Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Faculty of Life Sciences

Module compendium

Master degree programme
Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems

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Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

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Module compendium

Master degree programme

Biomedical Engineering:
Signal Processing-, Imaging- and Control-Systems

Faculty of Life Sciences
Department Medizintechnik

June 2015

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Introduction

This module compendium describes the course of studies "Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems" of the Hamburg University of Applied Sciences. It contains a tabular overview of the modules and courses and a detailed description of each module.

The full time study is designed for 3 semesters (1½ years). The graduate-level courses cover mathematical, scientific and engineering knowledge focused on the field of biomedical engineering with emphasis on the processing, control and imaging of biomedical signals and physiological control loops including virtual reality applications. The course is completed by regulatory and technology assessment aspects. Most lectures are complemented by associated practical courses with up-to-date software tools and hardware, e.g. in our research labs or at the hospital sites of our collaboration partners. In a mandatory scientific project the students are engaged in autonomous scientific studies in small groups. Enhanced soft skills are acquired in the seminars and during the lectures by intense discussions and small projects like preparation of presentations, posters and papers. In the master thesis, the students demonstrate their ability for autonomous scientific work at graduate level. The courses are held in English language.

The degree “Master of Science” is a second degree qualifying for a profession. It entitles its holder to exercise professional work in the field of biomedical engineering.

Graduates have the ability to independently acquire new fields of knowledge and to solve complex problems, even above the current state of knowledge, using scientific methods. Graduates are capable to isolate problems in a new area of expertise or such an area in development and to encircle the most probable solution approach. They have the continuing ability of composing new technical solutions and new process strategies in the field of biomedical engineering and to transfer these solutions into clinical use or in industrial production. Although the course is designed for students interested in designing biomedical applications, graduates can not only work in research & development, but also in a company’s production division or in technical functions in a hospital or research institutes. Graduates are qualified to join a doctorate program subsequently of this program.

The Study and Examination Regulation for this course (Studiengangsspezifische Prüfungs- und Studienordnung des Masterstudiengangs Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems (M.Sc. an der Hochschule für Angewandte Wissenschaften Hamburg) as well as the General Study and Examination Regulation for Bachelor- and Master Courses of Studies in Engineering, Natural and Health Science as well as Informatics of the Hamburg University of Applied Sciences (HAW) (Allgemeine Prüfungs- und Studienordnung für Bachelor- und Masterstudiengänge der Ingenieur-, Natur- und Gesundheitswissenschaften sowie der Informatik an der Hochschule für Angewandte Wissenschaften Hamburg (APSO-INGI)) are important applicable documents, too. These and more applicable regulations and further information are accessible at the HAW websites, in particular at the sites of the Faculty of Life Sciences, Department Medizintechnik.

Qualification goals: Master degree programme Biomedical Engineering

<table>
<tr><td colspan="2">General qualification goals: Master degree programme Biomedical Engineering
Versatility with regard-to different occupational fields
Transition from university to work
Self-regulated work (scientific or engineering)
Effektice work design (for self and others)
Personal development and mastery (e.g., pursuing a Ph.D. project)</td></tr>
<tr><td>Skill acquisition goals</td><td>Modules</td></tr>
<tr><td>Comprehension 1
Graduates will be able to describe and interpret the mathematical and technical foundations (essential theory) of signal processing, imaging- and control-systems
Graduates will be able to identify an articulate critical elements of engineering knowledge of health technologies</td><td>01 Mathematics
02 Data Acquisition
03 Advanced Biosignal Processing</td></tr>
<tr><td>Comprehension 2
Graduates will be able to develop integrated mental models of technical solutions based on essential mathematical and engineering theory (e.g., understand the function of medical image technology or control systems).
Graduates will be able to generalize principles of technical solutions to individual or context-related applications of a specific technological strategy.</td><td>04 Medical Image Processing
05 Application of Imaging Modalities
06 Advanced Control Systems
07 Modelling of Medical Systems
08 Medical Real Time Systems
09 Simulation and Virtual Reality in Medicine</td></tr>
<tr><td>Analysis objectives and tasks 1
Graduates will be able to formulate appropriate (operational) questions in order to solve a given task or problem
Graduates will be able to evaluate technical solutions (in diagnostics or therapy) in terms of functional logic and constraints. They will be able to recognize errors and missing information for further exploration and inquiry.
Graduates will be able to determine whether technical solutions are evidence based by referring to relevant scientific literature and/or technical standards presented to them.
Graduates will be able to select the best among alternatives based on an understanding of medical technologies and application contexts</td><td>Module 1-12
10 Biomedical Project
11 HTA/Regulation Affairs
12 Master Thesis</td></tr>
</table>

Skill acquisition goals	**Modules**
Finding and use of knowledge in new situations • Graduates will be able to transfer knowledge and practical skills to new situations (e.g., in development and application) • Graduates will be able to identify relevant sources of knowledge and evidence related to a problem and conduct a sound literature research • Graduates will be able to assess scientific evidence in the field of biomedical engineering and provide arguments for the selected evidence	Modules 02, 04, 05, 06, 07, 08, 09 (Practical work) Especially: 10 Biomedical Project 12 Master Thesis
Problem solving, research and decision making • Graduates will be able to generate and test research or practical hypothesis • Graduates will be able to plan and execute a research or evaluation design (specifying goals, process monitoring, process adjustment, outcome evaluation)) • Graduates will be able to develop strategies how to reach a goal coping with obstacles or limiting conditions • Graduates will be able to present research or problem solving outcomes and defend them • Graduates will be able to assess societal effects of new health technologies	Modules 02, 04, 05, 06, 07, 08, 09 (Practical work) Especially: 10 Biomedical Project 11 HTA/Regulatory Affairs 12 Master Thesis
Self-system, communikation • Graduates will be able to determine and analyze their motivation to learn new content • Graduates will be able to determine, analyze and change group dynamics in project teams • Graduates will be able to control their actions (e.g., establishing a task schedule, monitoring progress, adjusting) • Graduates will be able to present complex questions to a broad audience and critically discuss program related content	Modules 02, 04, 05, 06, 07, 08, 09 (Practical work) Especially: 10 Biomedical Project 12 Master Thesis

Module and course structure

Nr.	Modul	CP	Semester	Lehrveranstaltung	Course Type	SHW	Achievement type	Exam type	Group size
1	Mathematics	7	1	Numerical Mathematics	ST	4	PL	K, H, R, M	20
			1	Theroretical Mathematics	ST	2			
2	Data Acquisition	5	1	Data Acquisition	ST	2	PL	K, H, R; M	20
			1	Data Acquisition, **Practical Work**	ST	2			20
3	Advanced Biosignal Processing	5	1/2	Biosignal Processing	ST	2	PL	K, H, R, M	20
			1/2	Advanced Filtering Techniques for Biosignals	ST	2			
4	Medical Image Processing	5	1/2	Medical Image Processing	ST	2	PL	K, H, R, M	20
			1/2	Medical Image Processing, **Practical Work**	ST	2			20
5	Application of Imaging Modalities	5	1/2	Advanced Imaging (MR, US, CT)	ST	2	PL	K, H, R, M	20
			1/2	Advanced Imaging (MR, US, CT) **Practical Work**	ST	2			20
6	Advanced Control Systems	5	1/2	Advanced Control Systems Methods	ST	2	PL	K, H, R, M	20
			1/2	Biological Rhythms and homeostatic Control	ST	2		K, H, R, M	20
			1/2	Advanced Control Systems, Tools, **Practical Work**	ST	2		LA	20
7	Modelling Medical Systems	5	1	Modelling Methods	ST	2	PL	K, H, R, M	20
			1	Modelling Tools, **Practical Work**	ST	2			20
8	Medical Real Time Systems	7	1/2	Medical Real Time Systems Software Implementation	ST	1	PL	H, K, R, M	20
			1/2	Medical Real Time Systems Hardware Implementation	ST	1			20
			1/2	Medical Real Time Systems, **Practical work**	ST	2			20
9	Simulation and Virtual Reality in Medicine	6	1/2	Simulation and Virtual Reality in Medicine	ST	4	PL	H, K, R, M	20
			1/2	Simulation and Virtual Reality in Medicine, **Practical Work** (SimLab)	ST	2			20
10	Biomedical Project	5	2	Scientific Project	PJ	2	PL	H, R	20
			2	Research Seminar	ST	2	PVL		20
11	HTA /Regulatory Affairs	5	1/2	Regulatory Affairs	ST	2	SL	H,K, R	20
			1/2	HTA	ST	2			
12	Master Thesis	30	3	Master Thesis			PL	MT	
	Total	**90**				**50**			

<u>Legend</u>:
SHW = Presence hours per week during semester
Course type: ST = seminaristic teaching, PJ. = Project, Sem. = Seminar (>80% presence obligatory)
Achievement type: SL = Test (not graded), PL = Exam (graded)
Exam type: K = written exam, M = oral exam / presentation, R = seminar paper , H = homework, P = Project documentation/poster

Module descriptions

Master degree programme Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 01	**Mathematics**
Module coordination/ responsible person	Prof. Dr. Anna Rodenhausen
Lecturer	Prof. Dr. Anna Rodenhausen, Prof. Dr. Thomas Schiemann
Semester / Period / Offer of this turnus	1st semester / one Semester / summer and winter semester
ECTS Credits/Presence hours per week	7 CP / 6 SHW
Workload	210 h: 96 h presence, 114 h private studies
Status	Obligatory module
Preconditions / Required skills	None / Basic skills in programming and mathematics (e.g. acquired in a bachelor degree programme)
Teaching language	English

Acquired competences / educational objectives

Expertise and methodological competences

The students are able to use the computer as universal tool to solve practical problems. They can …

- apply a wide range of numerical methods.
- understand the fundamental principals of the discussed methods.
- implement and visualize problems from numerical mathematics in the MATLAB environment.
- judge about the quality of computational result.

Personal and interpersonal skills

The students are able to …

- help each other to eliminate programming errors from their files.
- discuss their computational results in order to get an estimation about the the quality and scientific relevance.

Learning matter

- Introduction to MATLAB
- Numerical solution of linear equation systems
- Curve fitting and interpolation
- Optimization
- Non-linear zero problems
- Numerical differentiation
- Numerical integration
- Numerical solution of ordinary differential equations

• Examples of numerical solution of partial differential equations	
Associated courses / presence hours per week	
Numerical Mathematics	4 SHW
Theoretical Mathematics	2 SHW
Teaching methods / methods generally / types of media	The course is split into a lecture part on theory and a practical part taking approximately the same amount of time. Lecture part: Mainly presented in form of a seminaristic lectures, i.e. with student interaction to discuss and present different solutions, results and programming approaches. The software environment and tools for numerical mathematics are demonstrated. In addition, exercises have to be solved by the students during the lectures to improve their comprehension. Lab (practical) part: Solution of prepared exercises during the attendance. Issues, which have not yet been understood can be discussed individually with the lecturers and mentors. Solutions to the programming problems are presented after a delay in time in the E-Learning system.
Course- and examination achievements	A graded exam at the end of the semester including questions of theory and programming exercises. The students answers to the exercises are delivered as files or in written form, depending on the type of question.
Literature / working materials	Chapra, S.C. (2005). Numerical Methods for Engineers. McGraw-Hill. Gilat, A., Subramaniam, V. (2011). Numerical Methods – An Introduction with Applications Using MATLAB, SI Version. Hoboken, NJ : Wiley. Hanke-Bourgeois, M. (2002). Grundlagen der Numerischen Mathematik und des wissenschaftlichen Rechnens. Wiesbaden: Teubner. Mathews, J. H., Fink, K.D. (2004). Numerical Methods using MATLAB. Upper Saddle River, NJ : Pearson/Prentice Hall. Stanoyevitch, A. (2005). Introduction to Numerical Ordinary and Partial Differential Equations Using MATLAB. Hoboken, NJ: Wiley. Yang, W.Y., Cao, W., Chung, T.-S., Morris, J. (2005). Applied Numerical Methods Using MATLAB, Hoboken, NJ :Wiley. Lecturenotes and Exercises edited by the Lecturers

Master degree programme Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 02	**Data Acquisition**
Module coordination/ responsible person	Prof. Dr. Kay Förger
Lecturer	Prof. Dr. Kay Förger
Semester / Period / Offer of this turnus	1st semester / one semester / summer and winter semester
ECTS Credits/Presence hours per week	5 CP / 4 SHW
Workload	150 h: 64 h presence, 86 h private studies
Status	Obligatory module
Preconditions / Required skills	None / Basic skills in programming and mathematics (e.g. acquired in a bachelor degree programme)
Teaching language	English

Acquired competences / educational objectives

Expertise and methodological competences

The students are able to use the computer as universal tool to solve practical problems:

- on the one hand complex simulations can be performed by LabVIEW with little effort and
- on the other hand data can be acquired and processed with a computer easily.

Data and signals are simulated to make the theoretical relations understandable and better applicable.

The students are able …

- to apply statistical methods and
- to test the developed evaluation methods by simulation to get more reliable programs.
- Especially by such an approach subtle programming errors become obvious, which otherwise could be found hardly but distort the results much. That sensitizes students especially to such errors.
- Additionally the students are enabled by computer simulations to analyze measurement and processing techniques (signal sampling, averaging, statistical tests etc.) if some restrictive mathematical prerequisites (e.g. sampling theorem, normal distribution of random variables) are not exactly met in practical problems. Methods which provide reliable results in such cases are highlighted as robust procedures.
- The students are able to look for robust procedures / techniques.

In practical applications the parallel acquisition and processing of measurands and the simultaneous reaction on user input is an essential requirement, which is difficult to understand and implement in text based programming languages. On the contrary the graphical programming environment of LabVIEW enables the students to

- design programs with parallel execution and synchronization which are easy to implement and understand.
- acquire and process data from real experiments correctly and scientifically founded.

Personal and interpersonal skills

The students are able to …

- keep one's distance to their results and especially to their own programs.
- recognize the must of software tests using simulations with results which are known in advance to assess the extent of tests for methods and procedures more precisely.
- develop solutions for a given data acquisition project using the methods presented.

Learning matter

- Introduction to LabVIEW programming,
- statistical evaluation of measured data
    - basic statistical quantities (mean, variance and standard error, median etc.)
    - hypothesis tests
    - parameter estimation
- acquisition and processing
    - Fourier Transform und series: basics, examples and discretization
    - Sampling Theorem: Aliasing, smoothing Windows etc.
    - Digital Filters: linear filters (FIR and IIR)

Associated courses / presence hours per week

Data Acquisition	2 SHW
Data Acquisition, Practical Work	2 SHW

Teaching methods / methods generally / types of media	The course is split into a lecture part and a practical part which last approximately the same amount of time. Lecture part: Mainly presented in form of a seminaristic lectures, i.e. with student interaction to discuss and present different solutions, results and programming approaches by demonstrating the usage of software tools directly. Additional exercises are to be solved by the students to improve their comprehension. Lab (practical) part: Solution of prepared exercises during the attendance. To difficulties and misunderstood issues is responded by mentoring individually. Selected solutions were presented to the study group.
Course- and examination achievements	A graded (written or oral) exam at the end of the semester.
Literature / working materials	Press, W. H. et al (1998). Numerical recipes in C. New York: Cambridge University Press. Bronstein, I.N., Semendyayev, K.A. et al. (2004). Handbook of Mathematics, 4th Ed. Berlin Heidelberg: Springer. Jamal, R., Pichlik, H. (1998). LabVIEW Applications. München: Prentice Hall. LabView User Manual, National Instruments, January 1998 Hamming, R.W. (1983). Digital Filters. New Jersey: Englewood Cliffs. Profos, P., Pfeifer, T. (1997). Grundlagen der Meßtechnik. München: Oldenburg Verlag.

Master degree programme Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 03	**Advanced Biosignal Processing**
Module coordination/ responsible person	Prof. Dr. Friedrich Ueberle
Lecturer	HAW professors and assistant lecturers with background in science, hospital or industry
Semester / Period / Offer of this turnus	1st or 2nd semester / one Semester / winter semester
ECTS Credits/Presence hours per week	5 CP / 4 SHW
Workload	150 h: 64 h presence, 86 h private study
Status	Obligatory module
Preconditions / Required skills	None / Appropriate knowledge from previous academic studies in a professionally associated field, bachelor degree: mathematics, informatics, electronics, physics, mechanics, signals and systems, human biology
Teaching language	English

Acquired competences / educational objectives

Expertise and methodological competences

Biosignal Processing

The students...

- are able to solve demanding scientific and engineering problems.
- know and apply advanced concepts of biomedical signals and systems and the processing of biomedical signals (e.g. EEG, ECG, phonocardiogram, EMG, EOG).
- know and apply advanced mathematical methods in technology, e.g. linear systems analysis and synthesis of medical sound fields, application of finite element methods for biomedical problems etc.
- know and apply advanced algorithms for the extraction of functional parameters from biomedical signals, (e.g independent component analysis - ICA, statistical parameter mapping - SPM).
- understand relevant literature and implement the knowledge in biomedical problems solving.
- are able to critically read, understand and review original articles and working documents.
- are able to present and discuss their concepts in a peer group and with experts
- are able to develop solutions for biomedical signals processing tasks.

Learning matter (examples, subjects are chosen by the lecturers)

Biosignal Processing Methods -1:

- Signal analysis in phonocardiography
- ECG signal processing
- EEG signal processing

Biosignal Processing Methods -2:

- z-Transformation, FIR and IIR Filter design, adaptive filters

• ICA, fourier methods, wavelets • Linear systems approach for field mapping (e.g. Ultrasound: Field-II, Dream) • Finite element methods	
Associated courses / presence hours per week Biosignal Processing 2 SHW Advanced Filtering Techniques for Biosignals 2 SHW	
(Teaching methods / methods generally / types of media)	Seminaristic lectures, labs, expert puzzle, teamwork, distance learning elements, web-based cooperation, autonomous studies / Power Point, blackboard, overhead projection, multimedia, software
Course- and examination achievements	Graded examination, chosen by the lecturers: Written exams, presentations, homework reports or combination of these elements (In concordance with the APSO regulations)
Literature / working materials	To be advised by the lecturers

Master degree programme Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 04	**Medical Image Processing**
Module coordination/ responsible person	Prof. Dr. Thomas Schiemann
Lecturer	Prof. Dr. Thomas Schiemann
Semester / Period / Offer of this turnus	1st or 2nd semester / one Semester / summer semester
ECTS Credits/Presence hours per week	5 CP / 4 SHW
Workload	150 h: 64 h presence, 86 h private study
Status	Obligatory module
Preconditions / Required skills	None / Appropriate knowledge from previous academic studies in a professionally associated field, bachelor degree: informatics, mathematics, biomedical engineering, electronics
Teaching language	English

Acquired competences / educational objectives

Expertise and methodological competences

The students …

- are able to solve comprehensive problems in engineering and science.
- know the concepts of medical image processing.
- are able to describe and apply methods of computer-based image processing and image interpretation.
- know scientific methods and solutions and are therefore able to evaluate the content of scientific references and apply these concepts in own software or concepts.

Personal and interpersonal skills

The students …

- are able to present and discuss problems and methods with other scientists.
- can work with technical and medical equipment in their own responsibility.
- are able to describe and explain theoretical concepts in the biomedical context.

Learning matter

Medical Image Processing:

- Basics of digital images and image processing
- Histograms and point-based operations
- Linear and non-linear filters and their applications (e.g. smoothing, edge-detection, extraction of structures)
- Processing of color-images and video-data
- Geometrical manipulations and image registration
- Relationships between image processing and computer-graphics

Associated courses / presence hours per week	
Medical Image Processing	2 SHW
Medical Image Processing, Practical Work	2 SHW

(Teaching methods / methods generally / types of media)	Seminaristic lectures, labs, expert puzzle, teamwork, distance learning elements, web-based cooperation, autonomous studies / Power Point, blackboard, overhead projection, multimedia, software
Course- and examination achievements	Graded examination: oral presentation, written reports, colloquium, written exams, practical exams (subject to examiners choice).
Literature / working materials	Bourne, R. (2010). Fundamentals of Digital Imaging in Medicine. London: Springer. Burger, W., Burge, M.J. (2008). Digital Image Processing. An Algorithmic Introduction Using JAVA. Springer. Preim, B. (2014). Visual Computing for medicine: theory, algorithms and applications. Amsterdam: Elsevier. Salzer, R. (2012). Biomedical Imaging: principles and applications. Hoboken, NJ: Wiley. Software MeVisLab, MS VisualStudio, ImageJ

Master degree programme Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 05	**Application of Imaging Modalities**
Module coordination/ responsible person	Prof. Dr. Ueberle
Lecturer	Assistant lecturers of science and industry
Semester / Period / Offer of this turnus	1st or 2nd semester / each in the winter term
ECTS Credits/Presence hours per week	5 CP / 4 SHW
Workload	150 h: 64 course / laboratory work, 86 h private study
Status	Obligatory module
Preconditions / Required skills	None / knowlegde in medical engineering, medical imaging, signals and systems, computer science (programming) as well as human biology of the bachelor degree course (e.g. medical engineering)
Teaching language	English

Acquired competences / educational objectives

The student ...

- are able to understand, analyse and solve demanding biomedical imaging problems.
- know and apply advanced concepts of biomedical imaging modalities.
- know and apply advanced mathematical methods in technology, e.g. linear systems analysis, advanced CT and MR Image reconstruction, analysis of medical sound fields etc.
- are able to understand relevant literature and implement the knowledge in biomedical problems solving.
- are able to critically read, understand and review original articles and working documents.
- are able to present and discuss their concepts in a peer group and with experts.

Learning matter (Examples, actual topics to be chosen by the lecturers)

- Advanced methods in Magnetic Resonance Imaging (E.g. parallel transmission and reception, tractography, functional imaging, analysis methods for disease of the brain / nerve system)

- Advanced Methods in Computed Tomography (E.g. Cardiac Imaging)

- Advanced methods in Ultrasound Imaging (E.g. Sound field measurement, multi-element array design, sound field simulation, transducer simulation, functional brain imaging)

Associated courses / presence hours per week

Advanced Imaging (MR, US, CT)	2 SHW
Advanced Imaging 2 (MR, US, CT), Practical Work	2 SHW

Remark: Courses may be split in smaller units of 1 SHW to support a greater plurality of topics

Practical work (Computer simulation) is included in the courses

Teaching methods / methods generally / types of media	Semester lectures, practical work /expert puzzle, working groups, power point, exercises, private study, table, beamer, software, e-learning elements

Course- and examination achievements	Graded examination: Academic record: seminar paper, presentation, oral examination or colloquium (Subject to examiners choice)
Literature and learning aids	**To be advised by the lecturers** E.g.: U. Morgenstern, M. Kraft (Hrsg.): Biomedizinische Technik Band 7: O. Dössel, T. Buzug: Biomedizinische Technik – Medizinische Bildgebung, DeGruyter 2014 --> Electronic Book available from the library Anders Brahme (ed.), Comprehensive Biomedical Technology, Elsevier 2014, (Vol. 1), Vol. 2: X-Ray and U/S, Vol. 3: MR --> Electronic Book available from the library Kramme: Medizintechnik, Springer Verlag, 4. Auflage 2011, ISBN-10: 3642161863, ISBN-13: 978-3642161865 --> Als elektronisches Buch in der Bibliothek Arnulf Oppelt (Ed.): Imaging Systems for Medical Diagnostics: Fundamentals, technical solutions and applications for systems applying ionization radiation, nuclear ... Nuclear Magnetic Resonance and Ultrasound, 2005, Publicis Publishing; 2. Auflage, ISBN-10: 3895782262, ISBN-13: 978-3895782268 Dowsett, Kenny and Johnston:The Physics of Diagnostic Imaging, Hodder Arnold, London, 2nd edition 2006, ISBN-10 0 340 80891 8 J. D. Bronzino: The Biomedical Engineering Handbook, Second Edition, Vol. 1, CRC Press 2000, ISBN 3-540-66351-7 P.D.Hoskins, Thrush, Martin, Whittingham; Diagnostic Ultrasound, Greenwich Med. Media, London 2003, ISBN 1-84110-042-0 R.L.Powis: A Thinker's Guide to Ultrasonic Imaging, Verlag Urban und Schwarzenberg, 1984, ISBN 3-541-71581-2 T.Szabo: Diagnostic Ultrasound Imaging – Inside Out, Elsevier, Amsterdam, 2nd ed., 2013, ISBN-9780123964878 Seeram, Computed Tomography, 2.nd edition, W.B. Saunders Company, 2001, ISBN 0-7216-8173-5 Hashemi, Bradley, Lisanti; MRI – the Basics, 2nd edition, Lippincott Williams Verlag, 2004, ISBN 0-7817-4157-2 C.Westbrook, Roth, Talbot: MRI in Practice, Blackwell Publishing, 3rd edition 2005, ISBN-10: 1-4051-2787-2 J.P.Hornack: MR-Course in Internet: www.cis.rit.edu\htbooks\mri\index.html W.Niederlag, Lemke, Semmler, Bremer: Molecular Imaging, Health Academy, Dresden 2006, ISBN 3-00-017900-3

Master degree programme Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 06	**Advanced Control Systems**
Module coordination/ responsible person	Prof. Dr. Gerwald Lichtenberg
Lecturer	Prof. Dr. Gerwald Lichtenberg, Prof. Dr. Jürgen Lorenz, Dipl.-Ing. Georg Pangalos
Semester / Period / Offer of this turnus	1st or 2nd semester / one semester / summer semester - once a year
ECTS Credits/Presence hours per week	5 CP / 6 SHW
Workload	150 h: Presence: 96 h, 54 h private study
Status	Obligatory module
Preconditions / Required skills	None / Appropriate knowledge from previous academic studies in a professionally associated field, bachelor degree: mathematics, informatics, systems theory, human biology
Teaching language	English

Acquired competences / educational objectives

Expertise and methodological competences

The courses of this module enable the student to...

- understand model-based engineering methods
- model dynamical systems
  - structured, by first principles (white box)
  - unstructured, from measurement data (black box)
  - semi-structured, by adapting model parameters (gray box)
- apply model-based methods for automation tasks
  - State feedback
  - Predictive and Learning Control
  - Adaptive Control
  - Supervisory Control
- design appropriate controllers
  - fix the control structure
  - choose the controller structure
  - optimize controller parameters
- use block-oriented simulation tools, e.g. MATLAB / Simulink to …
  - build a model from physical differential-algebraic equations (white box)
  - identify parameters from measurement data (black box / gray box)
  - validate a model
  - design controllers with model-based tools

Personal and interpersonal skills

The students are able to …

- discuss control concepts in a team.

- decide which concepts are applicable.
- guide the implementation process.
- understand basics for later usage of engineering tools.
- contribute to model-based controller design (e.g. hardware-in-the-loop).

Learning matter

Advanced Control System Methods:

- **Modelling:** Linear and nonlinear systems, Continuous- and discrete-time systems, Continuous- and discrete-variable systems, Hybrid systems, State space models, Block diagrams, Parameter identification
- **Analysis:** Stability, Controllability and observability, Performance
- **MATLAB:** matrix computing, linear models, MATLAB programming, data import and export, transfer functions, state space models
- **Simulink:** nonlinear models, Modelling continuous-time, discrete-time and hybrid systems, Solver settings, Model hierarchies, Modelling guidelines, Controller design using Simulink
- **Design:** State feedback and observers, Linear predictive control, Iterative learning control, Adaptive control, Response optimization

Biological Rhythms and Homeostatic Control:
Students are able to

- describe biological feed-back systems (e.g. heart rate variability) using mathematical analysis in time- and frequency domain and using non-linear methods
- describe biological system interactions by appropriate methods (e.g. transfer functions, path analysis, structural equation modeling)

Associated courses / presence hours per week

Advanced Control Systems Methods	2 SHW
Biological Rhythms and homeostatic Control	2 SHW
Advanced Control Systems, Tools, Practical Work	2 SHW

Teaching methods / methods generally / types of media	Seminaristic lectures, labs, expert puzzle, teamwork, distance learning elements, web-based cooperation, autonomous studies / Power Point, blackboard, overhead projection, multimedia, software, poster presentations
Course- and examination achievements	Graded examinations: oral presentation, written reports, colloquium, written exams, oral exams, poster presentations, modelling and design tasks (subject to examiners choice)
Literature / working materials	Lecture notes Current research papers Khalil, H.K. (2001). Nonlinear Systems. Upper Saddle River, NJ: Prentice-Hall. Maciejowski, J.M. (2001). Predictive Control with constraints. Harlow: Prentice-Hall.

Master degree programme Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 07	**Modelling Medical Systems**
Module coordination/ responsible person	Prof. Dr. Nick Bishop
Lecturer	Prof. Dr. Nick Bishop, Prof. Dr. Gerwald Lichtenberg, Dipl.-Ing. Georg Pangalos
Period / Semester/ Offer of this turnus	1st Semester / once a year
ECTS Credits/Presence hours per week	5 CP / 4 SHW
Workload	150 h: 64 h presence, 86 h private study
Status	Obligatory module
Preconditions / Required skills	None / Students should have knowledge in electronics, biomedical engineering, computer science (especially programming) and human biology.
Teaching language	English

Acquired competences / educational objectives

Expertise and methodological competences

The courses of this module enable the student to...

- understand model-based simulation methods
- model dynamical systems
  - structured, by first principles (white box)
  - unstructured, from measurement data (black box)
  - semi-structured, by adapting model parameters (gray box)
- model continuum mechanics problems
  - discretisation of continuum problems
  - solution by numerical methods
- use simulation tools, e.g. MATLAB / Simulink to…
  - build a model from physical differential-algebraic equations (white box)
  - identify parameters from measurement data (black box / gray box)
  - validate a model
  - simulate dynamic behavior
- use finite element analysis software
  - model mechanical structures

Personal and interpersonal skills

The students are able to …

- discuss modelling concepts in a team.
- decide which concepts are applicable.
- guide the parameter identification process.
- understand basics of engineering tools.

Learning matter
Concentrated parameter Models: • Methods: State space model as representations of ordinary differential equations**,** Linear and nonlinear systems, Continuous- and discrete-time systems, Continuous- and discrete-variable systems, Block diagrams, Parameter identification, stability, controllability, observability • Practical Work: MATLAB matrix computing, linear models, m-files, programming, data import and export, transfer functions, state space models, SIMULINK nonlinear block models, modelling continuous-time and discrete-time systems, solver settings, model hierarchies, modelling guidelines, **Distributed parameter Models** • Methods: Finite element analysis will be used to approximate solutions to distributed parameter models, described by partial differential equations. Discretisation of a problem into simpler elements allows efficient analysis of complex problems using numerical techniques. Particular attention will be paid to modelling elastic structures. A solid model must be generated, with appropriate boundary conditions, discretised, solved and assessed. Errors Involved in such modelling methods will be discussed. • Practical Work: Finite element software will be used to design a structure. Models will be developed based on verifiable steps. Accuracy of solutions will be achieved according to convergence analysis. Solution efficiency will be addressed by simulating symmetry planes using boundary conditions.

Associated courses / ECTS credits / presence hours per week	
Modelling Methods	2 SHW
Modelling Tools, Practical Work	2 SHW

Teaching methods / methods generally / types of media	Seminaristic lectures, practical courses, expert-puzzle, team-work PowerPoint-presentation, tutorials, private study blackboard, projector, software-demonstration e-Learning
Course- and examination achievements	Graded examination: oral presentation, written reports, colloquium, written exams, practical exams (subject to examiners choice).
Literature / working materials	Skogestad, S., Postlethwaite, I. (2007). Multivariable feedback control: analysis and design, Vol. 2. New York: Wiley. Khalil, H.K. (2001). Nonlinear Systems. Upper Saddle River, NJ: Prentice-Hall. Ljung, L. (1999). System Idenfication. Englewood Cliffs, NJ [u.a.]: Prentice-Hall. Bathe, K. (2007). Finite Element Procedures. New Jersey: Prentice Hall. Ramamurty, G. (2010). Applied Finite Element Analysis. New Dehli: I K International Publishing House. Steinke, P. (2007). Finite-Elemente-Methode – Rechnergestutzte Einführung. Berlin, Heidelberg, New York: Springer. Klein, K. (2012). Grundlagen und Anwendungen der Finite-Element-Methode in Maschinen und Fahrzeugbau. Wiesbaden: Vieweg+Teubner Verlag. Merkel, M & Öchsner, A, 2010, Eindimensionale Finite Elemente – Ein Einstieg in die Methode, Springer, Berlin, Heidelberg, New York.

Master degree programme Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 08	**Medical Real Time Systems**
Module coordination/ responsible person	Prof. Dr. Petra Margaritoff
Lecturer	Prof. Dr. Petra Margaritoff, Prof. Dr. Bernd Flick
Semester / Period / Offer of this turnus	1st or 2nd semester / one semester / each semester
ECTS Credits/Presence hours per week	7 CP / 4 SHW
Workload	210 h: 64 h presence, 146 h private study
Status	Obligatory module
Preconditions / Required skills	Appropriate knowledge from previous academic studies in a professionally associated field, bachelor degree
Teaching language	English

Acquired competences / educational objectives

Expertise and methodological competences

This course enables the student to …

- assess the suitability of hard- and software realtime solutions for biomedical product requirements.
- develop small hard- and software realtime solutions for biomedical embedded systems.
- be aware of the influence of high frequencies in electronic circuits concerning emission and absorption.
- construct high frequency circuit
- know antenna basics.

Personal and interpersonal skills

The students will be able to…

- approach the design and implementation of biomedical systems according to given requirements.
- patiently and systematically implement and debug real time systems.

Learning matter

Medical Real Time Systems Software Implementation:

- Distinctive software-aspects of real time systems with focus on biomedical applications
  - Deterministic behaviour
  - quasi concurrent processing, measures of "safe" data access
  - interrupt handling, interrupt levels
  - watchdog, timers
  - testability
  - efficiency
  - Inter-device communication

Medical Real Time Systems Hardware Implementation:

- Choice of processors and microcontrollers
- Communication on several layers (data-, physical-, link-layer etc. according the OSI-model)
- Analogue circuit design of amplifiers, filters and oscillators
- High frequency circuit and antenna design
- Difference between analogue and digital circuit behaviour and design
- Development of a wireless data and signal communication

Medical Real Time Systems, Practical Work:

- Implementation of small systems for biomedical measurement and processing applications consisting of hard- and software in C.
- (Development of a wireless data and signal communication)

Associated courses / presence hours per week

Medical Real Time Systems Software Implementation	1 SHW
Medical Real Time Systems Hardware Implementation	1 SHW
Medical Real Time Systems, Practical Work	2 SHW

Teaching methods / methods generally / types of media	• Seminaristic lectures and practical work • Powerpoint presentations • Group work (internet retrieval, discussions) • Excursions (“expert interviews”)
Course- and examination achievements	Graded exam ("Prüfungsleistung"): Oral presentation, written study report, written exam or combination thereof (subject to examiners choice)
Literature / working materials	Bronzino, J.D. (1995). IEEE Handbook of Biomedical Engineering. Florida: CRC Press Boca Raton. Nikita, S.K. (2014). Handbook of Biomedical Telemetry (IEEE Press Series on Biomedical Engineering). Hoboken, New Jersey: John Wiley & Sons. Meinke, H.H., Grundlach, F.W. (1992). Taschenbuch der Hochfrequenztechnik. Berlin: Springer Verlag. Zinke, O., Brunswig, H. (2013). Hochfrequenztechnik 1 & 2. Berlin: Springer Verlag. Frohberg, W., Kolloschie, H., Löffler, H. (2008). Taschenbuch der Nachrichtentechnik. München: Hanser Verlag. Gustrau, F. (2013). Hochfrequenztechnik. München: Hanser Verlag.

Master degree programme Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 9	**Simulation and Virtual Reality in Medicine**
Module coordination/ Resposible person	Prof. Dr. Boris Tolg
Lecturer	Prof. Dr. Boris Tolg, Prof. Dr. Marc Schütte, Prof. Dr. Jürgen Lorenz
Semester / Period / Offer of this turnus	1st or 2nd semester / one semester / each semester
ECTS Credits/Presence hours per week	6 CP / 6 SHW
Workload	180 h: 96 h presence, 84 h private study
Status	Obligatory module
Preconditions / Required skills	
Teaching language	English

Acquired competences / educational objectives

Expertise and methodological competences

The courses of this module enables the students to...

- decide based on a given scenario which simulation technique fits best.
- develop training scenarios for given situations.
- evaluate and analyze training results.

Personal and interpersonal skills

The students are able to…

- critically read, understand and review original articles and working documents.
- present and discuss their concepts in a peer group.
- develop solutions for simulation tasks.

Learning matter

- 3D Simulation
  - Mathematical Background
    - Transformation matrices
    - Quaternions
    - Kinematics
    - Propagation Models
    - …
  - Computer Graphics Background
    - Lighting
    - Data Structures
    - …
  - Simulation Background
    - Main Loop

- Events
- Storing results with MySQL
- …

- Other Simulation methods
  - Simulation Patients
  - Mass Casualty Incidents (MCI)
  - …
- Evaluation
  - Mathematical Background
    - Statistics
    - …
  - Methodical Background
    - Questionnaires
    - …
  - Psychological Background
    - …

Related courses / presence hours per week:

Simulation and Virtual Reality in Medicine	4 SHW
Simulation and Virtual Reality in Medicine, Practical work (SimLab)	2 SHW

Teaching methods/ methods generally / types of media	Typically: experimental laboratory work / hardware and software engineering / literature work / seminar / presentations / project meetings / project documentation / web based cooperation
Course- and examination achievements	Graded examination: Each student has to deliver: Written project report, poster (A1), at least one oral presentation. The results will be graded. The participation in at least 80% of the project seminar meetings is obligatory, presentations (1..2, not graded) required.
Literature and learning aids	Scientific literature, depending on the project

Master degree programme Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit :10	**Biomedical Project**
Module coordination/ Resposible person	Prof. Dr. Friedrich Ueberle
Lecturer	All university lecturers of the department MT, Prof. Dr. Ueberle
Semester / Period / Offer of this turnus	2nd semester / one semester / each semester
ECTS Credits/Presence hours per week	5 CP / 4 SHW
Workload	150 h, laboratory work, private study, includes 32 h seminar
Status	Obligatory module
Preconditions / Required skills	Appropriate knowledge from previous academic studies in a professionally associated field, bachelor degree The projects must be individually supervised by a professor of the biomedical department (Department Medizintechnik / Fakultät LS). The project regulations of the Department Medizintechnik apply.
Teaching language	English

Acquired competences / educational objectives

The students are able to develop a biomedical component, device, software or study.

Therefore, they …

- approach and handle complex problems, tasks and projects in the biomedical field.
- understand and apply complex laboratory and biomedical equipment to solve the project tasks.
- find and understand appropriate literature, assess and understand complex informations and apply them to the project (E.g. literature data bases, specialized publications).
- autonomously design, develop and implement laboratory experiments / software / hardware.
- autonomously design, keep records and interpret measurements using appropriate mathematical and scientific methods.
- provide and track a project plan.
- understand and define project goals and negotiate them with the project sponsors.
- present the results to peers and sponsors.

The students are able to…

- handle projects responsible, with awareness to cost, risk and safety.
- autonomously organize project groups, organize meetings and communication among the project participants and identify and solve all problems typical to scientific projects.
- get in contact to experts, where necessary, discuss project and test plans with co-workers and project sponsors and defend their plans and results against critical objections.

Learning matter

project skills in practice

the scientific matters depend on the projects, which must be supervised / approved by a professor of the biomedical department

the projects should address scientific level problems from any aspect of biomedical engineering and biomedical sciences	
Related courses / Presence hours per week: Scientific Project — 2 SHW Research Seminar — (Obligatory) 2 SHW	
Teaching methods/ methods generally / types of media	Typically: experimental laboratory work / hardware and software engineering / literature work / seminar / presentations / project meetings / project documentation / web based cooperation
Course- and examination achievements	Graded examination: Each student has to deliver: Written project report, poster (A1), at least one oral presentation. The results will be graded. The participation in at least 80% of the project seminar meetings is obligatory, presentations (1..2, not graded), writing of 1..2 seminar minutes and project poster required.
Literature and learning aids	Scientific literature, depending on the project

Master degree programme Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 11	**HTA/Regulatory Affairs**
Module coordination/ responsible person	Prof. Dr. Marc Schütte
Lecturer	Prof. Dr. Marc Schütte, Prof. Dr. Jürgen Stettin
Semester / Period / Offer of this turnus	1st or 2nd semester / one semester / each semester
ECTS Credits/Presence hours per week	5 CP / 4 SHW
Workload	150 h: 64 h presence, 86 h private study
Status	Obligatory module
Preconditions / Required skills	Appropriate knowledge from previous academic studies in a professionally associated field, bachelor degree
Teaching language	English

Acquired competences / educational objectives

Expertise and methodological competences

This course enables the student to …

- describe the basic strategy and procedures of Health Technology Assessment (HTA) based on the general concept of evidence-based medicine.
- identify quality criteria of scientific publications (ethics, study design, statistical methods, outcome measures, publication bias, journal impact etc.).
- apply HTA both as a prospective and retrospective tool of quality assurance in the development and evaluation of medical technologies.
- retrieve and evaluate relevant information using internet-based data bases (PubMed, Medline, Cochrane library etc.).
- apply economical evaluation methods (cost/benefit-analysis) to healthy technologies.

Personal and interpersonal skills

The students will be able to …

- critically read and review original articles.
- present and discuss their critique on a paper in a group (“journal club presentation”).
- write a “peer review”-like evaluation report of a published paper.
- write and revise an own text contribution (“workpackage”) to a review paper prepared by the group.

Learning matter

Health Technology Assessment:

- basis and methodologies of evidence based medicine
- National and international health technology assessment organizations
- Process of peer-reviewed scientific publication

Regulatory Affairs: • Principal routes to marketing medical devices: premarket approval, investigational device exemption, product development protocol, premarket notification (FDA process) • Medical device regulation in Europe • Role of the biomedical engineer in premarket reviews and postmarket controls of medical devices	
Associated courses / presence hours per week Regulatory Affairs 2 SHW Health Technology Assessment (HTA) 2 SHW	
Teaching methods / methods generally / types of media	• Powerpoint presentations • Group work (internet retrieval, discussions) • Excursions (“expert interviews”)
Course- and examination achievements	Not graded exam (Studienleistung): Oral presentation, written study report, written exams (subject to examiners choice)
Literature / working materials	Introduction to health technology assessment. CS Goodmann. HTA 101, 2004. Sterne JA, Egger M, Smith GD. Systematic reviews in health care: investigating and dealing with publication and other biases in meta-analysis. BMJ. 2001; 323:101-5. Steinberg EP. Cost-effectiveness analyses. N Engl J Med. 1995; 332:123. Oxman AD, Sackett DL, Guyatt GH. Users' guides to the medical literature. I. How to get started. JAMA. 1993; 270(17): 2093-5. Guyatt GH, Haynes RB, Jaeschke RZ, et al. Users’ guide to the medical literature, XXV: Evidence-based medicine: principles for applying the users’ guides to patient care. Evidence-Based Medicine Working Group. JAMA. 2000; 284:1290-6.

Master degree programme Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 12	**Master-Thesis**
Module coordination/ Responsible person	Prof. Dr. Jürgen Stettin
Lecturer	All university lecturers
Semester / Period/ Offer of this turnus	3rd semester / one Semester / each semester
ECTS Credits	30 CP
Workload	900 h (Autonomous private study)
Status	Obligatory module
Preconditions / Required skills	At least 210 CP from the previous academic studies in relevant scientific fields/ relevant knowledge in electronics, biomedical engineering, informatics, human biology Before the official start of the assignment the subject-matter and the supervisors must be approved by the board of examiners of the Department Medizintechnik / Fakultät Life Sciences. The first examiner must be a professor of the Department Medizintechnik / Fakultät Life Sciences.
Teaching language	English, German language if agreed by the examiners

Acquired competences / educational objectives

Expertise and methodological competences

The students …

- can solve challenging engineering specific and natural scientific problems.
- are familiar with the concepts of scientific work in the medical engineering and use them conducive.
- use mathematical / physical and technical methods on problems in the bioengineering.
- have a scientific method-knowledge and are able to evaluate critical results from the literature and to express and transact them in their own words.
- have knowledges and abilities in project- and time management that allow them to work out large scientific results in the given period.

Personal and interpersonal skills

The students …

- are able to talk in trade public about correlative job definitions and methods.
- are able to deal unaffiliated with technical and medical working materials.
- can describe and overbring theoretical contexts in the bio medicine.
- are specially invoked to present and protect their results in form of scientific publications and / or public presentations.

Learning matter

- See attachment: catalog of criteria for master thesis

Requirements - Master Thesis: in written form - poster or pdf file for a poster - the results are to be presented and protected in form of a presentation with following discussion in a specific forum which is named by the adviser (e.g. seminar in the module BME 02, 03, 05, 09, Hamburger Studententagung, expert conference, etc.)	
Teaching methods / methods generally / types of media	Active work, discussion, seminar, presentation, elaboration and publication
Course- and examination achievements	Graded examinations: Written composition, presentation, poster, colloquium
Literature and learning aids	Scientific literature

Lecturers

Professors

Name	Expertise
Prof. Dr. Andrea Berger-Klein	Führung und Management
Prof. Dr. Nick Bishop	Biomechanik
Prof. Dr. Constantin Canavas	Automatisierungstechnik
Prof. Dr. Friedrich Dildey	Physik
Prof. Dr. Bernd Flick	Electronics, Electro-, Measurement- and High-Frequency-Engineering
Prof. Dr. Carolin Floeter	Biologie
Prof. Dr. Kay Förger	Datenverarbeitung
Prof. Dr. Martin Geweke	Mechanische Verfahrenstechnik
Prof. Dr. Susanne Heise	Biogefahrstoffe/Toxikologie
Prof. Dr. Frank Hörmann	Präklinisches Rettungswesen/Gefahrenmanagement
Prof. Dr. Timon Kampschulte	Elektrotechnik
Prof. Dr. Bernd Kellner	Elektrotechnik/Medizintechnik
Prof. Dr. Bettina Knappe	Grundlagen der Chemie
Prof. Dr. Holger Kohlhoff	Mathematik und Informatik
Prof. Dr. Heiner Kühle	Elektrotechnik
Prof. Dr. Veit Dominik Kunz	Elektrotechnik / Erneuerbare Energien
Prof. Dr. Frank Lampe	Navigationstechniken in der Orthopädie und Sportmedizin
Prof. Dr. Gerwald Lichtenberg	Physics & Control Systems
Prof. Dr. Detlev Lohse	Betriebswirtschaftslehre
Prof. Dr. Jürgen Lorenz	Humanbiologie
Prof. Dr. Christoph Maas	Mathematik
Prof. Dr. Petra Margaritoff	Medizinische Datensysteme
Prof. Dr.-Ing. Holger Mühlberger	Elektronik
Prof. Dr. Stefan Oppermann	Präklinisches Rettungswesen/Gefahrenmanagement
Prof. Dr. Gabriele Perger	Arbeitswissenschaften
Prof. Dr. Anna Rodenhausen	Mathematik
Prof. Dr.-Ing. Bernd Sadlowsky	Technische Mechanik, Werkstoff- und Verpackungstechnik
Prof. Dr. Rainer Sawatzki	Mathematik und Informatik
Prof. Dr. Marcus Schiefer	Chemie und Werkstoffkunde
Prof. Dr. Thomas Schiemann	Datenverarbeitung
Prof. Dr. Marc Schütte	Psychologie
Prof. Dr. Marion Siegers	Mathematik und Physik
Prof. Dr, Rainer Stank	Technische Mechanik
Prof. Dr. Jürgen Stettin	Medizintechnik

Prof. Dr. Boris Tolg	Mathematik und Informatik
Prof. Dr. Friedrich Ueberle	Medizinische Mess- und Gerätetechnik
Prof. Dr. Gesine Witt	Umweltchemie

Academic personal

Dipl. Ing. Sakher Abdo
Dipl. Ing. Jan-Claas Böhmke
Dipl. Ing. Sylvia Haase
Dipl. Ing. Jens Martens
Dipl. Ing. Nico Mock
Dipl.-Ing. Georg Pangalos
Dipl.-Ing. Bernd Reinwardt
Dr. Dagmar Rokita
Dipl. Ing. Stefan Schmücker
Dipl.-Phys. Carsten von Westarp

External lecturers

Prof. Dr. Peter Berger
Dr. Hauke Bietz
Dr.-Ing. Marc Hölling
Dr. Anita König
Prof. Dr. Henning Niebuhr
Dr. Alaleh Raji
Birgit Döring-Scholz
Prof. Dr. Andreas Wille

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