Joint Master´s program Biomedical Engineering

Module X5M 1300: System Theory	
Aims:	The students shall deepen mathematical and theoretical knowledge. They shall know the principles of imaging as a basic technology in medical technology.
Workload:	Lecture attendance: 75 h Self-study: 165 h
Credit-points:	8
Person responsible for module:	Thorsten Buzug
Courses (lecturer):	Signals and Systems in Medical Imaging lecture (Buzug) Signals and Systems in Medical Imaging lab (Buzug) Numerical Methods in Medicine lecture (Botterweck)
Language:	English
Curriculum:	Master`s program Biomedical Engineering, 1st Semester
Signals and Systems in Medical Imaging	**Lecture, 2 SWS**
Prerequisites according to examination regulations	None
Recommended prerequisites:	Basic knowledge in mathematics and physics
Learning outcomes:	• Development of the basics of medical imaging with ionizing radiation • Learning about the connection between physical measurements and signal quality • Ability to deduce the reconstruction algorithms • Competence in the reconstruction of tomographical signals • Ability to self-contained application of the methods with real data • Knowledge about lecturer´s current research projects
Content:	This lecture gives a comprehensive overview of the main signal processing and system analysis methods in medical imaging. The basis of the reconstruction is undoubtedly mathematics. However, the beauty of e.g. computed tomography cannot be understood without a basic knowledge of X-ray physics, signal processing concepts and measurement systems. Therefore, students will be provided with a number of references to these basic disciplines as well as a brief introduction to many of the underlying principles. The main application focus of the lecture is given to computed tomography. The lecture is structured to cover the basics of

	signals and systems within CT, from photon statistics to modern cone-beam systems. However, without an elementary knowledge of X-ray physics, a number of the described imaging effects and artifacts cannot readily be understood. In the main part of the lecture the principles of signal processing are reviewed. This part focuses on the necessary background of computed tomography and, consequently, introducing the Fourier transform. Subsequently, a detailed overview of two-dimensional reconstruction mathematics is given as a straight forward application of the Fourier principles. Then, algebraic and statistical approaches are explained as a general tool for signal analysis and over-determined system solution. In the last lessons three-dimensional methods of CT image or volume reconstruction are reviewed. It is shown that some of the ideas are consequent extensions of the methods discussed the beginning of the lecture. The methods described here represent the basis of a highly active field of research.
Literature:	Kak and Slaney: Principles of Computerized Tomographic Imaging - SIAM Press, 1988 Buzug: Computed Tomography, From Photon Statistics to Modern Cone-Beam CT, Springer, 2008
Examination:	Oral examination
Teaching methods:	Board, LCD-projector

Signals and Systems in Medical Imaging	**Lab, 1 SWS**
Prerequisites according to examination regulations	None
Recommended prerequisites:	Mathematics on an Engineering-Bachelor´s degree level and basic understanding of programming using MATLAB
Learning outcomes:	• Understanding of the principles of image reconstruction in CT • Ability to implement a reconstruction algorithm for CT • Understanding of the origin of artifacts in CT • Development of simple artifact correction methods
Content:	The Lab is divided into three exercise sheets and two projects. The exercise sheets are voluntary and will give an introduction to programming with MATLAB as well as a basic understanding of the data acquisition and processing in CT. The first project will focus on a specific reconstruction algorithm in CT. The students will learn how to simulate a whole CT system and how to reconstruct images from given raw data. The second project is concerned with the correction of metal artifacts in CT. The students will learn how to find a segmentation of metal objects within an image, how to remove corresponding projection values from raw data, and how to

	find new values for the missing data. The Lab will be given in pc pools rooms where the students solve given exercises with the help of MATLAB. The Lab will be supervised and tutored.
Literature:	Kak and Slaney: Principles of Computerized Tomographic Imaging, SIAM Press, 1988 Buzug: Computed Tomography, From Photon Statistics to Modern Cone-Beam CT, Springer, 2008 Zeng: Medical Image Reconstruction, Springer 2010
Examination:	Project submission
Teaching methods:	Computer-assisted Lab work

Numerical Methods in Medicine	**Lecture, 2 SWS**
Prerequisites according to examination regulations	None
Recommended prerequisites:	Mathematics on an Engineering-Bachelor´s degree level
Learning outcomes:	The students have to work on numerical methodical problems in the area of medical-technical development (as well in research, simulation, quality check etc) in a systematical way: 1. Realizing the problem and mathematically expressing it (modelling). 2. Choosing an adequate numerical method, applying and checking the results critically. 3. Understanding a possibly existing solution (software, literature, expertises) and adjusting to the given problem. The most important methods of the operation research for basic numerical exercises are taught and practised.
Content:	I) Basic techniques 1 General criteria: condition, stability, convergence, efficiency 2 Linear systems of equations 3 Differentiation and optimization 4 Linear and non-linear regression, interpolation 5 Diagonalization and inversion of linear operators II) Application 6 Stationary problems (electrical networks, heat flow, mechanical systems in equilibrium) 7 Solving (P)Des (types, discretization, diagonalization, overview FEM, examples) 8 Statistical distributions (momenta, correlations, tests, sampling
Literature:	Press. W.: Numerical Recipes, Cambridge University Press,

	2007 Danaila et al.: An Introduction to Scientific Computing, Springer, 2006
Examination:	Written examination
Teaching methods:	Board, LCD-projector