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 of Biomedical Engineering

October 2020

approved by the Faculty Council of the Faculty of Life Sciences on 22.10.2020

Department of Biomedical Engineering/Faculty of Life Sciences
Hamburg University of Applied Sciences
Ulmenliet 20, D-21033 Hamburg
Tel.: +49.40.428 75-6400, Fax: +49.40.42 73 10-576
www.haw-hamburg.de

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Aims and organization of the program

The Master's degree (M.Sc.) program of "Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems" of the Hamburg University of Applied Sciences addresses applicants with an undergraduate (bachelor's) degree in biomedical engineering and related engineering specialties (e.g. electrical or software engineering). The program enables students to do advanced work in hospitals, industry and academia.

The study program has a duration of 3 semesters (1½ years) if realized in full-time. It covers mathematical, scientific and engineering knowledge with emphasis on technologies for acquisition, processing, control and imaging of biomedical signals and physiological control loops including applications in virtual reality and simulation. A focus of non-technical skills acquisition is on regulatory affairs and health technology assessment.

A noteworthy program feature is that modules regularly include practical courses in which students interact with up-to-date software and hardware in research labs of the faculty and/or in real work environments in partner hospitals and companies.

Module embedded scientific projects (and module 10 in particular) train the students in self-organized research & development in small groups. Students obtain soft and non-technical skills in seminars and during lectures by intense discussions and small group assignments that conclude with project presentations like posters and papers. In some modules the students form learning teams with students enrolled in the joint master program E**uropean Master of Medical Technology and Healthcare Business** (EMMaH) creating opportunities for collaboration in international and inter-professional collaboration.

The program consists of 11 modules and the master thesis. With exemption of the first module, modules conclude with a comprehensive module exam. The total number of credit points (CP) is 90. One CP is equivalent to 30 work hours. On *the following pages* detailed information on the modules can be found, i.e. module names, requirements, content, learning outcomes, workload, type of exam and so on.

In the master thesis, the students shall demonstrate their ability for autonomous scientific work at graduate level. The Master thesis represents the written composition of a research or development project. Thereby students prove their capability to express sound scientific hypotheses, explore relevant background literature, make informed decisions about methods, collect and analyze data, present results and discuss them. The time-limit for the master thesis is six months. It is credited by 30 credit points.

The program language is English.

The general learning and competence development aims of the program are:

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

In terms of professional performance areas in hospitals, industry and academia the program is oriented towards

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

The following table summarizes the program modules with respect to the general learning aims and professional performance areas. *Knowledge and Comprehension* refer to study contents of the first semester providing a platform for advanced studies in mathematics and data acquisition. *Methods and Analysis* refer to modules that combine the delivery of theoretical knowledge (knowing facts) with experiential learning and the delivery of methodical skills (knowing methods). Courses where students have to engage in longer or shorter periods of self-organized project learning rank under *Research and Development*. Modules with a non-technical or assessment and evaluation focus on biomedical and healthcare technology categorize under *Reflection and Communication*.

Module outcome matrix

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

x) Courses with possible co-assignments with students of European Master of Medical Technology and Healthcare Business
(x Modules with practical work component

Forms of examination

In accordance with § 14 APSO-INGI, as amended from time to time, the forms of examination for the subsequent module manual are defined as follows:

Case study (CS)
A case study is a piece of written work presenting a reasoned solution to a set problem. Students work either individually or in a group to establish, analyse and solve specific problems in practice by applying scientific and academic methods and findings. Case studies are set for specific classes, and must be completed in the same semester as the class and by the time the class ends. The programme-specific examination and study regulations may contain more detailed provisions on the time available for case studies.

Home project (HP)
A home project is a piece of written work, to be produced by the student on his or her own and outside class hours, in which the student is to prove that he or she is able to investigate and analyse a set question or subject independently. A maximum of three months is allowed for completion. If the home project constitutes an examination, the programme-specific examination and study regulations may specify whether or not a colloquium is to be held once the written project has been submitted. Colloquia should last between 15 and 45 minutes, and are generally to be held within one month of submission of the written work.

Written examination (WE)
A written examination is completed under supervision. Students must complete the set questions on their own, either without the use of study aids or with the use of specified study aids only. Written examinations last at least 60 and no longer than 240 minutes.

Colloquium (CO)
A colloquium may be required as part of certain types of examination, or in combination with the Bachelor or Master thesis. A colloquium is an oral examination in which students must prove their knowledge of the material examined, speaking and responding freely in an open discussion. A colloquium lasts at least 15 and no more than 45 minutes, and is also aimed at establishing that the written work submitted was all the student’s own work. Colloquia can be organised as individual or group examinations. The size of the group for group examinations should be considered accordingly when setting the length of the examination.

Construction task (CT)
A construction task is a piece of written work in which the student must prove his or her design skills by solving practical tasks. A maximum of three months is allowed for completion.

Lab work completion (LWC)
Lab work is successfully completed when students have successfully conducted the experiments set by the examiner during the semester and have demonstrated their knowledge by taking part in corresponding colloquia and/or by submitting written records of their work and/or by completing set written tasks. Colloquia last for a minimum of 15 and a maximum of 45 minutes. The written work must be submitted by a deadline set by the examiner; the latest deadline is the end of the semester in which the class in question was taken.

Lab work examination (LE)
Lab work examination consists of the completion of lab work and a final examination at the end of the class. In the examination, the student is required to conduct and solve an experiment on his or her own and independently. Examinations last at least 60 and no more than 240 minutes.

Oral examination (OE)
In an oral examination, a student must demonstrate in discussion with the examiner that he or she fully understands the material on which he or she is being examined. Oral examinations generally last at least 15 and no more than 45 minutes. Oral examinations may be conducted as individual or group examinations, and are to be conducted by one examiner and one assessor in accordance with Section 13 (4). An oral examination may alternatively be conducted by two or more examiners instead of one, i.e. by a panel of examiners; in such a case, the student is to be examined by one examiner only in each of the various examination subjects. Oral examinations are always assessed and graded by one examiner only, no matter whether they are conducted by several examiners or by an examiner and an assessor. The examiner responsible for grading in each case must consider the views of the other examiners/the assessor before deciding on the grade to be awarded. The main aspects covered in and results of each oral examination are to be recorded. The record is signed by the examiners and assessor and is filed with the examination documents.

Project (Pro)
A project is an interdisciplinary task relating to the area of industry or business for which the course is designed. The results of projects must be documented. At least 6 and no more than 26 weeks are allowed for projects. Project work is generally completed with a colloquium. The applicable programme-specific examination and study regulations may specify additional requirements in terms of the form, content and goal of the project, and may specify another form of final assessment instead of a colloquium.

Paper (Pap) or oral presentation
A paper is a presentation lasting between 15 and 45 minutes on the basis of written preparation by the student. A paper is followed by a discussion led by the student or tutor. Papers should not be read out from detailed notes; students should be able to speak spontaneously. Digital or hard copies of any presentations and graphics used are to be submitted to the examiner. The detailed written paper to be submitted to the examiner should summarise the key findings and conclusions.

Test (T)
Tests are pieces of written work in which students demonstrate their ability to solve set tasks in a clearly defined subject area under examination conditions. Tests last at least 15 and no more than 90 minutes. The programme-specific examination and study regulations may specify that test results are to be included in the overall grade for written examinations.
Exercise slip (ES)
An exercise slip is awarded once a student has successfully solved the written theory tasks set by the examiner and has demonstrated his or her knowledge of the subject in a colloquium or paper. Colloquia last at least 15 and no more than 45 minutes. The written work must be submitted by a deadline set by the examiner; the latest deadline is the end of the semester in which the class type in question (exercise) was taken.

Portfolio examination (PF)
A portfolio examination is a type of assessment consisting of not more than ten distinct components, in at least two different forms of assessment chosen from the forms of assessment listed in Section 14 subsection 3 APSO-INGI; practice tasks set during the semester may also be one of the components. At the beginning of the class or course, the member of academic staff in charge of delivering it shall determine and announce which components will comprise the portfolio examination and their weightings. Where the class concludes with a graded examination, the overall grade for the portfolio examination shall be calculated from each individual component, weighted in accordance with the weighting announced at the outset of the course. The total workload and the difficulty level of a portfolio examination shall not exceed the workload or difficulty level that would pertain to each form of assessment used were they to be used as the sole component of the examination.

Module and course structure

1	2	3	4	5	6	7	8	9	10	11	12	13
Nr.	**Modul**	**Semester***	**Angebot****	**ECTS-CP**	**Lehrveranstaltung**	**Lehrveranstaltungsart**	**SWS**	**ECTS-CP / Lehrveranstaltung**	**Prüfungsart*****	**Prüfungsform**	**Abschlussanteil in %**	**Gruppengröße**
1	Mathmatics A	1	WiSo	7	Numerical Mathematics	SeU	4	4	PL	K (H, R, M, PF)	4,3	20
		1/2	Wi		Advanced Calculus for Engineers	SeU	2	3	PL	K (H, R, M, PF)	3,3	20
2	Data Acquisition	1	WiSo	5	Data Acquisition	SeU	2	3	PL	K (H, R, M)	5,4	20
					Data Acquisition, **Practical Work**	Üb	2	2				10
3	Advanced Biosignal Processing	1/2	So	5	Biosignal Processing	SeU	2	3	PL	K (H, M, PF)	5,4	20
					Advanced Filtering Techniques for Biosignals	SeU	2	2				20
4	Medical Image Processing	1/2	So	5	Medical Image Processing	SeU	2	3	PL	PF (K, H, M)	5,4	20
					Medical Image Processing, **Practical Work**	SeU	2	2				20
5	Application of Imaging Modalities	1/2	So	5	Advanced Imaging (MR, US, CT)	SeU	2	3	PL	K (H, R, M, PF)	5,4	20
					Advanced Imaging (MR, US, CT), **Practical Work**	SeU	2	2				20
6	Advanced Control Systems	1/2	Wi	5	Advanced Control Systems Methods	SeU	2	3	PL	PF (K, R, M)	5,4	20
					Advanced Control Systems, Tools, **Practical Work**	SeU	2	2				20
7	Modelling Medical Systems	1/2	Wi	5	Biomechanical modeling and validation	SeU	2	3	PL	H (K, R. M)	5,4	20
					Finite Element Analysis	SeU	2	2				20
8	Medical Real Time Systems	1/2	So	5	Medical Real Time Systems, Software Implementation	SeU	1	1,5	PL	M (K, H, PF)	5,4	20
					Medical Real Time Systems, Hardware Implementation	SeU	1	1,5				20
					Medical Real Time Systems. **Practical Work**	Seu	2	2				20
9	Simulation and Virtual Reality in Medicine	1/2	Wi	5	Simulation and Virtual Reality in Medicine	SeU	2	3	PL	PF	5,4	20
					Simulation and Virtual Reality in Medicine, **Practical Work** (SimLab)	Üb	2	2				10
10	Biomedical Project	2	WiSo	8	Scientific Project	PJ	4	5	PL	H (K, M, R)	8,7	5
					Research Seminar	SeU	2	3				20
11	Health Technology Assessment /Regulatory Affairs	1/2	Wi	5	Regulatory Affairs	SeU	2	3	PL	M (H, R)	5,4	20
					Health Technology Assessment	SeU	2	2				20
12	Master Thesis (Masterarbeit)	3	WiSo	30		MTh		30	PL	Ma	35	1
	Summen			**90**			**48**				**100**	

Prüfungsart	**Lehrveranstaltungsart**	**Prüfungsform**
PL: Prüfungsleistung	SeU: Seminaristischer Unterricht	K: Klausur
	Üb: Übung	H: Hausarbeit
	PJ: Projekt	R: Referat
	MTh: Master Thesis	M: Mündliche Prüfung
		PF: Portfolio-Prüfung
		Ma: Masterarbeit

* Erläuterungen zur Spalte „Semester“: Die Lehrveranstaltungen "1/2" werden nur einmal jährlich (entweder im Sommer- oder im Wintersemester) angeboten. Die Studierenden belegen diese Veranstaltungen daher in ihrem 1. oder 2. Studiensemester je nach Aufnahmebgeinn des Studiums im Winter- oder Sommersemester. Die Lehrveranstaltungen "1" oder "2" werden jedes Semester angeboten. Die Studierenden sollten die Lehrveranstaltungen “1” in ihrem ersten und die Lehrveranstaltungen “2” im zweiten Studiensemester belegen. Die Masterthesis soll im dritten Studiensemester angefertigt werden.
** Erläuterungen zur Spalte “Angebot”: WiSo = Veranstaltungen werden im Winter- und Sommersemester angeboten. Wi = Veranstaltungen werden im Wintersemester angeboten. So = Veranstaltungen werden im Sommersemester angeboten.
*** Die Prüfungsformen in der Klammer sind mögliche Prüfungsformen.

Module descriptions

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Mathematics A	
Module Code Digit	1
Module coordination/ responsible person	Prof. Dr. Anna Rodenhausen
Semester/Period/Interval	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
Workload	210 h: 108 h course / computer laboratory work, 102 h self-organized
Status	Mandatory module
Requirements	Recommended: Basic skills in programming and mathematics (e.g. acquired in a bachelor degree program)
Language	English
Competences/ Learning Outcomes	The students are able to use the computer as an 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 results. The students are able to solve curve and surface integrals and to interpret the resulting numbers. They are able to apply integral operators and to make use of Gauss' and Stokes' Theorems in selected applications.

	The students are able to • help each other to identify programming errors, • analyze advanced integration problems and solve them in teams, • discuss their results and judge about their quality and scientific relevance.
Content	Numerical Mathematics: • Introduction to MATLAB • Numerical solution of linear equation systems • Curve fitting and interpolation • Optimization • Numerical differentiation and integration • Numerical solution of ordinary differential equations (ODEs) and systems of ODEs • Examples of numerical solution of partial differential equations Advanced Calculus for Engineers • Theory of planar curves and space curves • Vector fields, potentials, integral operators • Curve integrals and surface integrals Theorems of Gauss and Stokes
Applicability	The module enables to perform advanced quantitative analysis in own responsibility. In can also be used in other master programs in various fields of studies.
Course- and examination achievements	Regular form for the module examination: written exams (one per course). Further possible examinations: oral examination, presentation, homework reports, portfolio exam. The type of examination will be announced by the lecturer at the beginning of the course.
Associated lectures/courses	• Numerical Mathematics • Advanced Calculus for Engineers
Teaching methods/ methods generally/ types of media	Lectures, practical work in the computer lab, discussions, exercises, black board, movies, software examples, online materials,

Literature/working materials	Each in the current edition: Chapra, S.C.: Numerical Methods for Engineers, McGraw-Hill. Gilat, A., Subramaniam, V.: Numerical Methods – An Introduction with Applications Using MATLAB, Wiley. Mathews, J. H., Fink, K.D.: Numerical Methods using MATLAB, Pearson/Prentice Hall. Yang, W.Y., Cao, W., Chung, T.-S., Morris, J.: Applied Numerical Methods Using MATLAB, Wiley. Lecture notes and exercises edited by the Lecturers. *All books and materials are used in the latest edition.*

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Data Acquisition	
Module Code Digit	2
Module coordination/ responsible person	Prof. Dr. Kay Förger
Semester/Period/Interval	1st semester / one semester / winter and summer semester
ECTS Credits/ Presence hours per week	5 CP / 4 SHW
Workload	150 h: 72 h course / laboratory work, 78 h self-organized
Status	Mandatory module
Requirements	Recommended: Basic skills in programming and mathematics (e.g. acquired in a bachelor degree program)
Language	English
Competences/ Learning Outcomes	The students are able ... - to acquire data by a computer, - to select and to apply statistical and other methods for data processing and analysis, - to use simulations to verify and to analyze measurement and processing techniques. - to implement parallel execution for acquisition and processing and the simultaneous reaction to user input - keep one's distance to results and especially to own programs and to recognize the must of software tests using simulations
Content	Data Acquisition - Fourier Transform: basics, discretization - Sampling Theorem, Aliasing, Smoothing Windows etc. - Digital Filters: linear filters (FIR and IIR) Evaluation of Measured Data - Basic Statistical Quantities (mean, variance and standard deviation, median etc.) - Hypothesis Tests - Parameter Estimation (robust techniques are compared to standard procedures)

	Introduction to Graphical Programming Concepts (LabVIEW)
Applicability	Required for all practical applications where data are recorded and evaluated by a computer automatically.
Course- and examination achievements	Regular form for the module examination: written exam (PL). Further possible examinations: homework reports, presentation, oral examination. The type of examination will be announced by the lecturer at the beginning of the course.
Associated lectures/courses	• Data Acquisition • Data Acquisition, Practical Work
Teaching methods/ methods generally/ types of media	The course is split into a lecture part and a practical part. 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 programming exercises during the attendance. To difficulties and misunderstood issues is responded by mentoring individually. Selected solutions were presented to the study group.
Literature/working materials	Each in the current edition: Press, W. H. et al. Numerical recipes in C++. New York: Cambridge University Press. Bronstein, I.N., Semendyayev, K.A. et al. Handbook of Mathematics, Berlin Heidelberg: Springer. R. Jamal, H. Pichlik: LabVIEW Applications, Prentice Hall

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Advanced Biosignal Processing	
Module Code Digit	3
Module coordination/ responsible person	Prof. Dr. Petra Margaritoff
Semester/Period/Interval	1st or 2nd semester / one semester / winter semester
ECTS Credits/ Presence hours per week	5 CP/ 4 SHW
Workload	150 h: 72 h course work, 78 self-organized
Status	Mandatory module
Requirements	Recommended: Appropriate knowledge from previous academic studies in a professionally associated field, bachelor degree: Signal processing, mathematics, biomedical engineering, physiology
Language	English
Competences/ Learning Outcomes	The students... • 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. different kinds of discrete transforms and filtering for biomedical problems etc. • understand and are able to design digital signal processing chains • are able to develop solutions for biomedical signals processing tasks. • know and apply advanced algorithms for the extraction of functional parameters from biomedical signals. • 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 solve demanding scientific and engineering problems.
Content	Selection from the following topics **Biosignal Processing** • Recap of mathematical and signal processing basics (complex calculations, basic functions and distributions, time and spectral plane, ...) • General signal processing methods, continuous transforms (e.g. FT, LT, CWT) • Digital signal processing methods and transforms (e.g. DSTFT, DWT and other advanced transforms) • Elements,usage and constraints of digital signal processing chains • Further advanced methods of signal analysis and processing • Examples of the application of signal processing means to biosignal processing (functional analysis of biomechanical heart viablility, EEG, ECG, EMG,...) **Advanced Filtering Techniques for Biosignals** • Different filtering algorithms, e.g. IIR, FIR-filters, • Application of transforms to filtering problems
Applicability	This module covers advanced methods of signal processing and filtering with a focus on digital systems. This content builds on signal-processing bachelor's subjects and deepens the basics of the Data Acquisition Module. Contents and experiences of the module Mathematics A can be applied in this module. Contents of this module could be used for the Biomedical Project and serve as a supplement for the Medical Image Processing Module. In addition, the module has references to other study programs, e.g. electrical and electronic engineering.
Course- and examination achievements	Regular form of the module examination: written exam (PL) Further possible examinations: oral examination, homework reports, portfolio-exam The type of examination will be announced by the lecturer at the beginning of the course.
Associated lectures/courses	• Biosignal Processing • Advanced Filtering Techniques for Biosignals

Teaching methods/ methods generally/ types of media	Seminaristic lectures, teamwork/ distance learning elements, web-based cooperation, autonomous studies/ PowerPoint, blackboard, project work
Literature/working materials	To be advised by the lecturers

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Medical Image Processing	
Module Code Digit	4
Module coordination/ responsible person	Prof. Dr.-Ing. Thomas Schiemann
Semester/Period/Interval	1st or 2nd semester / summer semester / every year
ECTS Credits/ Presence hours per week	5 CP, 4 SWS
Workload	150 h, 72 h course / laboratory work, 78 h self-organized
Status	Mandatory module
Preconditions/Required skills	Recommended: Appropriate knowledge from previous academic studies in a professionally associated field, bachelor degree: informatics, mathematics, biomedical engineering
Teaching language	English
Competences/ Learning outcome	The students solve comprehensive problems of image processing and related engineering fields by selecting and correctly implementing and applying concepts and methods of image processing in order to successfully use and evaluate such solutions in medical applications.
Learning matter	The following topics will be examined theoretically and practically by implementation in own programs or usage of standard-software: – Basics of digital images and image processing – Point-based operations, e.g. histograms – Linear and non-linear filters and their applications (e.g. smoothing, edge-detection, extraction of structures) – Geometrical manipulations and image registration – Relationships between image processing and computer-graphics – Processing of color-images and video-data

Applicability	The students … … can present and discuss problems and methods with other scientists. … can develop software for image-processing in their own responsibility. … are able to describe and explain theoretical concepts.
Course- and examination achievements	Regular form of the module examination: portfolio-exam (PL) Further possible examinations: written examination, oral examination, homework reports The type of examination will be announced by the lecturer at the beginning of the course.
Associated lectures/courses	• Medical Image Processing • Medical Image Processing, Practical Work
Teaching methods/ methods generally/ types of media	Seminaristic lectures, programming lab, teamwork/ distance learning elements, web-based cooperation, autonomous studies/ PowerPoint, blackboard, software demonstration
Literature/working materials	Each in the current edition: Bourne, R.: Fundamentals of Digital Imaging in Medicine. Springer. Burger, W., Burge, M.J.: Digital Image Processing. An Algorithmic Introduction Using JAVA. Springer. Preim, B.: Visual Computing for medicine: Theory, Algorithms and Applications. Morgan Kaufman Salzer, R.: Biomedical Imaging: Principles and Applications. Wiley. Software: Microsoft VisualStudio, ImageJ, Mevislab

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Application of Imaging Modalities	
Module Code Digit	5
Module coordination/ responsible person	Prof. Dr. Udo van Stevendaal
Semester/Period/Interval	1st or 2nd semester / one semester / summer semester
ECTS Credits/ Presence hours per week	5 CP / 4 SHW
Workload	150 h: 72 h course / laboratory work, 78 h self-organized
Status	Mandatory module
Preconditions/Required skills	Recommended: Knowledge 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
Competences/ Learning outcome	**Acquired competences/educational objectives** The students ... • are able to understand, analyze 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, MR and x-ray-based device image reconstruction, analysis of medical sound fields etc. • are able to understand relevant literature and implement the knowledge in biomedical problem 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	• 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) – Advanced imaging methods, e.g. phase contrast imaging and magnetic particle imaging
Applicability	The module deals with understanding and getting to know the functioning of important imaging procedures in medicine. The focus of knowledge transfer is on the practical use of imaging devices in medical diagnostics. As a central module in the Biomedical Engineer Master program, the contents are related to almost all modules in this program, especially Mathematics, Data Acquisition, Advanced Biosignal Prosessing, Medical Image Processing, Health Technology Assessment, Regulatory Affairs, etc. In addition, the module has links to other study programs, e.g. to the Bachelor's programs in Medical Technology
Course- and examination achievements	Regular form for the module examination: written exam (PL) Further possible examinations: oral examination, presentation, homework reports, portfolio analysis The type of examination will be announced by the lecturer at the beginning of the course.
Associated lectures/courses	• Advanced Imaging (MR, US, CT) • Advanced Imaging (MR, US, CT), Practical Work
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
Literature/working materials	• Kalender, W.A. (2011). Computed Tomography: Fundamentals, System Technology, Image Quality, Applications. Publicis. • Dowsett, K. and J. (2006). The Physics of Diagnostic Imaging, 2nd edition. London: Hodder Arnold. ISBN-10 0 340 80891 8. • Bronzino, J. D. (2000). The Biomedical Engineering Handbook, Second Edition, Vol. 1. Boca Raton, Fla.:CRC Press. ISBN 3-540-66351-7. • Hoskins, P.R., Thrush, A. (2003). Diagnostic Ultrasound. London: Greenwich Medical Media. ISBN 1-84110-042-0. • Powis, R.L. (1984). A Thinker‘s Guide to Ultrasonic Imaging. Baltimore, Maryland: Verlag Urban und Schwarzenberg. ISBN 3-541-71581-2. • Szabo, T.L. (2004). Diagnostic Ultrasound Imaging – Inside Out. Amsterdam: Elsevier. ISBN-13 978-0-12-680145-3.

	• Seeram, E. (2001). Computed Tomography, 2.nd edition. PhiladeCPhia: W.B. Saunders Company. ISBN 0-7216-8173-5. • Hashemi, R.H., Bradley W.G., Lisanti;C.J. (2004). MRI – the Basics, 2nd edition. PhiladeCPhia, Pa. ; London: Lippincott Williams Verlag. ISBN 0-7817-4157-2. • Westbrook, C., Roth, T. (2005). MRI in Practice, 3rd edition. Blackwell Publishing. ISBN-10: 1-4051-2787-2. • Niederlag, W. (Hrsg.) (2006). Molecular Imaging. Dresden: Health Academy. ISBN 3-00-017900-3. • Brahme, A., Comprehensive Biomedical Technology, Elsevier 2014, (Vol. 1), Vol. 2: X-Ray and U/S, Vol. 3: MR

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Advanced Control Systems	
Module Code Digit	06
Module coordination/ responsible person	Prof. Dr. Gerwald Lichtenberg
Semester/Period/Interval	1st or 2nd semester/ one semester / winter semester
ECTS Credits/ Presence hours per week	5 CP / 4 SHW
Workload	150 h: 72 h course / laboratory work, 78 h self-organized
Status	Mandatory module
Requirements	Recommended: Appropriate knowledge from previous academic studies on bachelor level: mathematics, physics, informatics, feedback systems, human biology.
Language	English
Competences/ Learning Outcomes	**Competence in facts (knowledge & understanding)** The students are able 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) • design appropriate controllers - fix the control structure - choose the controller structure - optimize controller parameters **Competence in methods (knowledge application & development** The students are able to… • apply model-based methods for automation tasks - State feedback - Predictive and Learning Control - Adaptive Control - Supervisory Control • use block-oriented simulation tools (MATLAB/Simulink) - build models from basic equations (white box)

	- identify parameters from measurements (black/gray box) - validate a model - design controllers with model-based tools • decide which concepts are applicable, • guide the implementation process, • understand basics for later usage of engineering tools. **Social competence (communication & cooperation)** The students are able to … • discuss control concepts in a project team **Self-Competence (professionalism & self-regulation)** The students are able to … • reflect their ideas • evaluate their performance by objective measures
Content	**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
Applicability	Module *Advanced Control Systems* in the Master's Program *Renewable Energy Systems* (RES)
Course- and examination achievements	Regular form for the module examination: portfolio exam (PL) Further possible examinations: written exam, presentation, oral examination The content of the portfolio exam will be announced by the lecturer at the beginning of the course.
Associated lectures/courses	• Advanced Control Systems Methods • Advanced Control Systems Tools (Practical Work)

Teaching methods/ methods generally/ types of media	Lectures, computer labs, mini group projects, presentations in classroom and online.
Literature/working materials	Lecture notes Current research papers Each in current edition: Khalil *Nonlinear Systems*, Prentice-Hall. Skogestad & Postlethwaite *Multivariable feedback control: analysis and design*, Wiley. Ljung *System Identification*, Prentice-Hall. Maciejowski *Predictive Control with constraints*, Prentice-Hall.

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Modelling Medical Systems	
Module Code Digit	7
Module coordination/ responsible person	Prof. Dr. Nicholas Bishop
Semester/Period/Interval	1st or 2nd semester / one semester / summer semester
ECTS Credits/ Presence hours per week	5 CP / 4 SHW
Workload	150 h: 72 h course work, 78 h self-organized
Status	Mandatory module
Requirements	Recommended: Students should have knowledge of technical mechanics, Excel and programming
Language	English
Competences/ Learning Outcomes	**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 • build a model from physical differential-algebraic equations • identify parameters from measurement data • validate a model • use finite element analysis software **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. • critically read, understand and review original articles and working documents. • present and discuss their concepts in a peer group.

Content	Numerical Modelling of Structures • A particular simple mechanical problem will be addressed throughout this module in terms of deformation and strength of a structure. It will be analysed using multiple modelling methods, allowing confidence in the results to be accumulated, demonstrating the synthesis of multiple approaches and highlighting comparisons between methods. • Semester 1: The Biomechanical modelling and validation course will concentrate on devising a 1 dimensional analytical solution to the problem, solved by hand, followed by a spread sheet solution, allowing a parametric analysis. The problem will then be discretised and solved using a spreadsheet. An experimental validation will be undertaken, potentially using custom 3D printed parts, mounted on a uniaxial mechanical testing machine. • Semester 2: In the Finite Element Analysis (FEA) course the problem will be analysed using FEA by hand and then using commercially available software in 2D. The outputs will be compared with modelling and experimental results and potential errors highlighted. Solution efficiency will be addressed by simulating symmetry planes using boundary conditions. • A biomechanical implant may then be analysed using appropriate methods.
Applicability	• No prerequisites A knowledge of static technical mechanics, the use of spreadsheets and basic programming skills will be necessary.
Course- and examination achievements	Regular form for the module examination: written report (PL) Further possible examinations: Oral or written examination, presentation. The type of examination will be announced by the lecturer at the beginning of the course.
Associated lectures/courses	• Biomechanical modelling and validation • Finite Element Analysis
Teaching methods/ methods generally/ types of media	• Seminaristic lectures, practical courses, teamwork, PowerPoint-presentation, tutorials, private study, Blackboard, e-Learning
Literature/working materials	Hibbeler, R.C. Engineering Materials, Pearsons. (&similar / German)

	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.caewiki.info/wikiplus/index.php/Literatur Lee, H (2015) Finite Element Simulations with ANSYS Workbench: Theory, Applications, Case Studies. SDC Publishers. Bathe, K. (2007). Finite Element Procedures. Prentice Hall. Merkel, M & Öchsner, A, 2010, Eindimensionale Finite Elemente – Ein Einstieg in die Methode. Springer Verlag.

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Medical Real Time Systems	
Module Code Digit	8
Module coordination/ responsible person	Prof. Dr. Petra Margaritoff
Semester/Period/Interval	1st or 2nd semester / one semester / summer semester
ECTS Credits/ Presence hours per week	5 CP / 4 SHW
Workload	150 h: 72 h course / laboratory work, 78 h self-organized
Status	Mandatory module
Requirements	Recommended: Appropriate knowledge from previous academic studies in a professionally associated field, bachelor degree: informatics, electrical and electronic engineering, programming experience - preferably in a structured language
Language	English
Competences/ Learning Outcomes	The students … • Can assess the suitability of hard- and software solutions for biomedical products with realtime requirements. • Can develop small hard- and software realtime solutions for biomedical embedded systems. • Are aware of the influence of high frequencies in electronic circuits concerning emission and absorption. • Can construct sinple high frequency circuits • Know antenna basics. • Can approach the design and implementation of biomedical systems according to given requirements. • Can patiently and systematically implement and debug real time systems in hard- and software.

Content	**Medical Real Time Systems Software Implementation:**
	• Distinctive software-aspects of real time systems with focus on biomedical applications
	  o Deterministic behaviour
	  o quasi concurrent processing, measures of "safe" data access
	  o interrupt handling, interrupt levels
	  o watchdog, timers

	○ testability ○ efficiency ○ Inter-process / -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)
Applicability	This module deals with advanced aspects of microprocessor technology and high-frequency technology with a focus on the special requirements of deterministic real-time systems, as they are important in medical technology. The module includes the theory of real-time techniques, interfaces and communication systems, and the application of the methods in medical technology. Contents of the module could be used for the Biomedical Project. In addition, the module has references to other study programs, e.g. electrical and electronic engineering and computer science.
Course- and examination achievements	Regular form of the module examination: oral examination (PL) Further possible examinations: written examination, homework reports, portfolio-exam The type of examination will be announced by the lecturer at the beginning of the course.
Associated lectures/courses	• Medical Real Time Systems, Software Implementation • Medical Real Time Systems, Hardware Implementation • Medical Real Time Systems, Practical Work

Teaching methods/ methods generally/ types of media	• Seminaristic lectures, • Practical work / teamwork • distance learning elements, web-based cooperation, autonomous studies/ • PowerPoint, blackboard, project work
Literature/working materials	Bronzino, J.D. (1995). IEEE Handbook of Biomedical Engineering. Florida: CRC Press Boca Raton. Kernighan BW, Ritchie DM: The C Programming Language, >= 2nd. Ed., >= 1988. 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. Atmel Studio (Programming IDE)

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Simulation and Virtual Reality in Medicine	
Module Code Digit	9
Module coordination/ responsible person	Prof. Dr. Boris Tolg
Semester/Period/Interval	1st or 2nd semester / one semester / winter semester
ECTS Credits/ Presence hours per week	5 CP / 4 SHW
Workload	150 h: 72 h course work, 78 h self-organized
Status	Mandatory module
Requirements	
Language	English
Competences/ Learning Outcomes	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. 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.

Content	• 3D Simulation
	  o Mathematical Background
	    ▪ Transformation matrices
	    ▪ Quaternions
	    ▪ Kinematics
	    ▪ Propagation Models
	    ▪ …
	  o 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 …
Applicability	The module conveys essential knowledge of simulation methods and technologies used in medicine. The focus is on practical applicability, scientific methods and engineering abilities. The module can be used in other study programs with a mathematical and scientific background.
Course- and examination achievements	Regular form of the module examination: portfolio-exam (PL) containing • Oral project presentation • Written project documentation • Project outcome, for example: ○ source code ○ literature research ○ other content ○ … The type of examination will be announced by the lecturer at the beginning of the course.

Associated lectures/courses	• Simulation and Virtual Reality in Medicine • Simulation and Virtual Reality in Medicine, Practical Work (SimLab)
Teaching methods/ methods generally/ types of media	The lecture is based on projects Projects contain • experimental laboratory work • hardware and software engineering • literature research • seminars • presentations • project meetings • project documentation web based cooperation
Literature/working materials	Scientific literature, depending on the project

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Biomedical Project	
Module Code Digit	10
Module coordination/ responsible person	Prof. Dr. Bernd Flick
Semester/Period/Interval	2nd semester / one semester / winter and summer semester
ECTS Credits/ Presence hours per week	8CP / 6 SHW
Workload	240 h: 108 h laboratory work, private study, includes 32 h seminar
Status	Mandatory module
Requirements	Recommended: 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 Medical Technologies/Faculty LS). The project regulations of the Department Medical Technologies apply.
Language	English
Competences/ Learning Outcomes	**Competence in facts (knowledge & understanding)** The students are able to • Present correctly and assess in relation to the chosen topic from the field of the degree-specific specialization area. • Narrow down the question and define the problem in such a way that the prerequisites and objectives for the methodology for answering the question or problem solving become clearly apparent. • Research, describe and assess solution alternatives (methods and procedures) and selection criteria • Discuss the results of the question and the method and provide an outlook • Understand and apply complex laboratory and biomedical equipment to solve the project tasks.

	Competence in methods (knowledge application & development
	The students are able to
	• Obtain information on the state of research or the state of the art (e.g. with the heCP of a literature search), excerarate and (evidence-based) evaluate
	• To take formal requirements into account when writing a scientific paper, such as structure in EMED format (introduction, method, results, discussion) and correct citation
	• Professionally implement researched or relevant methods and procedures acquired during studies and adapt them to the respective conditions:
	  o in the case of empirical work, this means getting involved in the scientific and technical foundations of experimental technology, developing and carrying out a meaningful and effective experimental program and scientifically assessing the results of these experiments.
	  o in the case of theoretically oriented work, this means formulating selection criteria and questions for source material, explaining the classification of source procurement and evaluation, composing synopsis of important content and making weighting summaries of the content.
	• Display and summarize results using informative figures and table
	• Provide and track a project plan.
	
	Social competence (communication & cooperation)
	The students are able to
	• Respond to the views of examiners, supervisors or other stakeholders
	• Contribute your own ideas and represent them to the outside world
	• 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.
	• Autonomously organize project groups, organize meetings and communication among the project participants and identify and solve all problems typical to scientific projects.

	Self-Competence (professionalism & self-regulation) The students are able to • Reflect the ethical, legal and social implications of their work • Assess their skills and have ideas for their further development • Work persistently and purposefully on problems • Divide their time • Handle projects responsible, with awareness to cost, risk and safety.
Content	Project work in which the students independently work on a task from the professional field of activity of their course of study using scientific methods and findings.The content of the biomedical project depends on the task. The task is proposed and defined by the student in cooperation with supervisor, examiner and, if necessary, the external setup.
Applicability	• Methods and Analysis, Research and Development, Reflection and Communication • Project management
Course- and examination achievements	Regular form for the module examination: written project report (PL) Further possible examinations: written exam, oral examination, presentation The type of examination will be announced by the lecturer at the beginning of the course.
Associated lectures/courses	• Scientific Project • Research Seminar
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
Literature/working materials	Scientific literature, depending on the project

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Health Technology Assessment / Regulatory Affairs	
Module Code Digit	11
Module coordination/ responsible person	Prof. Dr. Bernd Kellner
Semester/Period/Interval	1st or 2nd semester / one semester / winter semester
ECTS Credits/ Presence hours per week	5 CP / 4 SHW
Workload	150 h: 72 h course work 72 h, 78 h self-organized
Status	Mandatory module
Requirements	Recommended: appropriate knowledge from previous academic studies in a professionally associated field, bachelor degree
Language	English
Competences/ Learning Outcomes	**Competence in facts (knowledge & understanding)** The students are able to… • investigate complex HTA and RA problems • use and apply international standards and laws of in the field of HTA and medical approvals **Competence in methods (knowledge application & development)** The students are able to… • solve challenging engineering specific and natural scientific problems • apply concepts of scientific work in the medical engineering field and use them conducive • use mathematical/physical and technical methods on problems in the field of biomedical engineering • to use their method-knowledge and 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

	Social competences (communication & cooperation) The students are able to… • talk in trade public about correlative job definitions and methods • deal unaffiliated with technical and medical working materials • describe and overbring theoretical contexts in the bio medicine • present and protect their results in form of scientific publications and/or public presentations **Self-Competence (professionalism & self-regulation)** The students are able to… • critically read, understand and review original articles, laws, standards and working documents • present and discuss their concepts in a peer group
Content	• Medical Device Regulation (MDR) • In Vitro Diagnostic Regulation (IVDR) • Medical Device Directive (MDD) • Active Implantable Medical Device Directive (AIMDD) • In Vitro Diagnostic Directive (IVDD) • Medical Devices Implementation Act (MPDG) • QM & RA in the development process of medical devices • Usability for medical products • Medical device software • general approvals & worldwide approvals for medical devices • CE marking – approval procedure in Europe • approval procedure in the USA • Risk management for medical devices • Quality management systems for medical devices • International RA & QM norms / standards for medical devices • Basis and methodologies of evidence-based medicine • HTA as a prospective and retrospective tool of quality assurance in the development and evaluation of medical technologies

	• National and international health technology assessment organizations and their tasks
Applicability	The module conveys essential knowledge of Health Technology Assessment and Regulatory Affairs for medical devices. The practical Applicability is also in the foreground, as is the scientific way of working and the engineering way of thinking. The module can be used in other study programs with a mathematical and scientific background e. g. as an optional subject.
Course- and examination achievements	Regular form for the module examination: oral presentation (PL) Further possible examinations: presentation, homework reports The type of examination will be announced by the lecturer at the beginning of the course.
Associated lectures/courses	• Regulatory Affairs • Health Technology Assessment
Teaching methods/ methods generally/ types of media	• presentations • group work (internet retrieval, discussions) • excursions ("expert interviews")
Literature/working materials	del Llano-Senaris J.E. and Campillo-Artero C., Health Technology Assessment and Health Policy Today: A Multifaceted View of their Unstable Crossroads, Springer International Publishing Switzerland 2015, ISBN 978-3-319-15003-1, Friedman L.M. and Furberg C.D. and DeMets D.L., Fundamentals of Clinical Trials, Fourth Edition, Springer Science + Business Media, LLC 2010, ISBN 978-1-4419-1585-6 Introduction to health technology assessment. CS Goodmann. HTA 101, 2004.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. international laws an standards acc. to approval procedures of medical devices scientific literature announced in the course

Master degree program Biomedical Engineering: Signal Processing-, Imaging- and Control-Systems	
Master Thesis	
Module Code Digit	12
Module coordination/ responsible person	Prof. Dr. Bernd Flick
Semester/Period/Interval	3rd semester/one semester/winter and summer semester
ECTS Credits/ Presence hours per week	30 CP / not applicable
Workload	900 h (autonomous private study)
Status	Mandatory module
Requirements	The master thesis can only be started when 30 CP of the first academic year were achieved. Exceptions to this may be approved by the board of examiners. 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.
Language	English
Competences/ Learning Outcomes	**Competence in facts (knowledge & understanding)** The students are able to • Present correctly and assess in relation to the chosen topic from the field of the degree-specific specialization area. • Narrow down the question and define the problem in such a way that the prerequisites and objectives for the methodology for answering the question or problem solving become clearly apparent. • Research, describe and assess solution alternatives (methods and procedures) and selection criteria • Discuss the results of the question and the method and provide an outlook

	Competence in methods (knowledge application & development)
	The students are able to
	• Obtain information on the state of research or the state of the art (e.g. with the heCP of a literature search), excerarate and (evidence-based) evaluate
	• To take formal requirements into account when writing a scientific paper, such as structure in EMED format (introduction, method, results, discussion) and correct citation
	• Professionally implement researched or relevant methods and procedures acquired during studies and adapt them to the respective conditions:
	    o in the case of empirical work, this means getting involved in the scientific and technical foundations of experimental technology, developing and carrying out a meaningful and effective experimental program and scientifically assessing the results of these experiments.
	    o in the case of theoretically oriented work, this means formulating selection criteria and questions for source material, explaining the classification of source procurement and evaluation, composing synopsis of important content and making weighting summaries of the content.
	• Display and summarize results using informative figures and table
	
	Social competence (communication & cooperation)
	The students are able to
	• Respond to the views of examiners, supervisors or other stakeholders
	• Contribute their own ideas and represent them to the outside world
	
	Self-Competence (professionalism & self-regulation)
	The students are able to
	• Reflect the ethical, legal and social implications of their work
	• Assess their skills and have ideas for their further development
	• Work persistently and purposefully on problems
	Divide their time

Content	The content of the Master's thesis depends on the task. The Master's thesis can be prepared at HAW Hamburg, other universities, research institutions or in public authorities and companies. The task is defined by the examiner and, if necessary, the external setup.
Applicability	Thesis in which the students independently work on a task from the professional field of activity of their course of study using scientific methods and findings. Students can submit thematic proposals and propose the examiners.
Course- and examination achievements	Regular form of examination for module examination (Master Thesis) (PL): written elaboration, volume approx. 50 - 70 pages (without cover sheet, directories and appendix).
Associated lectures/courses	Not applicable
Teaching methods/ methods generally/ types of media	Self-employed written elaboration Personal discussion of interim results with supervisors and examiners.
Literature/working materials	Scientific literature, e.g. Society of Electromedical Engineering (IEEE)

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