Curriculum for Biomedical Engineering M.Sc.

Content

BM=Specialisation Biomedicine; ME=Specialisation Medical Engineering

1. Introduction to Biomedicine, 1st Sem. BM

Introduction to biomedicine					
	Workload 180 h	Credits 6	Semester 1	Frequency of course once a year	Duration 1 semester

	Module	Language	Contact hours	Self study	Class size
1	a) Systembiological analysis of expression data b) Introduction into biomedicine	English	a) 2 SWS (22,5h) b) 2 SWS (22,5h)	a) 67,5 b) 67,5	a) 12 b) 12

2 Learning outcome

On successful completion of this module you should be able to

Application (3):

- describe the range of approaches and methods in biomedicine
- understand the main principles of biomedicine especially in the field of expression analysis and its systembiological modelling as well as in the field of molecular therapies
- apply specific methods of gene expression analysis and mathematical modeling of biological processes via ordinary differential equations

Analysis (4) / Synthesis (5):

- evaluate and explain results in a scientific presentation
- determine parameters and settings required for successful performance of the expression analysis and the mathematical modeling
- determine robustness and noise sensitivity of the biomedical measurement system
- understand the basic principles of mathematical modelling of biological processes
- outline and present the ideas of scientific publications in the field of biomedicine and discuss their contents critically in relation to the state of the art

3 Content

a) From biological data to mathematical model:
- determine gene expression of stimulated and unstimulated eukaryotic cells by the appropriate methods
- quantitatively analyze the expression data using internal standards
- determine suitable parameters for mathematical modeling of the expression data
- mathematical modeling of the expression data using ordinary differential equations

b) introduction into the principles of biomedicine recent developments in molecular therapy approaches

4 Teaching methods

a) lecture, practical training,
b) lecture, seminar

5 Prerequisites

Basic knowledge of molecular biology and human biology
Understanding of ordinary differential equations

6 Methods of assesment

a) practical training and written report (50% each)
b) introduction into biomedicine oral presentation (100%)

7 Applicability of module

Mandatory module in BME

8 Person responsible for module /lecturer

Margareta Müller

9 Literatur

a) Alberts, Molecular Biology of the Cell and script
b) Alberts, Molecular Biology of the Cell and selected biomedical research publications

2. Introduction to Medical Engineering, 1st Sem. ME

Introduction to medical engineering						
	Workload 180 h	Credits/CP 6	Semester 1	Frequency of module Once a year		Duration 1 Semester
1	Module a) Development of Blood pressure monitoring b) Introduction to medical Engineering	Teaching Language english	Contact hours a) 2 SWS / 22,5 h b) 2 SWS / 22,5 h	Self-study a) 67,5 h b) 67,5 h	Class size a) 20 b) 20	
2	Learning outcomes On successful completion of this module you should be able to Application (3): - describe the range of applications and approaches in the field of Biomedical Engineering - understand main principles in Biomedical Engineering especially in the field of modeling & simulation, measurement techniques and artificial organs - apply methods of Biomedical Engineering to the specific application of blood pressure monitoring - apply methods from electronics to tailor application specific solutions - use standard software to analyze sound signals and design simple user interfaces Analysis (4) / Synthesis (5): - demonstrate and explain results in a scientific presentation - determine parameters and settings required in electronic measurement systems - determine robustness and noise sensitivity of a biomedical measurement system - outline the ideas of relevant scientific publications, reproduce results and inspect for reproducibility - understand mathematical problems in Biomedical Engineering and describe possible solutions to those					
3	Individual component content a) From physiology to signal interpretation: - Physiology of blood pressure - Korotkoff method of blood pressure measurement - Design of amplifiers - Signal acquisition and analysis - Simple interface programming b) Overview of different fields of Biomedical Engineering: - Physiological basis of organ systems - Available measurements and their accuracy and robustness - artificial organs e.g. artificial heart, kidney replacement, artificial limbs, cochlea implants, artificial retina - modeling of organ systems - optimization of therapeutic measures					
4	Teaching methods a) Lecture, Practical training b) Lecture, Seminar					
5	Prerequisites Undergraduate programming, electronic circuits, signal analysis, : - Physiology of organ system - Signal acquisition, amplifier design, signal analysis Basics of engineering and presentation skills: - measurement devices - engineering math - scientific presentation					
6	Methods of assessment a) blood pressure monitor: 2 oral examinations on practical tasks (each 50%) b) Introduction to BioMedical Engineering: 1 presentation (100%)					
7	Applicability of module Mandatory module in BME/elective in other study programs if places are available					
8	Person responsible for module/ lecturer Knut Möller / Jan Zijlstra					
9	Reading list (Core texts and recommended texts) - Kramme,R. ed.. (2011): Medizintechnik. Springer-Verlag, 2011. - Bronzino, J. D. ed. (2014): The Biomedical Eningeering Handbook, 4th edition, CRC Press, 2014. - Carr/Brown,. (2000): “Introduction to Biomedical Equipment Technology“, Prentice Hall, 2000					

3. Simulation, 1st Sem.

<table>
<tr><td colspan="7">Simulation</td></tr>
<tr><td colspan="2"></td><td>Workload
180 h</td><td>Credits/CP
6</td><td>Semester
1</td><td>Frequency of module
Once a year</td><td>Duration
1 Semester</td></tr>
<tr><td>1</td><td colspan="2">Module
a) Simulationstechnik (Simulation)
b) Computermathematik</td><td>Teaching Language
english</td><td>Contact hours
a) 2 SWS / 22,5 h
b) 2 SWS / 22,5 h</td><td>Self-study
a) 67,5 h
b) 67,5 h</td><td>Class size
a) 30
b) 30</td></tr>
<tr><td>2</td><td colspan="6">Learning outcomes
On successful completion of this module you should be able to
Application (3):
- describe and generalize mathematical models for processes
- solve initial value problems numerically
- apply the Method of Lines to translate a partial differential equation to a system of ordinary differential equations
- apply methods of parameter identification to identify parameters of static and dynamic systems based on measured data
- implement dynamic systems in SIMULINK and design closed-loop controllers
Analysis (4) / Synthesis (5):
- calculate steady states and analyze their stability
- determine parameters in dynamical systems
- outline the ideas of relevant scientific publications, reproduce results and inspect for reproducibility
- understand mathematical problems and solve these by implementing appropriate algorithms in MATLAB
- compile graphical user interfaces and implement methods to prevent user based software errors.</td></tr>
<tr><td>3</td><td colspan="6">Individual component content
a)Ordinary differential equations:
- Steady states, asymptotic stability
- Numerical solution with MATLAB ODE solvers
- Reaction kinetics: enzyme reactions, pseudo steady state hypothesis
- fitting ODE parameters
- Numerical solution of partial differential equations: Method of lines
b)MATLAB/SIMULINK programming skills:
- vector based calculus
- import, export and graphic representation of data and simulation results
- functions and scripts for automated execution of algorithms
- parameter identification using MATLAB functions
- compiling graphical user interfaces using MATLAB GUIDE
- toolboxes and blocksets in SIMULINK
- implementing dynamic systems in SIMULINK
- SIMULINK based controller design</td></tr>
<tr><td>4</td><td colspan="6">Teaching methods
a) Lecture, MATLAB exercises
b) Lecture, MATLAB exercises</td></tr>
<tr><td>5</td><td colspan="6">Prerequisites
Undergraduate Mathematics:
- Matrices: systems of linear equations, determinant;
- Calculus: (partial) derivatives, elementary differential equations

Basics of text based programming:
- Boolean algebra
- Basic algorithms (loops, conditions)
- Use of functions/methods, local and global variables</td></tr>
<tr><td>6</td><td colspan="6">Methods of assessment
a) Simulation: 1 written examination (50%), 1 presentation (50%)
b) Computermathematik: 1 assignment (100%)</td></tr>
<tr><td>7</td><td colspan="6">Applicability of module
Mandatory module in BME/elective in other study programs</td></tr>
<tr><td>8</td><td colspan="6">Person responsible for module/ lecturer
Prof. Dr. Edgar Jäger / Dr. Jörn Kretschmer</td></tr>
</table>

9	Reading list (Core texts and recommended texts) a) Murray, J. D. (2002): Mathematical Biology. Springer-Verlag, 2002. Teufel, P. E. (2004): Eine Dosierungshilfe für Insulin bei Typ 1 Diabetis. Dissertation, Universität Ulm, 2004. Bergman, R. N. (2003): The Minimal Model of Glucose Regulation: A Biography. In: Novotny, J. A., Green, M. H., Boston, R. C. (eds.) Mathematical Modeling in Nutrition and the Health Sciences. Advances in Experimental Medicine and Biology, Volume 537, Kluwer Academic/Plenum Publishers, New York b) Beucher, O. (2008): "MATLAB und Simulink: Grundlegende Einführung für Studenten und Ingenieure in der Praxis", Volume 4, Pearson Studium MATLAB GUIDE toolbox tutorial: http://www.mathworks.com/access/helpdesk/help/techdoc/creating_guis/bqz6p81.html

4. Sensorics, 1st Sem.

<table>
<tr><td colspan="7">Sensorics</td></tr>
<tr><td colspan="2"></td><td>Workload
180 h</td><td>Credits/CP
6</td><td>Semester
1</td><td>Frequency of module
Once a year</td><td>Duration
1 Semester</td></tr>
<tr><td>1</td><td colspan="2">Module
a) Microcontroller Programming
b) Sensorik</td><td>Teaching Language
English</td><td>Contact hours
a) 20 h
b) 2 SWS / 22,5 h</td><td>Self-study
a) 70 h
b) 67,5 h</td><td>Class size
a) 30
b) 30</td></tr>
<tr><td>2</td><td colspan="6">Learning outcomes

On successful completion of this module you should be able to

a)
Application (3):
- Apply bitwise operators to access individual pins
- employ interrupt service routines in order to react to events
- diagnose programming errors by using the debugger
- apply print/scan customization to direct input/output to specific hardware
Analysis (4):
- Appraise algorithms by simulating external signals

b)
Application (3):
- calculate the transfer funtions of various sensor interfaces
- develop methods of signal processing of biomedical signals
- design biomedical measurement systems
Analysis (4):
- analyse the transfer functions of sensor interfaces
- examine biomedical measurement systems</td></tr>
<tr><td>3</td><td colspan="6">Individual component content

a) C Basics:
- Local/global variables
- Projects consisting of several source files
- Preprocessor directives
- Console output/keyboard input
- Pointers
- Bitwise operators
- Digital I/O, Interrupts
- Analog-to-Digital Conversion
- RS232 communication, I2C bus, customizing printf/scanf, LCD output

b) Biomedical sensors
- General biomedical signal processing
- Origin and characteristics of biomedical signals
- Biopotential amplifiers
- Analog signal processing
- Digital signal processing
- General requirements for safety
- Electrocardiogram
- Electroencephalogram
- Electromyogram
- Invasive and noninvasive blood pressure measurement
- Infrared temperature measurement
- Ultrasound measurement systems
- Magnetic resonance imaging</td></tr>
</table>

4	Teaching methods a) Blended learning: Online material, tutorials, presence date b) Lecture, student's projects
5	Prerequisites a) Basics of text based programming b) Basics of electrical engineering and electronics, basics in anatomy and electrophysiology
6	Methods of assessment a) Microcontroller programming: elaboration assignments b) 1 written examination (70%), 1 presentation (30%)
7	Applicability of module Mandatory module in BME/elective in other study programs
8	Person responsible for module/ lecturer Prof. Dr. Bernhard Vondenbusch / Prof. Dr. Edgar Jäger
9	Literature (Core texts and recommended texts) a) - Mike Banahan, Declan Brady, Mark Doran: The C Book. Addison Wesley, 1991. http://publications.gbdirect.co.uk/c_book/ b) - John D. Enderle, Susan M. Blanchard, Joseph D. Bronzino: Introduction to biomedical engineering. Elsevier Academic Press, 2005. - Eugene N. Bruce: Biomedical signal processing and signal modeling. Wiley, 2009.

5. Modelling and Systems Theory, 1st Sem.

<table>
<tr><td colspan="7">Modelling and systems theory</td></tr>
<tr><td colspan="2"></td><td>Workload
180 h</td><td>Credits/LP
6</td><td>Semester
6</td><td>Frequency of course
once a year</td><td>Duration
1 Semester</td></tr>
<tr><td>1</td><td colspan="2">Module
a) modeling
b) sytems theory</td><td>Language
english</td><td>Contact hours
a) 2 SWS / 22,5 h
b) 2 SWS / 22,5 h</td><td>Self study
a) 37,5 h
b) 37,5 h</td><td>Class size
a) 30
b) 30</td></tr>
<tr><td>2</td><td colspan="6">Learning outcome
Knowledge (1):
upon successful completion of the module you should be able to (,)
- know the terminology and basic principles of control theory
Understanding (2):
upon successful completion of the module you should be able to(,)
- understand modeling (for) in the context of controlled systems and processes
- understand the difference between open and closed loop control and (are) be able to illustrate the mathematical principles of controlled systems in Laplace and time scale.
- design a speed and position controlled system
Application (3):
upon successful completion of the module you should be able to(,),
- Mathematically describe power systems with elastically coupled mechanical structures
- determine the stability of open and closed loop systems
- establish mathematical models (ordinary differential equations) of different controlled systems
Analysis (4):
upon successful completion of the module you should be able to(,)
- analyze the statistical and dynamical behavior of controlled systems in both time and frequency domain and determine their characteristics and physical parameters
- determine the resulting behavior of controlled systems for different inputs in the time domain and transform them into the frequency domain
- construct a p-controler as well as a cascading p- and pi-controller
- evaluate the quality of a controlled systems and its dynamical behavior
- graph a Bode-diagram of the frequency domain of controlled systems
- analyze the systems behavior using the Nyquist theorem and determine the amplification factor of a controlled system</td></tr>
<tr><td>3</td><td colspan="6">Content
a) and b)
- Modeling of power systems and mechanical transmission elements
- Laplace-transformation
- Input and output signals in time and frequency domain
- Behavior of controlled systems in the time domain establishment of characteristics and physical parameters
- Pole zero plot
- Transfer elements and their transfer functions
- Block diagram
- Frequency response, Bode diagram, Nyquist plot
- Stability prameters, Hurwitz criterion, central limiting value theorem
- Linear controlled systems, Nyquist method
- P-/PI control</td></tr>
<tr><td>4</td><td colspan="6">Teaching methods
a) lecture
b) b) lecture</td></tr>
<tr><td>5</td><td colspan="6">Prerequisites
a) and b):
basics of measument and control theory, technical mechanics 1 and 2, dynamics, mathematics for engineers, physics</td></tr>
<tr><td>6</td><td colspan="6">Methods of assessment
One written exam</td></tr>
<tr><td>7</td><td colspan="6">Applicability of module
Mandatory module in BME/elective in other study programs</td></tr>
<tr><td>8</td><td colspan="6">Person responsible for module/ lecturer
Prof. Dr. Ketterer</td></tr>
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9	Literature a) & b)		
		H. Lutz,	Taschenbuch der Regelungstechnik Verlag Harri Deutsch,
		W. Wendt	7. Auflage 2007, ISBN 978-3817118076
		O. Föllinger	Regelungstechnik, Hüthig Verlag,
			5. verbesserte Auflage 1985, ISBN 3-7785-1137-8
		R. Isermann	Identifikation dynamischer Systeme. Springer Verlag; Band I und Band II; 1988.
		R. Isermann	Regelungstechnik Band 1 - 3.
			Braunschweig, Wiesbaden: Friedrich Vieweg & Sohn, 1988.
		H. Unbehauen	Regelungstechnik Band 1 - 3.
			Braunschweig, Wiesbaden: Friedrich Vieweg & Sohn, 1988.
		S. Zacher	Übungsbuch Regelungstechnik, Vieweg + Teubner Verlag, 2010

6. Management competences, 1st Sem.

<table>
<tr><td colspan="7">Management competences</td></tr>
<tr><td colspan="2">Module Code</td><td>Workload
180 h</td><td>Credits
6</td><td>Semester
1</td><td>Frequency of course
once a year</td><td>Duration
1 semester</td></tr>
<tr><td>1</td><td colspan="2">Module
a) Project management
b) Human machine interface or experimental design
c) Language or any other course with management content</td><td>Language
English</td><td>Contact hours
a) 2 SWS (22,5h)
b) 2 SWS (22,5h)
c) 2 SWS (22,5h)</td><td>Self-study
a) 67,5h
b) 67,5h
c) 67,5h</td><td>Class size
a) 24
b) 24
c) 24</td></tr>
<tr><td>2</td><td colspan="6">Learning outcome
On successful completion of this module you should be able to
Comprehension (2) / Application (3):
a) - understand the criteria that defined a project (SMART) and the differences between project and process
- describe and understand the different approaches to project management
- describe and understand the tools for planning and steering of projects
b) understand and apply the basic principles of scientific writing in the generation of a scientific/experimental paper
c) gain management competences depending on content of course
Analysis (4)/ Synthesis (5):
a) - determine tools and parameters required for successful planning of projects the associated risk management
- recognize and correct discrepancies between planned and actual project progress
- critical project documentation
b) - critically analyse ideas in the field of human machine Interaction in relation to the state of the art and edit them for presentation in a scientific paper
c) depends on content of the course</td></tr>
<tr><td>3</td><td colspan="6">Content
a) from idea to successful completion of a project:
Project ideas and start –up, time scale and project structure, risk management and decision techniques, content of grant applications, and contracts, documentation, tools of project management (e.g. SWOT analysis, magic triangle, etc.)
b) experimental from data to scientific publication
scientific writings the core objective, exercises are done with the important field of human machine interfaces
c) depends on course chosen</td></tr>
<tr><td>4</td><td colspan="6">Teaching methods
a) lecture,
b) lecture, seminar
c) depends on course chosen</td></tr>
<tr><td>5</td><td colspan="6">Prerequisites
Basic knowledge of literature search
Understanding of scientific publications</td></tr>
<tr><td>6</td><td colspan="6">Methods of assessment
a) written exam
b) written paper (50%) and oral presentation (50%)
c) depends on course chosen</td></tr>
<tr><td>7</td><td colspan="6">Applicability of module
Mandatory module in BME/ elective in other study programs</td></tr>
<tr><td>8</td><td colspan="6">Person responsible for module /lecturer
Margareta Müller</td></tr>
<tr><td>9</td><td colspan="6">Literature
b)
- Thomas A. Lang (2009). How to Write, Publish, and Present in the Health Sciences: A Guide for Physicians and Laboratory Researchers. American College of Physicians.
- Michael Jay Katz (2009). From Research to Manuscript: A Guide to Scientific Writing. Springer Verlag.
- Mimi Zeiger (1999). Essentials of Writing Biomedical Research Papers. Second Edition. McGraw-Hill Professional</td></tr>
</table>

7. Research practical biomedicine, 2nd Sem. BM

<table>
<tr><td colspan="7">Research practical biomedicine</td></tr>
<tr><td colspan="2"></td><td>Workload
180 h</td><td>Credits
6</td><td>Semester
2</td><td>Frequency of course
once a year</td><td>Duration
1 semester</td></tr>
<tr><td>1</td><td colspan="2">Module
Forschungspraktikum</td><td>Language
English</td><td colspan="2">Contact hours
2 SWS (22,5h)</td><td>Self study
157,5
Class size
20 in groups of one or 2 students</td></tr>
<tr><td>2</td><td colspan="6">Learning outcome
On successful completion of this module you should be able to
Analysis (4):
- Plan and perform scientific investigations in the field of biomedicine
- Perform a focused literature research on the chosen research topic, evaluate and summarize the relevant state of the art
Synthesis (5)
- Apply methods of biomedical research to a specific project
- analyze and evaluate your data, perform statistical analysis of data
Evaluation (6):
- evaluate different approaches to the solution of your experimental
- describe your results in a scientific report comparable to a research publication
- summarize and explain results in a scientific (oral) presentation</td></tr>
<tr><td>3</td><td colspan="6">Content
From project description to scientific publication:
- specification of project, especially formulation of a clear objective
- summary of the stat of the art
- selection and realization of appropriate methods
- perform experiments to obtain significant results
- critical discussion of the relevance of the obtained results
- formulation of a proper conclusion
- short presentation highlighting the main findings</td></tr>
<tr><td>4</td><td colspan="6">Teaching methods
Lecture, practical training, presentation</td></tr>
<tr><td>5</td><td colspan="6">Prerequisites
Dependent on the topic chosen including basic knowledge of molecular and cell biology, selected biomedical methods
Scientific writing and presentation</td></tr>
<tr><td>6</td><td colspan="6">Methods of assessment
a) research (50%)
b) written report (30%)
c) presentation (20%)</td></tr>
<tr><td>7</td><td colspan="6">Applicability of module
Mandatory module in BME/elective in other study programs</td></tr>
<tr><td>8</td><td colspan="6">Person responsible for module /lecturer
Prof. Dr. Margareta Müller</td></tr>
<tr><td>9</td><td colspan="6">Literature
Alberts, Molecular Biology of the Cell and selected biomedical research publications dependent on the topic chosen</td></tr>
</table>

8. Research practical medical engineering, 2nd Sem. ME

<table>
<tr><td colspan="7">Research practical medical engineering</td></tr>
<tr><td colspan="2">Module code</td><td>Workload
180 h</td><td>Credits/CP
6</td><td>Semester
2</td><td>Frequency of module
Once a year</td><td>Duration
1 Semester</td></tr>
<tr><td>1</td><td>Module
Forschungspraktikum</td><td colspan="2">Teaching Language
english</td><td>Contact hours
2 SWS / 22,5 h</td><td>Self-study
157,5 h</td><td>Class size
20 in groups of 1 or 2 students</td></tr>
<tr><td>2</td><td colspan="6">Learning outcomes
On successful completion of this module you should be able to
Analysis (4):
- plan and perform scientific investigations in the field of Biomedical Engineering
- perform a focused literature research, evaluate and summarize the relevant state of the art
Synthesis (5)
- apply methods of Biomedical Engineering to a specific application
- perform statistical analysis on experimental data
Evaluation (6):
- evaluate the quality of different approaches,
- describe your work in a scientific report comparable to reports published on international conferences
- summarize and explain results in a scientific presentation</td></tr>
<tr><td>3</td><td colspan="6">Individual component content
From project description to scientific publication:
- specification of project, especially formulation of a clear objective
- Summarize the state of the art
- selection and realization of appropriate methods
- perform experiments to obtain significant results
- discussion and critical review of the relevance of your obtained solution
- formulation of a proper conclusion
- short presentation of your research highlighting the main findings</td></tr>
<tr><td>4</td><td colspan="6">Teaching methods
lecture, practical training, presentations</td></tr>
<tr><td>5</td><td colspan="6">Prerequisites
Undergraduate programming, electronic circuits, signal analysis
- basic understanding of medical concepts
- Signal acquisition, signal analysis
- optimization, model design Scientific writing and presentation skills:</td></tr>
<tr><td>6</td><td colspan="6">Methods of assessment
- research (50%)
- written report (30%)
- presentation (20%)</td></tr>
<tr><td>7</td><td colspan="6">Applicability of module
Mandatory module in BME/elective in other study programs</td></tr>
<tr><td>8</td><td colspan="6">Person responsible for module/ lecturer
Prof. Dr. Knut Möller</td></tr>
<tr><td>9</td><td colspan="6">Literature
- Reading list (Core texts and recommended texts)
- Kramme,R. ed.. (2011): Medizintechnik. Springer-Verlag, 2011.
- Bronzino, J. D. ed. (2014): The Biomedical Eningeering Handbook, 4th edition, CRC Press, 2014. Special scientific papers to be searched in relevant databases depending on the subject of research</td></tr>
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9. Data management, 2nd Sem. BM

Data management						
	Workload 180 h	Credits/CP 6	Semester 2. semester	Frequency of module yearly		Duration 1 semester
1	Module a) Datenbanksysteme b) Statistik	Teaching Language German or English	Contact hours a) 2 SWS / 22.5 h b) 2 SWS / 22.5 h	Self-study a) 67.5 h b) 65.5 h	Class size a) 20 students b) 20 students	
2	Learning outcomes Upon successful completion of the module the students are able to Analysis (4): - carry out database queries in several important databases - apply p value adjustment in multiple testing Synthesis (5): - summarise biological information for biomedical problems - explain the results of unsupervised and supervised statistical learning methods Evaluation (6): - assess the information contained in biological databases - validate the results of supervised statistical learning methods					
3	Individual component content a) Biological databases, protein sequences, similarity searches, protein domains, protein structure, enzyme kinetics, mathematical models, biological networks b) Multiple testing, hierarchical clustering, partitioning, principal component analysis, multidimensional scaling, performance measures, feature selection, discriminant analysis, generalized partial least squares, k-nearest neighbours, decision trees, random forest, support vector machines					
4	Teaching methods a) and b) Lecture with exercises					
5	Prerequisites Module Einführung in die Biomedizin should be completed, basic knowledge in mathematics and statistics					
6	Methods of assessment a) Written report (during semester, 3 LP) b) Written report (during semester, 3 LP)					
7	Applicability of module Mandatory module in BME/elective in other study programs					
8	Person responsible for module/ lecturer Prof. Kohl					
9	Literature (Core texts and recommended texts) - Böchenhauer, Bongratz (2007). Algorithmic Aspects of Bioinformatics. Springer. - Hastie, Tibshirani, Friedman (2009). The Elements of Statistical Learning. Springer. - Izenman (2008). Modern Multivariate Statistical Techniques. Springer. - James, Witten, Hastie, Tibshirani (2013). An Introduction to Statistical Learning. Springer. - Sung (2009). Algorithms in Bioinformatics: A practical introduction. Chapman & Hall.					

10.Systembiologie, 2nd Sem. BM

Systembiologie						
	Workload 180 h	Credits/CP 6	Semester 2. semester	Frequency of module yearly	Duration 1 semester	
1	Module a) Bioinformatik b) Systembiologie	Teaching Language German or English	Contact hours a) 2 SWS / 22.5 h b) 2 SWS / 22.5 h	Self-study a) 67.5 h b) 65.5 h	Class size a) 20 students b) 20 students	
2	Learning outcomes After visiting this module, students are able to Analysis (4): - carry out parameter estimation in systems biology models - model biochemical reactions - execute pairwise sequence alignments Synthesis (5): - explain models for molecular events - explain sequence motifs and profiles Evaluation (6): - compare systems biology models - describe scoring schemes					
3	Individual component content a) Pairwise alignment of sequences, distances and similarity measures, sequence motifs, sequence profiles, scoring schemes, FASTA, BLAST, extensions of BLAST b) Basic mathematics, excitable systems, stochastic differential equation, FitzHugh-Nagumo model, continuous models, models for molecular events, modelling of biochemical reactions, dynamic models of gene regulation, parameter estimation					
4	Teaching methods a) and b) Lecture with exercises					
5	Prerequisites Module Einführung in die Biomedizin should be completed, basic knowledge in mathematics and statistics					
6	Methods of assessment a) Written exam (50%, 3 LP) b) Written report (during semester, 50%, 3 LP)					
7	Applicability of module Mandatory module in the master course Biomedical Engineering, electoral module for other master courses					
8	Person responsible for module/ lecturer Module: Prof. Kohl Lectures: Prof. Kohl, contract lecturer					
9	Literature (Core texts and recommended texts) - Böchenhauer, Bongratz (2007). Algorithmic Aspects of Bioinformatics. Springer. - Edelstein-Keshet (2005). Mathematical Models in Biology. SIAM. - Ingalls (2013). Mathematical Modeling in Systems Biology. MIT Press. - Sung (2009). Algorithms in Bioinformatics: A practical introduction. Chapman & Hall.					

11.Medical Modelling, 2nd Sem. ME

<table>
<tr><td colspan="8">Medical Modelling</td></tr>
<tr><td colspan="2">Module code</td><td>Workload
180 h</td><td>Credits/CP
6</td><td>Semester
2</td><td colspan="2">Frequency of module
Once a year</td><td>Duration
1 Semester</td></tr>
<tr><td>1</td><td colspan="2">Module
a) Physiological Modeling
b) System Identification</td><td>Teaching Language
english</td><td colspan="2">Contact hours
a) 2 SWS / 22,5 h
b) 2 SWS / 22,5 h</td><td>Self-study
a) 67,5 h
b) 67,5 h</td><td>Class size
a) 20
b) 20</td></tr>
<tr><td>2</td><td colspan="7">Learning outcomes
On successful completion of this module you should be able to
Comprehension (2) / Application (3):
- understand the concept of system identification
- describe different approaches to prove identifability
- understand the importance of identifiability in model based therapy in Medicine
Analysis (4) / Synthesis (5):
- compare different modeling approaches
- analyze properties of model formulations e.g. computational complexity, stability, identifiability
- develop own models and derive formal mathematical representations
- understand mathematical problems and solve these by implementing appropriate algorithms in MATLAB
- combine approaches on different levels to "multi-level" models
- derive simple approaches for model-based optimization in medical applications
Evaluation (6):
- demonstrate and explain results in a scientific presentation
- determine model parameters in dynamical systems
- analyze robustness of system, identify sensitivity on parameter settings.</td></tr>
<tr><td>3</td><td colspan="7">Individual component content
a) From physiology to mathematical represenations:
- Physiology of gas exchange, pulmonary mechanics, cardio-vascular systems
- Modeling basics, system equations, transforms
- Mathematical representations
- Sensitivity analysis
- hierarchically structured models
b) From mathematical representations to therapeutic decisions:
- Signal acquisition and evaluation
- System identification, structural, practical identifiability
- identification in hierarchies of models</td></tr>
<tr><td>4</td><td colspan="7">Teaching methods
a) Lecture, practical training
b) Lecture, practical training</td></tr>
<tr><td>5</td><td colspan="7">Prerequisites
Undergraduate programming, electronic circuits, signal analysis, :
- Physiology of organ systems
- Signal acquisition, amplifier design, signal analysis
Basics of engineering and presentation skills:
- measurement devices
- engineering math
- scientific presentation</td></tr>
<tr><td>6</td><td colspan="7">Methods of assessment
a) physiological modeling: 1 written paper (60%), 1 oral presentation (40%)
b) system identificiation: homework assignments, final exam (100%)</td></tr>
<tr><td>7</td><td colspan="7">Applicability of module
Mandatory module in BME/elective in other study programs</td></tr>
<tr><td>8</td><td colspan="7">Person responsible for module/ lecturer
Prof. Dr. Knut Möller</td></tr>
</table>

9	Literature (Core texts and recommended texts) a) Khoo, . (2011): -Verlag, 2011. Bronzino, J. D. ed. (2014): The Biomedical Eningeering Handbook, 4th edition, CRC Press, 2014. b) Lennart/Ljung. (2000): "Introduction to System Identification", Prentice Hall, 2000 Schranz, Chr (2013)

12.Signal processing, 2nd Sem. ME

Signal processing						
	Workload 180 h	Credits/CP 6	Semester 1	Frequency of module Once a year		Duration 1 Semester
1	Module a) Image processing, Computer Graphics b) Biosignal-Processing	Teaching Language English	Contact hours a) 2 SWS / 22,5 h b) 2 SWS / 22,5 h	Self-study a) 67,5 h b) 67,5 h		Class size a) 30 b) 30
2	Learning outcomes On successful completion of this module you should be able to a) Application (3): - apply different methods of image processing - apply different tools of image processing Analysis (4): - realize application possibilities of image processing - assess results of image processing - optimize methods of image processing b) Application (3): - design a system for digital signal processing - apply various window functions during discrete Fourier transform - calculate parameters of digital filters - apply different methods for coding / decoding of biosignals - design systems for pattern recognition Analysis (4): - analyze the transfer functions of discrete systems in time and frequency domain - assess results of a discrete Fourier transform and optimize the result - optimize digital filters - optimize systems for problem dependant pattern recognition					
3	Individual component content a) Digitalization, histogram, Fourier-Transform, filtering, texture, classification, 3D-imaging, segmentation methods, colour quantification, data compression methods, JPEG, Wavelet-Transform, Radon-Transform b) Digital Signal Processors - Sampling and analog-digital/digital-analog conversion - Discrete signals and systems - Z-Transform, Discrete Fourier Transform - Design of digital filters (FIR/IIR) - Coding and decoding of signals - Methods of pattern recognition					
4	Teaching methods a) seminar b) Lecture, student's projects					
5	Prerequisites a) Basic Mathematics b) Basics of electrical engineering and electronics					
6	Methods of assessment a) Presentation & summary paper b) 1 written examination (70%), 1 presentation (30%)					
7	Applicability of module Mandatory module in BME/elective in other study programs					
8	Person responsible for module/ lecturer Module: Prof. Dr. U. Busolt Lecturer: Prof. Dr. U. Busolt / Prof. Dr. Bernhard Vondenbusch					

9	Literature (Core texts and recommended texts) - Gonzalez, R.C., Woods, R.E.: *Digital Image Processing*. Sec. Ed., Prentice Hall 2003 - Abmayr: Einführung in die digitale Bildverarbeitung 2.Aufl., Stuttgart: Teubner 2002 - Tietze, U., Schenk, Ch.: Halbleiter-Schaltungstechnik, Springer, 2012. - Werner, M.: Digitale Signalverarbeitung mit MATLAB, Vieweg, 2012. Kammeyer, K-D., Kroschel, K.:Digitale Siganlverarbeitung, Teubner, 2012. Theodoridis, S.: Pattern Recognition, Elesevier, 2008.

13.Advanced Medical Technologies, 2nd Sem.

<table>
<tr><td colspan="7">Advanced Medical Technologies</td></tr>
<tr><td colspan="2"></td><td>Workload
180 h</td><td>Credits/CP
6</td><td>Semester
1</td><td>Frequency of module
Once a year</td><td>Duration
1 Semester</td></tr>
<tr><td>1</td><td colspan="2">Module
a) Minimal Invasive Medicine / Technologies
b) Artificial Organs</td><td>Teaching Language
English</td><td>Contact hours
a) 2 SWS / 22,5 h
b) 2 SWS / 22,5 h</td><td>Self-study
a) 67,5 h
b) 67,5 h</td><td>Class size
a) 30
b) 30</td></tr>
<tr><td>2</td><td colspan="6">Learning outcomes
On successful completion of this module you should be able to
Application (3):
- understand how to use Artif. Org. in an optimal manner (machine and device)
- decide upon parameters like external blood flow, pressures, etc..
- provide ideas for further development of Artif. Org.
- discuss features of minimally invasive diagnostic and surgical techniques with surgeons
Analysis (4):
- understand basics in mass transfer of most important components
- identify shortcomings of currently available surgical instrumentation
- analyse the requirements for instruments and equipment needed to implement new techniques
Synthesis (5):
- develop ideas for the technical implementation of new techniques</td></tr>
<tr><td>3</td><td colspan="6">Individual component content
a) Minimally Invasive Med.:
- Basic techniques of minimally invasive medicine (e.g. laparoscopy, endoscopy)
- Technical requirements: instruments, endoscopy, electrosurgery, navigation, manipulator systems, diagnostic systems
- Advanced optical methods in diagnosis and treatment
- Recent developments: NOTES, ….
b) Artificial Organs:
- Principles of membrane Processes
- Manufacturing of Membranes / Modules
- Mass transfer models in Art. Kidney, Art. Liver, Art. Lung
- Basics about individual processes (machines,..)</td></tr>
<tr><td>4</td><td colspan="6">Teaching methods
a) Lecture, Presentations, Excursion (Endoscopy department or Manufacturer)
b) Lecture, Exercises, Excursion to Manufacturer of Art. Organs and Machines for Appl.</td></tr>
<tr><td>5</td><td colspan="6">Prerequisites
a) Minimal Invasive Medicine / Technologies
- Basics of medical nomenclature and human anatomy
- Basic knowledge of surgical techniques and instrumentation
- Basic knowledge in optics, electricity and mechanics
b) Process Engineering:
- Mass Balances, Concentrations,..
- Basics in Diffusion, Convection, Phase Equlibria,..
- Basics in fluid dynamic (laminar flow, dimensionless numbers, etc..)</td></tr>
<tr><td>6</td><td colspan="6">Methods of assessment
a) 1 written examination (50%)
b) 1 written examination (50%)</td></tr>
<tr><td>7</td><td colspan="6">Applicability of module
Mandatory module in BME/elective in other study programs</td></tr>
<tr><td>8</td><td colspan="6">Person responsible for module/ lecturer
Module: Prof. Dr. Manfred Raff
Lecture: Prof. Dr. Manfred Raff / Dr. habil. Ludger Schnieder</td></tr>
</table>

9	Literature - Nathaniel J. Soper, Carol E.H. Scott-Connor (Eds.); Springer (2012): The SAGES Manual: Volume 1 Basic Laparoscopy and Endoscopy; ISBN 978-1-4614-2343-0 - Eloot, S. (2004): "Experimental and Numeric Modeling of Dialysis", PhD dissertation, Ghent University 2004, ISBN 9090186980 - Raff, M. et. al.(2002): "Advanced modeling of highflux hemodialysis", J. Membr., Sc. 5531 (2002),1-11 - Krause, B. et. al (2003): "Polymeric Membranes for Medical Applications", Chemie-Ing. Techn. (2003), 75

14.Electives part 1 and 2, 2nd and 3rd Sem.

Electives part 1 and 2						
		Workload 330 h	Credits 9	Semester 2. and 3. semester	Frequency of module twice a year	Duration 1 semester
1	Module 4 courses comprising at least 9 credits		Language german or english	Contact hours Dependent upon course chosen	Self study Dependent upon course chosen	Class Size Dependent upon course chosen
2	Learning outcome The modules allow the students to acquire in depth knowledge /consolidate existing knowledge in the field of medical technology, biomedicine and scientific competences. The detailed learning outcome depends upon the course chosen and can be found in the respective module description.					
3	Content Dependent upon the course chosen.					
4	Teaching methods Dependent upon the course chosen.					
5	Prerequisite Dependent upon the course chosen.					
6	Assessment methods Dependent upon the course chosen At least 4 course amounting to at least 8 credits must be completed with a graded assessment (Prüfungsleistung/PL).					
7	Applicability of module Mandatory module in BME/elective in other study programs.					
8	Person responsible for module/ lecturer Module: Dean od stud course lecturer: dependent upon the course chosen					
9	Literature dependent upon the course chosen					

15. Thesis, 3rd Sem.

<table>
<tr><td colspan="7">Master-Thesis</td></tr>
<tr><td colspan="2"></td><td>Workload
720 h</td><td>Credits
24 (22/2)</td><td>Semester
3</td><td>Frequency of course
each semester</td><td>Duration
1 semester</td></tr>
<tr><td>1</td><td>Module
a) Thesis
b) Thesis Seminar</td><td colspan="2">Language
German or English</td><td>Contact hours
a) 22 h
b) 2SWS (22,5h)</td><td>Self study
677,5</td><td>Class size
a) 24 in group sizes of one
b) 24 S</td></tr>
<tr><td>2</td><td colspan="6">Learning outcome
The thesis project can be done as a research project at the HFU or in a company. Students can also choose a thesis project abroad to gain additional social and language competence.

On successful completion of this module you should be able to
Application (3):
- organize and plan a scientific project independently
- chose the appropriate methods for a scientific project on the basis of the current scientific knowledge
- implement a thesis report summarizing a research project
- analyze and presents defined topics of higher complexity based on current scientific knowledge and methods
Analysis (4):
- critically analyse and evaluate a scientific project and include the results of this analysis in the future development of the project
- critically discuss a scientific project on the basis of current knowledge
- select the key results of a project die(?) and analyze and present them in the context of current scientific knowledge and literature.</td></tr>
<tr><td>3</td><td colspan="6">Content
a) scientific realization and summary of a chosen thesis project
b) Presentation of the thesis project</td></tr>
<tr><td>4</td><td colspan="6">Teaching methods
a) master-thesis
b) presentation</td></tr>
<tr><td>5</td><td colspan="6">Prerequisites
Dependent on the topics chosen</td></tr>
<tr><td>6</td><td colspan="6">Methods of assessment
a) 1 thesis (80%)
b) 1 presentation (20%)</td></tr>
<tr><td>7</td><td colspan="6">Applicability of module
Mandatory module in BME</td></tr>
<tr><td>8</td><td colspan="6">Person responsible for module /lecturer
Dean of study course
Primary supervisor: HFU professors and staff ,
Secondary supervisor: HFU professors and staff , visiting lecturer, external supervisor</td></tr>
<tr><td>9</td><td colspan="6">Literature
Dependent on the topic chosen</td></tr>
</table>

16.Oral Exam, 3rd Sem.

<table>
<tr><td colspan="6">Oral Exam</td></tr>
<tr><td colspan="2"></td><td>Workload
90 h</td><td>Credits
3</td><td>Semester
3</td><td>Frequency of course
twice a year</td><td>Duration
1 semester</td></tr>
<tr><td>1</td><td colspan="2">Module
Oral exam</td><td>Language
English</td><td>Contact hours
0,5h</td><td>Self study
89,5h</td><td>Class size
1</td></tr>
<tr><td>2</td><td colspan="6">Learning outcome
On successful completion of this module you should be able to:
Conprehension (2):
- Reproduce a broad spectrum of study related knowledge
- Describe methods of scientific work and studies
- Understand the selected fields of science and engineering
Application (3):
- select and apply appropriate methods and instruments for defined scientific questions
Analysis (4):
- independently comprehend and describe a defined topic of science or engineering
Synthesis (5):
- independently research and structure a defined topic of science and/or engineering to orally present it in a short comprehensive way and discuss it on the background of the state of the art</td></tr>
<tr><td>3</td><td colspan="6">Content
The content includes the knowledge of all module of the 3 semester master course, and consists of at least two modules of the lecturers involved in the exam</td></tr>
<tr><td>4</td><td colspan="6">Teaching methods
preparation for self study</td></tr>
<tr><td>5</td><td colspan="6">Prerequisites
Maximally 2 module exams of the 3 semester master course can be open</td></tr>
<tr><td>6</td><td colspan="6">Methods of assessment
Oral exam</td></tr>
<tr><td>7</td><td colspan="6">Applicability of module
Mandatory module in BME</td></tr>
<tr><td>8</td><td colspan="6">Person responsible for module /lecturer
Module: dean of study course
Lecturer: all HFU professors of the study course BME</td></tr>
<tr><td>9</td><td colspan="6">Literature
Is given by the lecturer of the selected topics</td></tr>
</table>