HAW HAMBURG

Faculty of Life Sciences

Module compendium

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

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Module compendium

Master degree program

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

Faculty of Life Sciences
Department Medizintechnik

March 2017

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Aims of the study program

The Master's degree (M.Sc.) program of "Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems" of the Hamburg University of Applied Sciences is open to graduates in Biomedical Engineering and related Engineering programs. It entitles degree holders to execute professional work in all fields of biomedical engineering in hospitals, industry and academia.

This full time study program is designed for 3 semesters (1½ years) and covers mathematical, scientific and engineering knowledge and comprehension with emphasis on technologies for acquisition, processing, control and imaging of biomedical signals and physiological control loops including applications in virtual reality and simulation. Non-technical skills focus on regulatory affairs and health technology assessment. Most lectures and seminars are complemented by associated practical courses with up-to-date software and hardware tools of on-site research labs or at work places of our collaboration partners in hospitals and industrial companies. In a mandatory scientific project the students are engaged in self-organized 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.

After completing the study program, degree holders will have adopted competences in the following learning aims:

I) Knowledge and Comprehension
II) Methods and Analysis
III) Research and Development
IV) Reflection and Communication

These competences enable degree holders to successfully apply in the following work fields at health care institutions, industry and academia:

I) Innovation management
II) Implementation, maintenance and service
III) Project Management
IV) Marketing and Distribution
V) Controlling

The study courses are organized in modules based on their topics. Generally, modules are completed by a module exam. The total number of credit points (CP) is 90. One CP is equivalent to 30 work hours (1 hour = 60 minutes).On the following pages all modules are described in detail with information on e.g. course titles, learning content and aims, kind of exam etc.. The table below contains a matrix of learning goals organizing the modules according to the learning aims and work fields mentioned above.

Courses within *Knowledge and Comprehension* refer to study contents of the first semester providing basics in mathematics and data acquisition. *Methods and Analysis* contains courses that combine theoretical with practical work. Courses with self-organized planning and conducting projects are ranked under *Research and Development*. Non-technical courses put particular emphasis on *Reflection and Communication*.

The table shows in the right portion how the various modules comply with characteristic demands of work fields at health care institutions, industry and academia.

Master thesis (Masterarbeit)

The Master thesis represents the written composition of a theoretical, empirical and/or experimental study. With the Master thesis students prove their capability to express a sound scientific study hypothesis, explore its relevant bibliographic background, select, adapt or develop appropriate scientific study methods to collect and analyze gathered data and discuss the results in relation to the study aims and relevant literature conclusively. The time-limit for delivery of the master thesis is six months. It is credited by 30 credit points.

Matrix of study goals

1	2	General learning aims				Work fields				
Nr	**Modul**	**Knowledge and Comprehension**	**Methods and Analysis**	**Research and Development**	**Reflection and Communication**	**Innovation management**	**Implementation, maintenance and service**	**Project Management**	**Marketing and Distribution**	**Controlling**
1	Mathematics	x								
2	Data Acquisition	x								
3	Advanced Biosignal Processing		x				x			
4	Medical Image Processing		x				x			
5	Application of Imaging Modalities		x				x			
6	Advanced Control Systems		x	x		x				
7	Modelling Medical Systems		x	x		x				
8	Medical Real Time Systems		x	x		x				
9	Simulation and Virtual Reality in Medicine		x	x		x				
10	Biomedical Project		x	x	x			x		
11	HTA/Regulatory Affairs				x			x	x	x
12	Master Thesis		x	x	x			x		

Module and course structure

Nr.	Modul	CP	Semester	Offer	Lehrveranstaltung	Course Type	SHW	Achievment type	Exam type	Group size
1	Mathematics	7	1	WiSo	Numerical Mathematics	ST	4	PL	K, H, R, M	20
			1/2	Wi	Advanced Calculus for Engineers	ST	2	PL	K, H, R, M	20
2	Data Acquisition	5	1	WiSo	Data Acquisition	ST	2	PL	K, H, R; M	20
			1	WiSo	Data Acquisition, **Practical Work**	ST	2			20
3	Advanced Biosignal Processing	5	1/2	Wi	Biosignal Processing	ST	2	PL	K, H, R, M	20
			1/2	Wi	Advanced Filtering Techniques for Biosignals	ST	2			
4	Medical Image Processing	5	1/2	So	Medical Image Processing	ST	2	PL	K, H, R, M	20
			1/2	So	Medical Image Processing, **Practical Work**	ST	2			20
5	Application of Imaging Modalities	5	1/2	So	Advanced Imaging (MR, US, CT)	ST	2	PL	K, H, R, M	20
			1/2	So	Advanced Imaging (MR, US, CT) **Practical Work**	ST	2			20
6	Advanced Control Systems	5	1/2	Wi	Advanced Control Systems Methods	ST	2	PL	K, H, R, M	20
			1/2	Wi	Advanced Control Systems, Tools, **Practical Work**	ST	2			
7	Modelling Medical Systems	5	1/2	So	Biological Rhythms and homeostatic Control	ST	2	PL	K, H, R, M	20
			1/2	So	Modelling Methods	ST	1	PL	K, H, R, M	20
			1/2	So	Modelling Tools, **Practical Work**	ST	1			
8	Medical Real Time Systems	5	1/2	So	Medical Real Time Systems Software Implementation	ST	1	PL	K, H, R, M	20
			1/2	So	Medical Real Time Systems Hardware Implementation	ST	1			20
			1/2	So	Medical Real Time Systems, **Practical work**	ST	2			20
9	Simulation and Virtual Reality in Medicine	5	1/2	Wi	Simulation and Virtual Reality in Medicine	ST	2	PL	H, K, R, M	20
			1/2	Wi	Simulation and Virtual Reality in Medicine, **Practical Work** (SimLab)	ST	2			20
10	Biomedical Project	8	2	WiSo	Scientific Project	PJ	4	PL	H, R	20
			2	WiSo	Research Seminar	ST	2	PVL		20
11	HTA/Regulatory Affairs	5	1/2	Wi	Regulatory Affairs	ST	2	PL	H,K, R	20
			1/2	Wi	HTA	ST	2			20
12	Master Thesis	30	3	WiSo	Master Thesis (Masterarbeit)			PL	MT	
	Gesamt	**90**					**48**			

<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
Offer: Wi = Winter semester, Su = Summer semester

Module descriptions

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 01	**Mathematics**
Module coordination/ responsible person	Prof. Dr. Anna Rodenhausen
Associated courses	• Numerical Mathematics • Advanced Calculus for Engineers
Lecturer	Prof. Dr. Anna Rodenhausen, Prof. Dr. Thomas Schiemann
Semester/Period/Offer of this turnus	Numerical Mathematics: 1st semester/one semester/winter and summer semester Advanced Calculus for Engineers: 1st or 2nd semester/one semester/winter semester
ECTS Credits/Presence hours per week	7 CP/6 SHW • Numerical Mathematics (4 SHW) • Advanced Calculus for Engineers (2 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 program)
Teaching language	English
General learning aims and work fields	• Knowledge and Comprehension • all work fields

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	
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	Regular form for the module examination: written exams (one per course) Further possible examinations: oral examination, presentation, homework reports The type of examination will be announced by the lecturer at the beginning of the course.
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 program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 02	**Data Acquisition**
Module coordination/ responsible person	Prof. Dr. Kay Förger
Associated courses	• Data Acquisition • Data Acquisition, Practical Work
Lecturer	Prof. Dr. Kay Förger
Semester/Period/Offer of this turnus	1st semester/one semester/winter and summer semester
ECTS Credits/Presence hours per week	5 CP/4 SHW • Data Acquisition (2 SHW) • Data Acquisition, Practical Work (2 SHW)
Workload	150 h: 64h 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 program)
Teaching language	English
General learning aims and work fields	• Knowledge and Comprehension • all work fields

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)

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	Regular form for the module examination: written exam Further possible examinations: oral examination, presentation, homework reports The type of examination will be announced by the lecturer at the beginning of the course.
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 program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 03	**Advanced Biosignal Processing**
Module coordination/ responsible person	Prof. Dr. Friedrich Ueberle
Associated courses	• Biosignal Processing • Advanced Filtering Techniques for Biosignals
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 • Biosignal Processing (2 SHW) • Advanced Filtering Techniques for Biosignals (2 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
General learning aims and work fields	• Methods and Analysis • Implementation, maintenance and service

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

(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	Regular form for the module examination: written exam Further possible examinations: oral examination, presentation, homework reports The type of examination will be announced by the lecturer at the beginning of the course.
Literature/working materials	To be advised by the lecturers

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 04	**Medical Image Processing**
Module coordination/ responsible person	Prof. Dr. Thomas Schiemann
Associated courses	• Medical Image Processing • Medical Image Processing, Practical Work
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 • Medical Image Processing (2 SHW) • Medical Image Processing, Practical Work (2 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
General learning aims and work fields	• Methods and Analysis • Implementation, maintenance and service
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	
(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	Regular form for the module examination: written exam Further possible examinations: oral examination, presentation, homework reports The type of examination will be announced by the lecturer at the beginning of the course.
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 program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 05	**Application of Imaging Modalities**
Module coordination/ responsible person	Prof. Dr. Friedrich Ueberle
Associated courses	• Advanced Imaging (MR, US, CT) • Advanced Imaging (MR, US, CT), Practical Work
Lecturer	Assistant lecturers of science and industry
Semester/Period/Offer of this turnus	1st or 2nd semester/one semester/summer semester
ECTS Credits/Presence hours per week	5 CP/4 SHW • Advanced Imaging (MR, US, CT) (2 SHW) • Advanced Imaging (MR, US, CT), Practical Work (2 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
General learning aims and work fields	• Methods and Analysis • Implementation, maintenance and service

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)	
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	Regular form for the module examination: written exam Further possible examinations: oral examination, presentation, homework reports The type of examination will be announced by the lecturer at the beginning of the course.
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 program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 06	**Advanced Control Systems**
Module coordination/ responsible person	Prof. Dr. Gerwald Lichtenberg
Associated courses	• Advanced Control Systems Methods • Advanced Control Systems, Tools, Practical Work
Lecturer	Prof. Dr.-Ing. Gerwald Lichtenberg, M.Sc. Kai Kruppa
Semester/Period/Offer of this turnus	1st or 2nd semester/one semester/winter semester
ECTS Credits/Presence hours per week	5 CP/4 SHW • Advanced Control Systems Methods (2 SHW) • Advanced Control Systems, Tools, Practical Work (2 SHW)
Workload	150 h: 64 course/laboratory work, 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, systems theory, human biology
Teaching language	English
General learning aims and work fields	• Methods and Analysis, Research and Development • Innovation management

Acquired competences/educational objectives

Expertise and methodological competences

This module enables 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, observability, performance, robustness
- **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, learning and adaptive control, response optimization

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	Regular form for the module examination: written exam Further possible examinations: oral examination, oral presentation, homework reports, colloquium, practical exams

	The type of examination will be announced by the lecturer at the beginning of the course.
Literature/working materials	Lecture notes Current research papers Khalil, H.K. (2001). Nonlinear Systems. Upper Saddle River, NJ: Prentice-Hall. Skogestad, S., Postlethwaite, I. (2007). Multivariable feedback control: analysis and design, Vol. 2. New York: Wiley. Ljung, L. (1999). System Idenfication. Englewood Cliffs, NJ [u.a.]: Prentice-Hall. Maciejowski, J.M. (2001). Predictive Control with constraints. Harlow: Prentice-Hall.

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 07	**Modelling Medical Systems**
Module coordination/ responsible person	Prof. Dr. Nicholas Bishop
Associated courses	• Biological Rhythms and homeostatic Control • Modelling Methods • Modelling Tools, Practical Work
Lecturer	Prof. Dr. Nicholas Bishop, Prof. Dr. Jürgen Lorenz
Period/Semester/Offer of this turnus	1st or 2nd Semester/one semester/summer semester
ECTS Credits/Presence hours per week	5 CP/4 SHW • Biological Rhythms and homeostatic Control (2 SHW) • Modelling Methods (1 SHW) • Modelling Tools, Practical Work (1 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
General learning aims and work fields	• Methods and Analysis, Research and Development • Innovation management

Acquired competences/educational objectives

Expertise and methodological competences

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

- understand model-based simulation methods
- 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
    - identify parameters from measurement data
    - validate a model
- 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.
- 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
- critically read, understand and review original articles and working documents.
- present and discuss their concepts in a peer group.

Learning matter

Numerical Modelling of Structures

- 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.

Biological Rhythms and Homeostatic Control:

- Methods: BioPack-Software (ECG, EEG, EMG, Evoked Potentials), HRV-Analyses Software
- Practical work: Prepare and conduct scientific paper presentation in the team (Journal Club) write an ethical proposal for experiments with human study participants, conduct an experiment using biological and psychological study variables

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	Regular form for the module examination: written exams (one per course) Further possible examinations: oral examination, presentation, homework reports The type of examination will be announced by the lecturer at the beginning of the course.

Literature/working materials	Müller, G & Groth, C (2007). FEM für Praktiker, I: Grundlagen: Basiswissen und Arbeitsbeispiele zur Finite-Element-Methode mit dem Programm ANSYS Expert Verlag. http://www.cae-wiki.info/wikiplus/index.php/Literatur Lee, H (2015) Finite Element Simulations with ANSYS Workbench 16: Theory, Applications, Case Studies. SDC Publishers. Chen, X & Liu Y (2014). Finite Element Modeling and Simulation with ANSYS Workbench. CRC Press. Bathe, K. (2007). Finite Element Procedures. New Jersey: Prentice Hall. Merkel, M & Öchsner, A, 2010, Eindimensionale Finite Elemente – Ein Einstieg in die Methode, Springer Verlag. Scientific Journals and papers depending on the project

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 08	**Medical Real Time Systems**
Module coordination/ responsible person	Prof. Dr. Petra Margaritoff
Associated courses	• Medical Real Time Systems Software Implementation • Medical Real Time Systems Hardware Implementation • Medical Real Time Systems, Practical Work
Lecturer	Prof. Dr. Petra Margaritoff, Prof. Dr. Bernd Flick
Semester/Period/Offer of this turnus	1st or 2nd semester/one semester/summer semester
ECTS Credits/Presence hours per week	5 CP/4 SHW • Medical Real Time Systems Software Implementation (1 SHW) • Medical Real Time Systems Hardware Implementation (1 SHW) • Medical Real Time Systems, Practical Work (2 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
General learning aims and work fields	• Methods and Analysis, Research and Development • Innovation management

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)

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	Regular form for the module examination: oral exam Further possible examinations: written examination, oral presentation, written study report, homework reports, colloquium, practical exams or combination thereof

	The type of examination will be announced by the lecturer at the beginning of the course.
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 program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 9	**Simulation and Virtual Reality in Medicine**
Module coordination/ responsible person	Prof. Dr. Boris Tolg
Associated courses	• Simulation and Virtual Reality in Medicine • Simulation and Virtual Reality in Medicine, Practical work (SimLab)
Lecturer	Prof. Dr. Boris Tolg, Prof. Dr. Jürgen Lorenz
Semester/Period/Offer of this turnus	1st or 2nd semester/one semester/winter semester
ECTS Credits/Presence hours per week	5 CP/4 SHW • Simulation and Virtual Reality in Medicine (2 SHW) • Simulation and Virtual Reality in Medicine, Practical work (SimLab) (2 SHW)
Workload	150 h: 64 h presence, 86 h private study
Status	Obligatory module
Preconditions/Required skills	
Teaching language	English
General learning aims and work fields	• Methods and Analysis, Research and Development • Innovation management

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)
    - CAVE
    - 3D-Visual systems
- Evaluation
    - Mathematical Background
        - Statistics
        - …
    - Methodical Background
        - Questionnaires
        - Physiological data
    - Psychological Background
        - …

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	Regular form for the module examination: written project report Further possible examinations: written exam, oral examination, oral presentation, homework reports The type of examination will be announced by the lecturer at the beginning of the course.

	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 program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit :10	**Biomedical Project**
Module coordination/ resposible person	Prof. Dr. Friedrich Ueberle
Associated courses	• Scientific Project • Research Seminar (Obligatory)
Lecturer	All university lecturers of the department MT, Prof. Dr. Ueberle
Semester/Period/Offer of this turnus	2nd semester/one semester/winter and summer semester
ECTS Credits/Presence hours per week	8 CP/6 SHW • Scientific Project (4 SHW) • Research Seminar (Obligatory) (2 SHW)
Workload	240 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
General learning aims and work fields	• Methods and Analysis, Research and Development, Reflection and Communication • Project management
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	
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	Regular form for the module examination: written project report Further possible examinations: written exam, oral examination, oral presentation, homework reports The type of examination will be announced by the lecturer at the beginning of the course. 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 program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Module code digit: 11	**HTA/Regulatory Affairs**
Module coordination/ responsible person	Prof. Dr. Marc Schütte
Associated courses	• Regulatory Affairs • Health Technology Assessment (HTA)
Lecturer	Prof. Dr. Marc Schütte, Prof. Bernd Kellner, Prof. Udo van Stevendaal
Semester/Period/Offer of this turnus	1st or 2nd semester/one semester/winter semester
ECTS Credits/Presence hours per week	5 CP/4 SHW • Regulatory Affairs (2 SHW) • Health Technology Assessment (HTA) (2 SHW)
Workload	150 h: 64h 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
General learning aims and work fields	• Reflection and Communication • Project management, Marketing and Distribution, Controlling

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	
Teaching methods/methods generally/types of media	• Powerpoint presentations • Group work (internet retrieval, discussions) • Excursions ("expert interviews")
Course- and examination achievements	Regular form for the module examination: oral presentation Further possible examinations: oral examination, presentation, homework reports The type of examination will be announced by the lecturer at the beginning of the course.
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 program **Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems**	
Module code digit: 12	**Master Thesis (Masterarbeit)**
Module coordination/ responsible person	Prof. Dr. Bernd Flick
Associated courses	
Lecturer	All university lecturers
Semester/Period/Offer of this turnus	3rd semester/one Semester/winter and summer 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
General learning aims and work fields	• Methods and Analysis, Research and Development, Reflection and Communication • Project management
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	Regular form for the module examination: written composition, presentation, poster, colloquium Further possible examinations: written exam, oral examination, oral presentation, homework reports, colloquium, practical exams The type of examination will be announced by the lecturer at the beginning of the course.
Literature and learning aids	Scientific literature

Lecturers

Professors

Name	Expertise
Prof. Dr. Nicholas Bishop	Biomechanik/Technische Mechanik
Prof. Dr. Constantin Canavas	Automatisierungstechnik
Prof. Dr. Friedrich Dildey	Physik
Prof. Dr. Susanne Heise	Biogefahrstoffe/Toxikologie
Prof. Dr. Bernd Flick	Electronics, Electro-, Measurement- and RF-Engineering
Prof. Dr. Carolin Floeter	Biologie
Prof. Dr. Kay Förger	Datenverarbeitung
Prof. Dr. Frank Hörmann	Präklinisches Rettungswesen/Gefahrenabwehr (1/2 W2)
Prof. Dr. Timo 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. Frank Lampe	Navigationstechniken in der Orthopädie und Sportmedizin
Prof. Dr. Gerwald Lichtenberg	Physics & Control Systems
Prof. Dr. Christoph Maas	Mathematik
Prof. Dr. Petra Margaritoff	Medizinische Datensysteme
Prof. Dr. Jürgen Lorenz	Humanbiologie
Prof. Dr. Stefan Oppermann	Präklinisches Rettungswesen/Gefahrenabwehr (1/2 W2)
Prof. Dr. Anna Rodenhausen	Mathematik
Prof. Dr. Rainer Sawatzki	Mathematik und Informatik
Prof. Dr. Thomas Schiemann	Mathematik und Informatik
Prof. Dr. Marc Schütte	Arbeits- Organisationspsychologie
Prof. Dr. Marion Siegers	Mathematik
Prof. Dr, Rainer Stank	Technische Mechanik
Prof. Dr. Boris Tolg	Mathematik und Informatik
Prof. Dr. Friedrich Ueberle	Medizinische Mess- und Gerätetechnik

Prof. Dr. Udo van Stevendaal	Medizinische Gerätetechnik
Prof. Dr. Gesine Witt	Umweltchemie

Academic personal

Dipl. Ing. Sakher Abdo

Dipl. Ing. Jan-Claas Böhmke

Dipl. Ing. Peter Krüß

Dipl. Ing. Jens Martens

Dr. Dagmar Rokita

Dipl. Ing. Stefan Schmücker

External lecturers

Prof. Dr. Andreas Brensing

PD Dr. Fehlauer

Dr. Ulrich Katscher

Dr. Wolfgang Wöllmer

Kai Kruppa, M.Sc.

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