credits:	5
Grading:	benotet
Workload:	Es wird von einem Workload von 30 Stunden je ECTS ausgegangen.
Duration of the module:	one semester
Frequency of offering:	Every semester
Literature:	1. John L. Hennessy, David A. Patterson; Computer Architecture: A Quantitative Approach 2. David A. Patterson, John L. Hennessy; Computer Organization and Design: The Hardware/Software Interface
Compulsory attendance:	no

Competence dimensions Circuit & Systems 1

Knowledge and understanding: Broadening of prior knowledge

The graduates know the principle of computer architectures. They know how to design an ASIC.

Use, application and generation of knowledge/art: Use and transfer

The graduates can implement and organize a system on Chip with its peripherals. They can implement and use Test- and- Debug methods.

Communication and cooperation

With the contents for the module, sustainable work, design and economics will be teached. It will be improved to a level, that it fits to the needs of companies. The intercultural competence of the graduates will be developed by

- international tandem teams
- mixed teams in the labs
- mixed teams for projects and seminars

Scientific / artistic self-image and professionalism

Profile 1

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM05
Modul title:	Profile 1
Module responsible:	Prof. Dr.-Ing. Andreas Siggelkow
Typ of module:	Compulsory elective module
Module Content:	s. Table 2 and 3 (Modules)
Courses:	see Modules
Teaching and learning forms:	see Modules
Prerequisites for participation:	see Modules
Applicability of the module:	SG: Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	see Modules
ECTS credits:	5
Grading:	benotet
Workload:	see Modules
Duration of the module:	one semester
Frequency of offering:	Every semester
Literature:	see Modules
Compulsory attendance:	no

Competence dimensions Profile 1

Knowledge and understanding: Deepening of individual components of knowledge

see Modules

Use, application and generation of knowledge/art: Use and transfer

see Modules

Communication and cooperation

see Modules

Scientific / artistic self-image and professionalism

see Modules

Signalprocessing 1

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM06
Modul title:	Signalprocessing 1
Module responsible:	Prof. Dr.-Ing. Andreas Siggelkow
Typ of module:	Mandatory module
Module Content:	Deterministic Continuous Signals - Laplace- and Fourier Transforms - Continuous Systems and Circuits for Signal Processing - Stability Issues - Nodal Admittance Method - MATLAB - OP-Amp Circuits - Stochastic Signals - Noise Analysis of OP-Amps - Integrated Lab Exercises
Courses:	Signalprocessing 1 Signalprocessing 1 Lab
Teaching and learning forms:	Lecture and Laboratory / practical course
Prerequisites for participation:	Bachelor knowledge
Applicability of the module:	Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	K90
ECTS credits:	5
Grading:	graded
Workload:	150 h
Duration of the module:	one semester
Frequency of offering:	Every semester
Literature:	[Ghausi] Ghausi, Laker Modern Filter Design, Prentice-Hall, 1981 [Horowitz] Paul Horowitz, W. Hill The Art of Electronics, Cambridge University Press [Cooper] Cooper G. R., McGillem C. D., Probabilistic Methods of Signal an System Analysis, CBS 1986 [Doe] Doetsch, G. Anleitung zum praktischen Gebrauch der Laplace-Transformation. Oldenbourg, 1989
Compulsory attendance:	no

Competence dimensions Signalprocessing 1

Knowledge and understanding: Deepening of individual components of knowledge

The students are able to explain digital filters, stability, and signals.

Use, application and generation of knowledge/art: Scientific innovation

The students are able to explain digital filters, stability, and signals.

Communication and cooperation

With the contents for the module, sustainable work, design and economics will be teached. It will be improved to a level, that it fits to the needs of companies.

The intercultural competence of the graduates will be developed by
- international tandem teams
- mixed teams in the labs
- mixed teams for projects and seminars

Scientific / artistic self-image and professionalism

The graduates understand specifications for analog circuits for signal processing. Thus being able to design new circuits based on the basic circuits and methods known in theory and in practice from the teaching module.

Profile 2

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM07
Modul title:	Profile 2
Module responsible:	Prof. Dr.-Ing. Andreas Siggelkow
Typ of module:	Compulsory elective module
Module Content:	s. Table 2 and 3 (Modules)
Courses:	See choosable modules
Teaching and learning forms:	see Modules
Prerequisites for participation:	see Modules
Applicability of the module:	SG: Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	see Modules
ECTS credits:	5
Grading:	benotet
Workload:	see Modules
Duration of the module:	one semester
Frequency of offering:	Every semester
Literature:	as needed
Compulsory attendance:	no

Competence dimensions Profile 2

Knowledge and understanding: Deepening of individual components of knowledge

See modules

Use, application and generation of knowledge/art: Use and transfer

See modules

Communication and cooperation

See modules

Scientific / artistic self-image and professionalism

See modules

Embedded Control

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM09
Modul title:	Embedded Control
Module responsible:	Prof. Dr.-Ing. Lothar Berger
Typ of module:	Mandatory module
Module Content:	Attendees are first given an overview of recent research in control engineering, applicable for industrial process embedded control, like optimal control, nonlinear robust control, data driven control, application of Kalman filter, and machine learning control. Then attendees group in teams, and each team selects one method for working upon. Each team collaborates in researching literature, working out implementation, visualization, and operation of selected process model and embedded control algorithm, within the lab, either through simulation or embedded design; and prepares a seminar paper and seminar presentation. This seminar presentation is then given by all members of a team consecutively, to the audience of all attendees.
Courses:	Embedded Control Seminar Embedded Control Lab
Teaching and learning forms:	Seminar; Lab - or - E-Learning: Seminar; Homework: Practical work
Prerequisites for participation:	Advanced Control Systems
Applicability of the module:	Master Thesis
Prerequisites allocation ECTS:	RPA (PF: 50% PA graded, 50% R graded): Practical work, documented by a seminar paper and presentation
ECTS credits:	5
Grading:	benotet
Workload:	Presence: 48h, Self-study: 102h - or - Online: 24h, Self-study: 102h, Homework: 24h
Duration of the module:	one semester
Frequency of offering:	Winter semester only
Literature:	
Compulsory attendance:	no

Competence dimensions Embedded Control

Knowledge and understanding: Knowledge Comprehension

Attendees learned about recent research in control engineering, applicable for industrial process embedded control, like optimal control, nonlinear robust control, data driven control, application of Kalman filter, and machine learning control.

Use, application and generation of knowledge/art: Scientific innovation

Attendees learned researching literature, working out implementation, visualization, and operation of industrial process model and embedded control algorithm, and preparing a seminar paper and seminar presentation.

Communication and cooperation

Attendees learned presenting scientific results in a structured manner, utilizing adequate terminology, and gained experience in intercultural team collaboration and communication.

Scientific / artistic self-image and professionalism

Attendees learned developing scientific results through adequate proceeding and planning.

Embedded Computing

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM10
Modul title:	Embedded Computing
Module responsible:	Prof. Dr. rer. nat. Markus Pfeil
Typ of module:	Mandatory module
Module Content:	- Embedded Systems in motor management, ABS, medical devices and its increasing programming needs. - Modeling of embedded systems (Cyber-Physical Systems) - Functions of 32-bit micro controllers (ARM), interface functions, its programming under Linux - Implementation of operating systems on microcontrollers
Courses:	Embedded Computing Embedded Computing Lab Embedded Project
Teaching and learning forms:	Lecture and Laboratory / practical course and Project Lecture with integrated applications, development and programming of functions for embedded systems, project management (project idea, realization, presentation)
Prerequisites for participation:	Bachelor knowledge
Applicability of the module:	Electrical Engineering and Embedded Systems Mechatronics
Prerequisites allocation ECTS:	PF
ECTS credits:	10
Grading:	graded
Workload:	10 ECTS Embedded Computing 150 h (60 h Lecture, 90 h Homework) Embedded Computing Lab 60 h (30 h Lecture, 30 h Homework) Embedded Project 90 h (30 Lecture, 60 h Homework)
Duration of the module:	two semester
Frequency of offering:	Every semester
Literature:	B. P. Douglas; "Real-Time UML", Second Edition. Addision Wesley Longman, Inc., 2000. P. Marwedel; "Embedded System Design", Springer Verlag, 2006. D. Abbott; "Linux for Embedded and Real-time Applications", Elsevier Science, 2003
Compulsory attendance:	no

Competence dimensions Embedded Computing

Knowledge and understanding: Knowledge Comprehension

The graduates have broadened their knowledge in the following fields and are capable of reproducing this knowledge:
- Mechatronic and electrical engineering
- Model and simulate mechatronic systems
- Construct electrical and IT components

Use, application and generation of knowledge/art:

Communication and cooperation

With the contents for the module, sustainable work, design and economics will be teached. It will be improved to a level, that it fits to the needs of companies. The intercultural competence of the graduates will be developed by
- international tandem teams
- mixed teams in the labs
- mixed teams for projects and seminars

Scientific / artistic self-image and professionalism

In the course of their study, the graduates have already reached a level of knowledge and understanding that enables them to analyze not only simple but also complex interactions. On this basis, they are capable of independently identifying scientific or practice-related issues in the following fields:
- mechatronic questions
- model and simulate mechatronic systems
- construct electrical and IT components
- present mechatronic projects

Optional Module

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM11
Modul title:	Optional Module
Module responsible:	Prof. Dr.-Ing. Andreas Siggelkow
Typ of module:	Compulsory elective module
Module Content:	See table of electives (published every semester)
Courses:	See table of electives (published every semester)
Teaching and learning forms:	See table of electives (published every semester)
Prerequisites for participation:	Dependent on the lecture
Applicability of the module:	SG: Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	See table of electives (published every semester)
ECTS credits:	5
Grading:	See table of electives (published every semester)
Workload:	See table of electives (published every semester)
Duration of the module:	one semester
Frequency of offering:	Every semester
Literature:	as needed
Compulsory attendance:	no

Competence dimensions Optional Module

Knowledge and understanding: Deepening of individual components of knowledge

Use, application and generation of knowledge/art: Scientific innovation

The graduates can develop sustainable products and learn the content of a new aspect of embedded systems. The graduates can create sustainable products under the aspects of different kinds of embedded systems.

Communication and cooperation

Scientific / artistic self-image and professionalism

Master Thesis

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM12
Modul title:	Master Thesis
Module responsible:	Prof. Dr.-Ing. Andreas Siggelkow
Typ of module:	Mandatory module
Module Content:	The students should prove their knowledge of the theoretical and practical lectures on an engineering project. With the contents for the module, sustainable work, design and economics will be teached. It will be improved to a level, that it fits to the needs of companies.
Courses:	Master-Thesis incl. Colloquium
Teaching and learning forms:	Engineering experience
Prerequisites for participation:	The Master's thesis can only be commenced if all courses and related coursework required for semesters EMM1 and EMM2 have been completed, corresponding to at least 50 credit points.
Applicability of the module:	SG: Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	MT After completion of the Master's thesis the results shall be presented at the Hochschule Ravensburg-Weingarten – University of Applied Sciences in an event open to all members of the university.
ECTS credits:	25
Grading:	graded
Workload:	The Master's thesis shall have a duration of 6 months. It will be assessed and graded by two professors one of whom shall be lecturing at the Hochschule Ravensburg-Weingarten – University of Applied Sciences.
Duration of the module:	one semester
Frequency of offering:	Every semester
Literature:	as needed
Compulsory attendance:	no

Competence dimensions Master Thesis

Knowledge and understanding: Knowledge Comprehension

The students are able to define, work on, evaluate and explain scientific topics.

Use, application and generation of knowledge/art: Scientific innovation

The students are able to define, work on, evaluate and explain scientific topics.

Communication and cooperation

The students are able, by means of a scientific project, to implement, discuss and explain their theoretical and practical skills.

Scientific / artistic self-image and professionalism

Realize an engineering project by means of the knowledge so far achieved.

- Energy transition,
- Sustainable economic activity,
- Application of green energy,
- Application of autonomous cars and the problems,
- embedded systems and IoT, Industry 4.0 and autonomous driving.

Communication in international teams in projects and seminars.

Computer Vision

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM13
Modul title:	Computer Vision
Module responsible:	Prof. Dr. rer. nat. Stefan Elser
Typ of module:	Elective module
Module Content:	1. Brief introduction 2. The pinhole camera model 3. Recognition 4. Motion analysis 5. 3D reconstruction We will take a look at both, traditional and machine learning algorithms in Computer Vision. For traditional algorithms, we will work with OpenCV. For machine learning algorithms, we will take a look at the TensorFlow Object Detection API or a comparable framework. As part of this course, you will implement or evaluate one of these algorithms using C++ or Python. The algorithms will either have to work on already recorded data (like the datasets above) or a given sensor.
Courses:	7781 Computer Vision
Teaching and learning forms:	Vorlesung
Prerequisites for participation:	Good understanding of mathematics in general. Good understanding of at least one programming language, preferable Python or C++.
Applicability of the module:	Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	PF consiting of 50% PA and 50% K60
ECTS credits:	5
Grading:	benotet
Workload:	ca. 50h für Lehrveranstaltungen, ca. 100h für das Selbststudium (Vor- und Nachbereitung, Prüfungsvorbereitung)
Duration of the module:	one semester
Frequency of offering:	Summer semester only
Literature:	Szeliski, Richard. "Computer vision: algorithms and applications." Springer Science & Business Media Janai, Joel, et al. "Computer vision for autonomous vehicles: Problems, datasets and state of the art.", arXiv:1704.05519v2
Compulsory attendance:	no

Competence dimensions Computer Vision

Knowledge and understanding: Deepening of individual components of knowledge

Absolventinnen und Absolventen haben ihr Wissen auf folgenden Gebieten erweitert und können dieses Wissen auch wiedergeben:
Grundlegende Algorithmen der Computer Vision wie Object Detection, Motion Analysis, 3D Reconstruction.

Use, application and generation of knowledge/art: Use and transfer

Absolventinnen und Absolventen können das Wissen aus folgenden Themenbereichen praktisch anwenden:
Implementierung von Computer Vision Algorithmen und deren Evaluation.

Communication and cooperation

Scientific / artistic self-image and professionalism

Lidar and Radar Systems

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM14
Modul title:	Lidar and Radar Systems
Module responsible:	Prof. Dr. rer. nat. Stefan Elser
Typ of module:	Elective module
Module Content:	1. Brief introduction 2. Radar sensors and signals 3. Radar: Velocity and distance measurement 4. Lidar sensors 5. Lidar: Distance measurement 6. Algorithms: simple object detection and tracking We will focus on automotive applications but also take a look at other applications. As part of this course, you will use a sensor or already recorded data to implement your own algorithms or evaluate already existing functions using C++ or Python
Courses:	7945 Lidar and Radar Systems
Teaching and learning forms:	Vorlesung
Prerequisites for participation:	Good understanding of mathematics in general. Good understanding of at least one programming language, preferable Python, C or C++.
Applicability of the module:	Electrical Engineering and Embedded Systems
Prerequisites allocation ECTS:	PF consiting of 50% PA and 50% K60
ECTS credits:	5
Grading:	benotet
Workload:	approx. 50h for lectures, approx. 100h for self-study (preparation and follow-up, exam preparation)
Duration of the module:	one semester
Frequency of offering:	Winter semester only
Literature:	Merril Ivan Skolnik: "Introduction to radar systems", McGraw Hill Book Co. Christian Wolff: "Radartutorial", www.radartutorial.eu Feng, Di, et al. "Deep multi-modal object detection and semantic segmentation for autonomous driving: Datasets, methods, and challenges." IEEE Transactions on Intelligent Transportation Systems (2020).
Compulsory attendance:	no

Competence dimensions Lidar and Radar Systems

Knowledge and understanding: Deepening of individual components of knowledge

Absolventinnen und Absolventen haben ihr Wissen auf folgenden Gebieten erweitert und können dieses Wissen auch wiedergeben:
Physikalische Grundlagen von Radar- und Lidar-Sensoren, grundlegende Algorithmen zur Signalauswertung, Geschwindigkeitsberechnung und Objekterkennung.

Use, application and generation of knowledge/art: Use and transfer

Absolventinnen und Absolventen können das Wissen aus folgenden Themenbereichen praktisch anwenden:
Implementierung und Evaluation einer Objekterkennung in Punktewolken.

Communication and cooperation

Scientific / artistic self-image and professionalism

SW-HW-Design

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM15
Modul title:	SW-HW-Design
Module responsible:	Prof. Dr.-Ing. Andreas Siggelkow
Typ of module:	Compulsory elective module
Module Content:	- Introduction to System-on-Chip - Requirements management - Writing a Specification - Modelling (SystemC and VHDL) of a SoC - Development of a SoC
Courses:	SW- and HW-Design
Teaching and learning forms:	Lecture and Project
Prerequisites for participation:	Bachelor knowledge of digital circuit design, Circuit & Systems 1, VHDL and C++
Applicability of the module:	SG: Electrical Engineering and Embedded Systems SG: Master Mechatronics SG: Master Informatik Module: Master-Thesis
Prerequisites allocation ECTS:	PF (50% Practical, 50% K60) Practical: - Requirements (10% of 50%) - 1. Specification (10% of 50%) - 1. Simulation Sign-Off (10% of 50%) - 2. Simulation Sign-Off (10% of 50%) - Final Specification (40% of 50%) - Presentation & Questions (20% of 50%) K60: - 50%
ECTS credits:	5
Grading:	graded PF (50% P, 50% K60)
Workload:	30 h per ECTS = 150 h in total 60 h for lectures 90 h for preparations
Duration of the module:	one semester

Frequency of offering:	Winter semester only
Literature:	1. Arora, Mohit; The Art of Hardware Architecture: Design Methods and Techniques for Digital Circuits 2. Douglas Perry; VHDL : Programming By Example 3. Patrick Schaumont; A Practical Introduction to Hardware/Software Codesign 4. SystemC from the Ground Up
Compulsory attendance:	yes
Reason:	1. Lab.- work 2. minimum 80 % 3. there will be dates for repetition of tasks (Because of Corona, the presence times will be reduced)

Competence dimensions SW-HW-Design

Knowledge and understanding: Deepening of individual components of knowledge

The graduates know what the specifics of a System-on-Chip are. They know how to model a complex electrical system (SoC).

Use, application and generation of knowledge/art: Use and transfer

The graduates will be able to develop a SoC and to describe a SoC with SystemC. They will be able to describe a SoC with VHDL and synthesize it.

Communication and cooperation

The intercultural competence of the graduates will be developed by

- international tandem teams
- mixed teams in the labs
- mixed teams for projects and seminars

With the contents for the module, sustainable work, design and economics will be teached. It will be improved to a level, that it fits to the needs of companies.

Scientific / artistic self-image and professionalism

The graduates can organize an architecture and a team of a SW-HW project (System Architect).

Computer Architecture

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	EMM16
Modul title:	Computer Architecture
Module responsible:	Prof. Dr.-Ing. Andreas Siggelkow
Typ of module:	Compulsory elective module
Module Content:	- A general overview of computer architectures - Critical discussion of design criteria - Scalar architectures - Instruction level parallelism - Thread level parallelism - Memory hierarchies - ARM and RISC-V architecture
Courses:	Computer Architecture
Teaching and learning forms:	Lecture and Project
Prerequisites for participation:	Basics of computer architectures
Applicability of the module:	SG: Electrical Engineering and Embedded Systems Module: Master-Thesis
Prerequisites allocation ECTS:	K90
ECTS credits:	5
Grading:	graded
Workload:	30 h per ECTS = 150 h in total 60 h for lectures 90 h for preparations
Duration of the module:	one semester
Frequency of offering:	Summer semester only
Literature:	J.L. Hennesy, D.A. Patterson; "Computer Architecture"; Morgan Kaufmann Publisher D.A. Patterson, J.L. Hennesy; "Computer Organization and Design"; Morgan Kaufmann Publisher
Compulsory attendance:	no

Competence dimensions Computer Architecture

Knowledge and understanding: Deepening of individual components of knowledge

The graduates know the difference of scalar and super-scalar architectures, they know how to evaluate the different kinds of caches and memory administrations.

Use, application and generation of knowledge/art: Scientific innovation

The graduates know the difference of scalar and super-scalar architectures, they know how to evaluate the different kinds of caches and memory administrations.

Communication and cooperation

The intercultural competence of the graduates will be developed by - international tandem teams

- mixed teams in the labs

- mixed teams for projects and seminars

With the contents for the module, sustainable work, design and economics will be teached. It will be improved to a level, that it fits to the needs of companies.

Scientific / artistic self-image and professionalism

The graduates can organize an architecture and a team of a CPU project (System Architect).

Advanced Control Systems

Course of study:	Electrical Engineering and Embedded Systems (Master)
Degree:	Master of Science (M.Sc.)
Modul number:	MM10
Modul title:	Advanced Control Systems
Module responsible:	Prof. Dr.-Ing. Lothar Berger
Typ of module:	Mandatory module
Module Content:	Attendees are first given an introduction to analysis and modeling of dynamic systems - electrical, mechanical, and thermal. Then, design and optimization of single and multiple stage digital PID control is presented, as well as single-input and multi-input state control - without and with observer, optimal control, and model-predictive control. Finally, adaptive control methods are illustrated; based upon recursive parameter estimation, and neural nets. Within the complementary lab, attendees are educated to choose and implement suitable digital control methods for given dynamic systems - like mixer tank setup and balanced beam setup - utilizing computer-based tools like MATLAB/Simulink; as C programmed algorithms.
Courses:	Digital Control Digital Control Lab
Teaching and learning forms:	Lecture; Lab - or - E-Learning: Lessons, Exercises; Homework: Practical work
Prerequisites for participation:	Advanced Mathematics
Applicability of the module:	Simulation of Mechatronic Systems, Integration of Mechatronic Systems, Robotics, Embedded Control, Scientific Project, Master Thesis
Prerequisites allocation ECTS:	K60: Written examination; 60 minutes
ECTS credits:	5
Grading:	benotet
Workload:	Presence: 60h, Self-study: 90h - or - Online: 36h, Self-study: 90h, Homework: 24h
Duration of the module:	one semester
Frequency of offering:	Summer semester only
Literature:	Script - or - lessons, exercises, and sample solutions; and complementary: Burns, R.S., Advanced Control Engineering, Butterworth-Heinemann Macia, N. F., Thaler, G. J.: Modeling and Control of Dynamic Systems, Cengage Learning Moudgalya, K. M.: Digital Control, Wiley Press, W. H., Teukolsky, S. A., Numerical Recipes in C, Cambridge
Compulsory attendance:	no

Competence dimensions Advanced Control Systems

Knowledge and understanding: Deepening of individual components of knowledge

Attendees learned about models of dynamic systems - electrical, mechanical, and thermal - and both classical control methods, like digital PID control, and advanced control methods, like state control without/with observer, model-predictive control, and adaptive control.

Use, application and generation of knowledge/art: Scientific innovation

Attendees learned to characterize, model, and simulate dynamic systems - electrical, mechanical, and thermal - and choose and implement suitable digital control methods, from both established methods, like digital PID control, and advanced methods, like state control without/with observer, optimal control, model-predictive control, and adaptive control. Attendees learned to assess these digital control methods, regarding effort, safety, and cost-effectiveness; and how to implement these, utilizing computer-based tools like MATLAB/Simulink; as C programmed algorithms. Through the complementary lab, attendees learned to choose and implement suitable digital control methods for given dynamical systems; like mixer tank setup and balanced beam setup.

Communication and cooperation

Attendees learned about presenting and applying advanced digital control methods as a systems science; aimed at interdisciplinary projects; operated within a team of scientists, engineers, designers, and economists.

Scientific / artistic self-image and professionalism

Attendees learned about economical and ecological considerations in choosing, implementing, and optimizing advanced digital control methods for industrial processes.

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