FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT

Module Handbook for M.Sc. Health and Medical Data Analytics

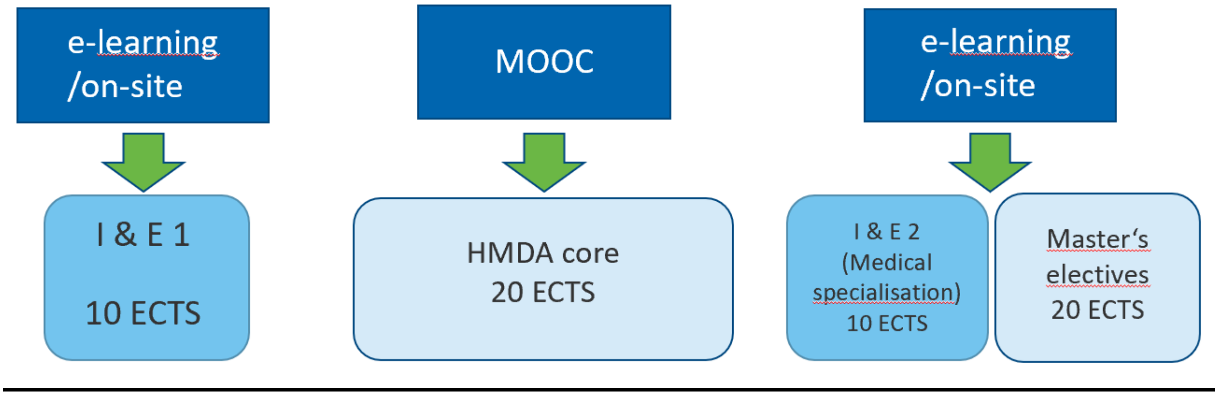
Study track at FAU

Please note, that all modules presented are just a selection of the elective courses. For more information, please visit the website of the respective university.

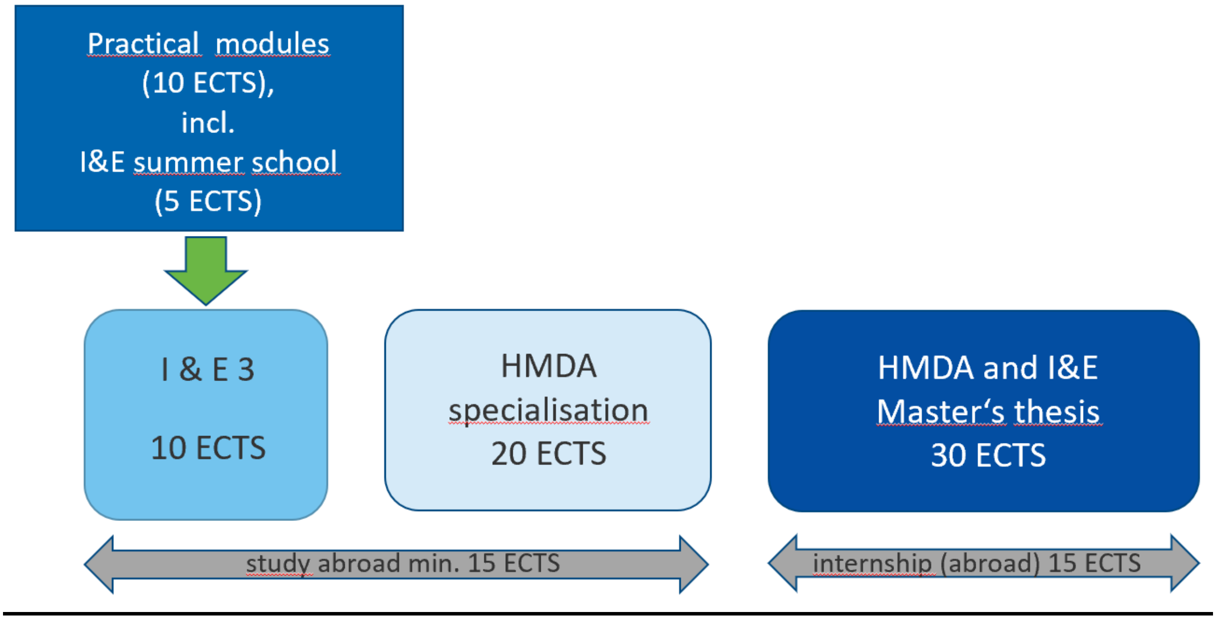
General Content

1 Alignment

1st year



2nd year



2 1st year, 1st semester (autumn/winter semester):

2.1 Innovation and Entrepreneurship 1 (10 ECTS)

2.1.1 Innovation and Leadership

Responsible lecturer: Prof. Dr. Kathrin Möslein
ECTS: 5
Course type and weekly hours: lecture (4 hours)
Exam type: presentation, project report

Contents:
Creating a sustainable innovative environment is a leadership task. In order to succeed at this task, leaders must develop innovative abilities to deal with the challenges inherent in a business environment characterized by fluid, unstructured and changing information. The aim of this course is thereby twofold.
First, the course delineates and describes different yet emerging innovation tools, organizing them into a coherent set of classes. Each class of tools is described using a set of up-to-date business cases that depict the current status of the information systems.
The second aim of this course is to get an overview of how to structure leadership systems towards innovation, how leaders can motivate to foster innovative thinking and what new forms of innovation (e.g. open innovation) mean for the definition of leadership.
In doing so, this lecture represents an Idea Transformation Class as students are encouraged not only to merely develop, but to actively deploy specifically developed concepts.

Learning outcomes and competencies:
The students

- will understand and explore the theories and practicalities of leadership in open innovation contexts.
- will gain knowledge on leading and communicating innovation and translate it in leadership behaviour in real case contexts.
- learn to assess, reflect and feedback the impact of practical leadership for innovation.
- can independently define new application-oriented problem solving in e-business in relation to the economic impact for businesses, along with solving problems using the appropriate methods.
- discuss possible solutions in groups and present their research results.

Literature: Huff, Möslein & Reichwald: **Leading Open Innovation**; 2013 MIT Press,
ISBN-13: 978-0262018494

Keywords: innovation, leadership

2.1.2 Designing Technology

Responsible lecturer: Prof. Dr. Kathrin Möslein
ECTS: 5
Course type and weekly hours: lecture (4 hours)
Exam type: Research project and written assignments

Contents:
The course covers the process of designing innovative artifacts to extend human as well as organizational capabilities, and to solve problems within organizations and industries. The course requires analytical thinking, where students can identify and clearly articulate problems that they would like to solve and the process of solution finding. While existing technical knowledge from students is welcome, it is not a prerequisite for the course. Students can also contribute by conducting theoretical/empirical research, along with developing IT artifacts. To conclude, the course offers a balance between creativity and scientific thinking, which can be of immense help to students seeking to learn either skill or both.

Theoretical approaches which will be covered in the course:

- Design theory, systems theory, communication theories
- Design science research and piloting
- Agile innovation and interactive value creation

Application domains for the design projects:
- Recommendation Systems
- Voice & Emotion & Pattern Recognition
- Internet of Things and associated technologies

Learning outcomes and competencies:
The students
- develop a sound understanding of both social and technological aspects of various innovative technologies
- apply the design science research method, build artifacts and evaluate them, around a given theme
- understand the design science paradigm and apply it to develop knowledge on the management and use of information technology for managerial purposes
- can effectively communicate this knowledge.
- Are familiar with innovation technologies in the context of artificial intelligence and augmented reality that can link and enable different types of innovation technologies across the boundaries of socio-technical systems
- adopt this knowledge in practical work on design problems, which will be related to the usage of humanoid robots for man-machine interaction.

Literature:

- Baldwin, C. Y., & Clark, K. B. (2004). Modularity in the Design of Complex Engineering Systems. In Complex Engineered Systems Understanding Complex Systems, 175–205.
- Kroes, P. (2010). Engineering and the dual nature of technical artefacts. Cambridge Journal of Economics, 34 (1), 51–62.Hevner, A. R., March, S. T., Park, J. & Ram, S. (2004). Design Science in Information Systems Research. MIS Quarterly: Management Information Systems, 28 (1), 75-106.

- Fichman, R., Dos Santos, B., & Zheng, Z. (2014). Digital Innovation as a Fundamental and Powerful Concept in the Information Systems Curriculum. MIS Quarterly: Management Information Systems, 38, 329–353.

Keywords: innovation, design thinking

2.1.3 Service innovation

Responsible lecturer: Prof. Dr. Kathrin Möslein
ECTS: 5
Course type and weekly hours: seminar (contact hours: 30h, independent study: 120h)
Exam type: Written assignments

Contents:
Services now account for over 80% of all transactions in developed economies, but typically receive much less R&D attention than products. Developing service innovations demands a clear strategy from businesses with four interlocking core elements: search, selection, implementation and evaluation of innovative concepts. If even one of these phases is not been clearly thought through, the entire innovation process is likely to collapse. This course focuses on successful approaches, methods, tools and efforts to develop service innovations.

Learning outcomes and competencies:
The students can:

- learn about items, notions, characteristics and special features in innovation management for services, service design methods and cases.
- learn to judge and discuss innovation management tasks and alternative solutions with respect to the specialities of services.
- experience methods of service design by themselves in interactive lectures, gain a feeling for suitable methods and learn to reflect different effects.
- apply their knowledge and competences in solving cases and thereby analyze selected issues of managing, developing and innovating services.
- work together in international small work groups, present their results in English, give feedback to other students' work and discuss different solution approaches.

Literature:
Specific literature will be listed in the course

2.1.4 Foundations of Innovation and Entrepreneurship (coming soon)

Responsible lecturer: Prof. John Bessant
ECTS: 5
Course type and weekly hours: online course (4 hours)
Exam type: t.b.d.

Contents:

Learning outcomes and competencies:

Literature:

Keywords: innovation, entrepreneurship

2.1.5 Strategic innovation management (coming soon)

Responsible lecturer: Prof. Dr. Kai-Ingo Voigt
ECTS: 5
Course type and weekly hours: seminar (t.b.d.)
Exam type: t.b.d.

Contents:
Learning outcomes and competencies:
Literature:

Keywords: innovation, entrepreneurship

2.1.6 Technology and innovation management

Responsible lecturer: Prof. Dr. Kai-Ingo Voigt
ECTS: 5
Course type and weekly hours: seminar (attendance: 45h, self-study: 105h)
Exam type: case studies

Contents:
Technologies and innovations are of fundamental importance to companies' growth and success. Therefore, future engineers and business executives need to be familiar with theory, concepts, and tools of technology as well as innovation management. In this regard, this course places special emphasis on economic decisions in the context of technology management, considering also disruptive changes in the business environment. Moreover, this course is about understanding success factors of innovations and the organization of innovation processes. We will additionally discuss options of timing strategies as well as special innovation concepts like open innovation and cross-industry innovation.
Furthermore, the challenges and possibilities of business model innovations will be emphasized. Transforming a business idea into a structured and well-developed business plan will be the final topic of this course. All topics will be illustrated by incorporating numerous practical examples.

Learning outcomes and competencies:
In this course, the students will acquire deep and comprehensive knowledge on the current state of research in the field of technology and innovation management. After finishing this course, the students will be able to assess and evaluate the crucial role of technologies and innovations as basis of competitive advantages for industry and service companies. Moreover, the students will learn to successfully transfer their acquired theoretical knowledge to practical real-world topics and to structure and solve related problems. The gained analytical and conceptual skills will enable the students to independently handle complex economic problems and to apply "the right" methods and concepts to deal with the challenges of technology and innovation management. They will also learn how to holistically reflect and present technology- or innovation-driven business ideas.

Literature: /

2.2 HMDA Common core (20 ECTS)

2.2.1 Pattern Recognition

Responsible lecturer: Prof. Dr.-Ing. Andreas Maier
ECTS: 5
Course type and weekly hours: lecture (3 hours), exercise class (1 hour)
Exam type: oral exam (30 min.)

Contents:
Mathematical foundations of machine learning based on the following classification methods:

- Bayesian classifier
- Logistic Regression
- Naive Bayes classifier
- Discriminant Analysis
- norms and norm dependent linear regression
- Rosenblatt's Perceptron
- unconstraint and constraint optimization
- Support Vector Machines (SVM)
- kernel methods
- Expectation Maximization (EM) Algorithm and Gaussian Mixture Models (GMMs)
- Independent Component Analysis (ICA)
- Model Assessment
- AdaBoost

Learning outcomes and competencies:
Students

- understand the structure of machine learning systems for simple patterns
- explain the mathematical foundations of selected machine learning techniques
- apply classification techniques in order to solve given classification tasks
- evaluate various classifiers with respect to their suitability to solve the given problem
- understand solutions of classification problems and implementations of classifiers written in the programming language Python

Literature:

- Richard O. Duda, Peter E. Hart, David G. Stock: Pattern Classification, 2nd edition, John Wiley&Sons, New York, 2001
- Trevor Hastie, Robert Tobshirani, Jerome Friedman: The Elements of Statistical Learning - Data Mining, Inference, and Prediction, 2nd edition, Springer, New York, 2009
- Christopher M. Bishop: Pattern Recognition and Machine Learning, Springer, New York, 2006

Keywords: pattern recognition, classification, machine learning, python programming

2.2.2 Machine Learning for Time Series

Responsible lecturer: Prof. Dr. Björn Eskofier, Prof. Dr. Oliver Amft
ECTS: 5
Course type and weekly hours: lecture (2 hours), exercise class (2 hours)
Exam type: oral exam (30 min.)

Contents:
Aim of the lecture is to teach Machine learning (ML) methods for a variety of time series applications. The following topics will be covered:

- An overview of applications of time series analysis
- Fundamentals of Machine learning (ML) methods, such as Gaussian processes, Monte Carlo sampling methods and deep learning, for time series analysis
- Design, implementation and evaluation of ML methods in order to address time series problems
- Working with widely-used tool boxes that can be used for implementation of ML methods, such as Tensorflow or Keras

Learning outcomes and competencies:

- Students develop an understanding of concepts of time series problems and their wide applications in industry, medicine, finance, etc.
- Students learn concepts of machine learning (ML) methods in general and tackling time series problems in particular
- Students understand the characteristics of time series data and will be capable of developing and implementing ML methods to model, predict and manipulate such data in concrete problems

Literature:

- Machine Learning: A Probabilistic Perspective, Kevin Murphy, MIT press, 2012
- The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Trevor Hastie, Robert Tibshirani, Jerome Friedman, Springer, 2009
- Deep Learning, Ian Goodfellow and Yoshua Bengio and Aaron Courville, MIT Press, 2016
- Reinforcement Learning: An Introduction, Richard S. Sutton and Andrew G. Barto, MIT press, 1998

Keywords: machine learning, data mining

2.2.3 Deep Learning

Responsible lecturer: Prof. Dr.-Ing. Andreas Maier
ECTS: 5
Course type and weekly hours: lecture (2 hours), exercise class (2 hours)
Exam type: oral exam (30 min.)

Contents:
Deep Learning (DL) has attracted much interest in a wide range of applications such as image recognition, speech recognition and artificial intelligence, both from academia and industry. This lecture introduces the core elements of neural networks and deep learning, it comprises:

- (multilayer) perceptron, backpropagation, fully connected neural networks
- loss functions and optimization strategies

- convolutional neural networks (CNNs)
- activation functions
- regularization strategies
- common practices for training and evaluating neural networks
- visualization of networks and results
- common architectures, such as LeNet, Alexnet, VGG, GoogleNet
- recurrent neural networks (RNN, TBPTT, LSTM, GRU)
- deep reinforcement learning
- unsupervised learning (autoencoder, RBM, DBM, VAE)
- generative adversarial networks (GANs)
- weakly supervised learning
- applications of deep learning (segmentation, object detection, speech recognition, ...)

The accompanying exercises will provide a deeper understanding of the workings and architecture of neural networks.

Learning outcomes and competencies:
The students
- explain the different neural network components,
- compare and analyze methods for optimization and regularization of neural networks,
- compare and analyze different CNN architectures,
- explain deep learning techniques for unsupervised / semi-supervised and weakly supervised learning,
- explain deep reinforcement learning,
- explain different deep learning applications,
- implement the presented methods in Python,
- autonomously design deep learning techniques and prototypically implement them,
- effectively investigate raw data, intermediate results and results of Deep Learning techniques on a computer,
- autonomously supplement the mathematical foundations of the presented methods by self-guided study of the literature,
- discuss the social impact of applications of deep learning applications.

Literature:
- Ian Goodfellow, Yoshua Bengio, Aaron Courville: Deep Learning. MIT Press, 2016.
- Christopher Bishop: Pattern Recognition and Machine Learning, Springer Verlag, Heidelberg, 2006
- Yann LeCun, Yoshua Bengio, Geoffrey Hinton: Deep learning. Nature 521, 436–444 (28 May 2015)

Keywords: deep learning, neural networks, pattern recognition, signal processing

2.2.4 Multi-omics data analysis

Responsible lecturer: Prof. Mário J. Gaspar da Silva
ECTS: 5
Course type and weekly hours: MOOC → Online course offered for all HMDA-students
Exam type: e-exam (30 min. - on-site at the partner institutions)

Contents:

1: Introduction to epigenetics

- The genetic code
- Code and personalized medicine
- Genome-wide association studies
- Limitations of genome-centric studies
- The role of epigenetics
- The central dogma
- Multi-omic data collection
- The need for multi-omic data analysis
- Epigenetics and personalized medicine
- Epigenetics in our daily life
- Case studies on identical twins
- Case studies on ancestral influence

2: Essential background on (biomedical) data analysis

- Sample omic datasets
- Data exploration
- Data preprocessing
- Clustering
- Biclustering and pattern mining
- Classification
- Regression

Module 3: Integrative multi-omics for personalized medicine

- Integrating multiple sources of omic data
- Essentials on heterogeneous data analysis
- The role of exposomics in personalized medicine
- Combining multi-omic and medical data for personalized medicine
- Unsupervised analysis of multi-omic data
- Enrichment analysis as the way of increasing current knowledge on epigenetics
- Comprehensive study of epigenetics from integrative patterns of disease
- Supervised analysis of multi-omic data
- Discovery of multi-source epigenetic markers for personalized medicine

Learning outcomes and competencies:

- structured view on epigenetics and its role in personalised medicine
- be familiar with current findings, opportunities and challenges in personalized medicine (along its prevention, diagnostic and treatment components)
- understand the relevance of genomic, proteomic, metabolomic, clinomic and exposomic data in epigenetics
- master essentials of supervised and unsupervised data analysis
- be able to analyze multiple sources of omic data and master principles on how to learn from heterogeneous multi-omic data

Literature: /

Keywords: epigenetics, multi-omic data analysis, personalised medicine

3 1st year, 2nd semester (spring/summer semester):

3.1 HMDA Common Core continuation:

3.1.1 Pattern Analysis

Responsible lecturer: Prof. Dr.-Ing. Andreas Maier
ECTS: 5
Course type and weekly hours: lecture (3 hours), exercise class (1 hour)
Exam type: oral exam (30 min.)

Contents:

Based on the lecture Pattern Recognition, this lecture introduces the design of pattern analysis systems as well as the corresponding fundamental mathematical methods. The lecture comprises:

- an overview over regression and classification, in particular the method of least squares and the Bayes classifier
- clustering methods: soft and hard clustering
- classification and regression trees and forests
- parametric and non-parametric density estimation: maximum-likelihood (ML) estimation, maximum-a-posteriori (MAP) estimation, histograms, Parzen estimation, relationship between folded histograms and Parzen estimation, adaptive binning with regression trees
- mean shift algorithm: local maximization using gradient ascent for non-parametric probability density functions, application of the mean shift algorithm for clustering, color quantization, object tracking
- linear and non-linear manifold learning: curse of dimensionality, various dimensionality reduction methods: principal component analysis (PCA), local linear embedding (LLE), multidimensional scaling (MDS), isomaps, Laplacian eigenmaps
- Gaussian mixture models (GMM) and hidden Markov models (HMM): expectation maximization algorithm, parameter estimation, computation of the optimal sequence of states/Viterbi algorithm, forward-backward algorithm, scaling
- Bayesian networks
- Markov random fields (MRF): definition, probabilities on undirected graphs, Hammersley-Clifford theorem, cliques, clique potentials, examples for MRF-based image pre-processing and processing of image sequences
- Markov random fields and graph cuts: sub-modular functions, global optimization with graph cut algorithms, application examples

Learning outcomes and competencies:

The students

- explain the discussed methods for classification, prediction, and analysis of patterns,
- define regression and classification tasks as optimization problems,
- compare and analyze methods for manifold learning and select a suited method for a given set of features and a given problem,
- compare and analyze methods for probability density estimation and select a suited method for a given set of features and a given problem,
- apply non-parametric probability density estimation to pattern analysis problems,
- apply dimensionality reduction techniques to high-dimensional feature spaces,
- explain statistic modeling of feature sets and sequences of features,

- explain statistic modeling of statistical dependencies,
- implement presented methods in MatLab or Python,
- supplement autonomously the mathematical foundations of the presented methods by self-guided study of the literature,
- discuss the social impact of applications of pattern analysis solutions.

Literature:

- Richard O. Duda, Peter E. Hart und David G. Stork: Pattern Classification, Second Edition, 2004
- Christopher Bishop: Pattern Recognition and Machine Learning, Springer Verlag, Heidelberg, 2006
- Antonio Criminisi and J. Shotton: Decision Forests for Computer Vision and Medical Image Analysis, Springer, 2013
- Kevin P. Murphy: Machine Learning: A Probabilistic Perspective, MIT Press, 2012
- papers referenced in the lecture

Keywords: pattern recognition, pattern analysis

3.2 Innovation and Entrepreneurship 2 (10 ECTS)

3.2.1 Safe Medical Devices

Responsible lecturer: Björn-Erik Erlandsson, Ph.D., Prof.
ECTS: 5 -7,5
Course type: online
Exam type: written examination and project work (online)

Learning outcomes and competencies:
The main objective with this course is to give the student substantial understanding about the regulatory framework for medical devices and how personal protection and intended product performance can be assured by the medical device industry and the health care sector.
After passing the course, the student should be able to:

- Describe, explain and apply in practical use the regulatory demands for medical devices.
- Describe the difference between regulatory demands in different countries.
- Explain the interaction between authorities, regulatory bodies, standardization organizations and industry when placing a medical device on the market.
- Define quality and explain different methods for assuring quality in an organization or for products or services.
- Enlarge upon the essential role of risk analysis and quality assurance for the medical device industry.
- Explain and discuss how standardization development enhances the work in the medical device industry and the healthcare sector.

Literature: /

3.2.2 Fundamentals of Anatomy and physiology

Responsible lecturer: Prof. Dr. Clemens Forster
ECTS: 5
Course type and weekly hours: lecture (2 hours)
Exam type: written exam (90 min.)

Contents:

- fundamentals of anatomy, physiology and pathophysiology
- important medical terms
- relevant and frequent clinical pictures
- relevant methods in biological and technical vision
- discussion of methods and theoretical approaches to recognize relevant medical questions
- critical consideration of the most important imaging techniques in important clinical pictures
- presentation of the organizational structures of diagnostic processes

Learning objectives and competencies:
The students

- understand and can apply the most important and common medical terms
- are familiar with the basics of anatomy and physiology
- can interpret important clinical pictures
- understand and explain medical questions in diagnostics and therapy using examples

Literature: /
Keywords: anatomy for engineers, physiology for engineers

3.2.3 Medical Device Regulation

Responsible lecturer: Heike Leutheuser
ECTS: 2.5
Course type and weekly hours: seminar, 5 x 8h
Exam type: written exam (60 minutes)

Contents:
Students must attend 5 seminar dates. The first two dates, which are offered every semester, are compulsory. You can choose the remaining 3 course days. You can also attend a course day in the following semester, if you like a topic better there, but it is advisable to complete the seminar within a semester. Seminar days are held from 9:00 am to 5:00 pm.

Learning objectives and competencies:
The certificate course Medical Device Regulation offers the combination of gaining knowledge in the university environment with a seminar character and the opportunity to make contacts with students as future specialist. You get to know the legal framework for medical devices. They understand the conditions, relationships and dependencies between corresponding directives, laws and standards. You will be able to successfully and timely take necessary measures to comply with legal requirements.

Literature: /

3.2.4 Medical Communications

Responsible lecturer: Dr. Miyuki Tauchi-Brück
ECTS: 2.5
Course type and weekly hours: lecture (3.5 hours)
Exam type: written exam (60 min.)

Contents:
Advancement in medicine is a huge collaborative work involving physicians, patients, medical professionals, engineers, scientists, and authorities to name a few. To promote and ease the development, there are rules and regulations to follow that enable interdisciplinary groups work together. Skills and knowledge for the entire structure in medical development belong to "medical communications". This lecture is to introduce "medical communications" to undergraduate and graduate students with medicine-related majors. The contents include physicians-patients and researchers-authorities communications in relation to pre-clinical and clinical studies. The focus of the lecture is on clinical studies. Published articles in medical journals, regulatory documents, and/ or websites from different organizations will be used as study materials and active participation of students is expected.

1. Clinical studies
    - 1a. Phase 0-IV clinical studies for a new drug Study designs/ terminologies Objective of studies in each phase Different study designs for different objectives Subjects Ethical issues in clinical studies Key statistics often used in clinical studies
    - 1b. Clinical study for medical devices Classification of medical devices
2. Communications
    - 2a. Formality Guidelines from International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use (ICH) Regulations in studies with animal

subjects (preclinical studies) European legislation Regulations in studies with human subjects (clinical studies) Arzneimittelgesetz (AMG)Sechster Abschnitt: Schutz des Menschen bei der klinischen Prüfung Declaration of Helsinki Good Clinical Practice Requirement for drug approval Requirement for CE marking of medical device

2b. Publication Journals: Manuscript writing/ reading Guidelines: CONSORT, STROBE, CARE, ARRIVE, etc Terminologies: MedDRA Conferences: Oral/ poster presentation

2c. Patients and publication ethics Patients' information/ informed consent Who are patients? What patients want to know: Information source for patients

Learning objectives and competencies:

The aim is to let the students:

- Understand the structures and designs of clinical studies, including drugs and medical devices;
- Be aware of ethical issues in clinical studies;
- Find problems and solutions in patient-physician communications;
- Practice soft skills used in medical communications, including "skimming and scanning" journal articles in unfamiliar fields, summarizing, writing, and presenting data.

Literature: /

3.2.5 Ethics of (Medical) Engineering

Responsible lecturers: Dr. rer. Nat. Jens Kirchner, Christoph Merdes

ECTS: 2,5

Course type and weekly hours: lecture (2 hours)

Exam type: 2 written reports (30 essays)

Contents:

This course provides an introduction to the ethical reflection of engineering, with a particular focus on the area of medical technology. It offers both an elementary introduction to normative ethics and the discussion of a variety of specific ethical problems including the engineer's responsibility, over the ethics of robotics and questions of justice and allocation in the context of the deployment of high-end medical technology.

The course addresses:

- the basics of utilitarianism, deontological ethics and virtue ethics
- the ethical challenges in the construction of semi-autonomous machines
- the ethical role and efficacy of professional codes
    - the just allocation of resources in society from the vantage point of medical technology
    - the responsibility of engineers and the ethical aspects of whistleblowing
    - dealing with test subjects and personal data

Literature:

- Kraemer, F., Van Overveld, K., & Peterson, M. (2011). Is there an ethics of algorithms?. Ethics and Information Technology, 13(3), 251-260.
- Kant, I. (1996[1785]). Groundworks for the metaphysics of morals. Kant's Practical Philosophy, Wood Allen & Gregor, Mary (ed.), Cambridge University Press, pp. 37-108.

Keywords: ethics, ethics of engineering, ethics of medicine

3.3 Master’s electives (choice of 10 ECTS)

5 ECTS to be chosen from the seminar catalog.

5 ECTS to be chosen from the modules M5 and M8. The following modules represent an example of selectable options.

3.3.1 Knowledge Discovery in Databases

Responsible lecturer: Klaus Meyer-Wegener
ECTS:2.5
Course type and weekly hours: lecture (2 hours)
Exam type: oral exam (30 minutes)

Contents:

- What is data mining and why do we do it?
- a multi-dimensional view of data mining
- what kinds of data or patterns can be mined?
- what technologies are used?
- what kinds of applications are targeted?
- major issues in data mining
- a brief history of data mining

Learning objectives and competencies:

- know the typical KDD process;
- know procedures for the preparation of data for data mining;
- know the definition of distance or similarity functions for the different kinds of attributes;
- define distance and similarity functions for a particular dataset;
- check attributes of a dataset for their meaning with reference to an analysis and transform attribute values accordingly, if required.
- know how a typical data warehouse is structured;
- are familar with the principle of the Apriori algorithm for the identification of frequent itemsets;
- know the FP-growth algorithm for a faster identification of frequent itemsets:
- present the definitions of support and confidence for association rules;
- describe the construction of association rules based on frequent itemsets;
- are capable of describing the course of action in classification tasks;
- present the construction of a decision tree based on a training dataset;
- present the principle of Bayes' classification;
- enumerate different clustering procedures;
- describe the steps of k-means clustering;
- know the different kinds of outliers.

Literature:

- Jiawei Han, Micheline Kamber, and Jian Pei: Data Mining – Concepts and Technologies, 3rd ed. Waltham, MA : Morgan Kaufmann, 2012 (The Morgan Kaufmann Series in Data Management Systems). - ISBN 978-0-12-381479-1

3.3.2 Architekturen der digitalen Signalverarbeitung / Architectures for Digital Signal Processing

Responsible lecturer: Dr. rer. nat Dr. phil. Jens Kirchner
ECTS: 5
Course type and weekly hours: lecture (2 hours)
Exam type: E-exam
Contents:

- Basic algorithms of signal processing (FFT, windowing, digital FIR and IIR-filters)
- Non-idealities of digital filters (quantization of filter coefficients, fixed-point arithmetic)
- CORDIC-architectures
- Architectures of systems with multiple sampling rates (conversion between different sampling rates)
- Digital signal generation
- Measures of performance improvement (pipelining)
- Architecture of digital signal processors
- Applications

Learning objectives and competencies: /
Literature: /

3.3.3 Medical Imaging System Technology

Responsible lecturer: Dr.-Ing. Wilhelm Dürr
ECTS: 5
Course type and weekly hours: lecture with exercise (4 hours)
Exam type: written exam

Contents:
Röntgen´s discovery of "a new kind of ray" about 100 years ago was the beginning of the partially spectacular development of imaging systems for medical diagnosis. New knowledge and developments, especially in physics, led to consequent applications in the area of medicine. Over time, there developed the following (most significant) medical imaging techniques: roentgenography, nuclear medical imaging, sonography, x-ray computer tomography and magnetic resonance tomography. After an overview of the historical development and the basic principles of the theory of
linear systems involved, the individual techniques will be discussed in detail. Following the description of the functional principles, the point of concentration will lie in the technical realization. Biological, physical and technical limits are to be described. What is possible today, is to be shown through examples in application.

Learning objectives and competencies: /

Literature:

- Fercher, A.F.: Medizinische Physik. Springer-Verlag, 1992
- Morneburg, H. (Hrsg.): Bildgebende Systeme für die medizinische Diagnostik. Publicis-MCD-Verlag, 1995
- Rosenbusch, G., Oudkerk, M., Amman, E.: Radiologie in der medizinischen Diagnostik. Blackwell

3.3.4 Advanced medical imaging for Clinical Navigation using Smart Devices

Responsible lecturer: Dr. Björn Heismann (Siemens Healthineers)
ECTS: 5
Course type and weekly hours: advanced seminar (2 hours), project work (2 hours)

Contents:
You will be part of an interdisciplinary project team challenged to prototype a novel (wearable) device for the emerging field of digital indoor navigation. You and your team will have the chance to develop your ideas and shape patient care of the future. Experts from industry, healthcare and research will give you valuable feedback and support you to bring your idea to the next level.

Learning outcomes and competencies:
Stage 1:

- Challenge introduction and lectures on state-of-the-art methodology, algorithms and sensors used for indoor navigation
- Project management workshop (e.g. design thinking approach, prioritizing exercise & introduction to useful PM tools)
- Clinical needs screening and interviews with healthcare experts
- Ideation process
- Development of concrete hardware/software design specifications. You will be guided in your team and project to set realistic milestones and iteratively prioritize your technical implementation.

Stage 2:

- Data capturing
- Rapid prototyping
- Feedback round with potential users and customers

Stage 3:

- Embracing user feedback and final hacksprint
- Prototype pitch with experts from healthcare and industry

Literature: /

3.3.5 Human Computer Interaction

Responsible lecturer: Prof. Dr. Björn Eskofier
ECTS: 5
Course type and weekly hours: lecture (3 hours), exercise class (1 hour)
Exam type: written exam (90 min.)

Contents:
Aim of the lecture is to teach basic knowledge of concepts, principles, models, methods and techniques for developing highly user-friendly Human Computer Interfaces. Beyond traditional computer system the topic of modern user interfaces is also discussed in the context of automobile and intelligent environments, mobile devices and embedded systems.
This lecture addresses the following topics:

- Introduction to the basics of Human Computer Interaction
- Design principles and models for modern user interfaces and interactive systems
- Information processing of humans, perception, motor skills, properties and skills of the users

- Interaction concepts, metaphors, standards, norms and style guides
- In- and output devices, design space for interactive systems
- Analysis-, design- and development methodologies and tools for easy to use user interfaces
- Prototypic implementation of interactive systems
- Architectures for interactive systems, User Interface Toolkits and components
- Acceptance, evaluation methods and quality assurance

Learning outcomes and competencies:

- Students develop an understanding for models, methods and concepts in the field of Human-Computer Interaction.
- They learn different approaches for designing, developing and evaluating User Interfaces and their advantages and disadvantages.
- Joining the course enables students to understand and execute a development process in the area of Human-Computer Interaction.
- Student will be able to do an UI evaluation by learning basics about Information processing, perception and motoric skills of the user.
- Additionally, appropriate evaluation method as well as acceptance and quality assurance aspects will be learned.

Literature: /

Keywords: human-computer interaction, human machine interface, mobile human computer interaction, ubiquitous and embedded interactive systems

4 2nd year, 1st semester (autumn/winter semester):

4.1 Innovation and Entrepreneurship 3 (10 ECTS)

4.1.1 I & E summer school or I & E practical module

Responsible lecturer: various
ECTS: 5
Course type: workshop/laboratory course (150 hours in total, including self-study and preparation of tasks in teams)
Exam type: /

Contents:
The I&E practical training includes the preparation, execution and documentation an pitch of a practical project, which is based on a real use case in the healthcare context. The practical work is carried out in teams a laboratory setting. The infrastructure of the lab gives students the chance to execute their own product ideas or to work on topics from industrial partners.

Learning outcomes and competencies:
Students are able to

- apply industry standard techniques and team management
- develop, independently and within a team, their problem-solving and creative skills
- implement their ideas as prototypes by applying agile software development methods
- use the results of their projects for the creation of start-ups

Literature: /

4.1.2 Innovation lab for Wearable und Ubiquitous Computing

Responsible lecturer: Prof. Dr. Eskofier
ECTS: 10
Course type and weekly hours: internship (4 hours)
Exam type: internship, graded certificate

Contents:
Mini-computers documenting our rhythm of life, EKG-Sensors tracing every detail or glasses, that transfer us into another reality are amongst the technologies we are meanwhile facing in our everyday lives. At the Innovation Lab for Wearable and Ubiquitous Computing students develop such technologies and learn about the possibilities and requirements to build a start-up. The Lab is funded by the Center of Digitalization Bavaria (ZD.B). By applying agile development methods (Scrum), teams of 5 to 8 students develop prototypes of products within the wearable and ubiquitous computing field. Participating students have open access to the Innovation Lab, which provides them with everything they need to develop their prototypes. The project ideas originate from cooperating companies or the students themselves. Besides the great practical experience gained during development, students also learn about entrepreneurship. There will be tutorials covering design thinking, market analysis, management of development processes, securing intellectual property, and business plan creation.

Learning objectives and competencies:
- Ideation, Design Thinking
- Patent Research, Markt Analysis
- Agile Development Methods (Scrum)
- Prototyping
- Securing Intellectual Property
- Introduction to Entrepreneurship, Startup Financing

Literature: /

4.1.3 MedTech Entrepreneurship Lab (EIT Campus project)
Responsible lecturer: Heike Leutheuser
ECTS: 5
Course type and weekly hours: lab course (hours t.b.d.)
Exam type: t.b.d.

Contents:
The MedTech E-Lab will provide learners with the opportunity to develop prototypes which support the following EIT Health Business Objectives:
Improving healthcare systems
- Multimodal neuro-monitoring in severe stroke patients for the early detection of secondary brain damage
- Pharmacokinetic modeling and medication dosing and dispensing systems
- Treating and managing chronic diseases
- Endoscopic and ultrasound imaging app roaches for the diagnosis and treatment of diseases of the gastrointestinal tract
- Patient/next-of-kin interface for providing daily palliative care patient data to a networked clinical data system
- Communication too ls for medical discussions between a patient's family and the physician
- MedTech E-Lab learners will work directly with medical doctors and business mentors and will receive an in-depth entrepreneurship education, including developing their business plans for a potential launch of their prototypes.

The MedTech E-Lab objectives are to:
- train students, professionals, and rising entrepreneurs to develop practical solutions to current healthcare issues
- provide learners with hands-on opportunities for creating innovations addressing real-life challenges from hospital and industry partners
- create value within the healthcare sector through developing prototypes and associated business plans
- collaborate with other EIT Health E-Labs via pitching events and remote learning modules
- achieve sustainability by integration within the FAU curriculum and external partner funding

Learning outcomes and competencies:
Students
- gain knowledge in entrepreneurship and business creation
- acquire competencies and skills in design thinking, business models, value proposition, prototyping, financing, and pitching

- learn about medical device and medical software regulations in Europe and abroad
- work in interdisciplinary teams addressing real-world challenges in healthcare
- gain knowledge about decision-making related to product development in the healthcare sector
- develop innovative, needs-based products together with hospital and industry partners be empowered to turn an idea into a startup venture

4.2 HMDA Specialization
Specialization offered by FAU: Medical Signal Processing (20 ECTS):

4.2.1 Wearable and Implantable Computing

Responsible lecturer: Prof. Dr. Oliver Amft
ECTS: 5
Course type and weekly hours: lecture (2 hours), exercise class (2 hours)
Exam type: written exam (60 min.)

Contents:
The course provides an overview on the system design of wearable computing systems and implantable systems. Electronic design topics will be addressed, including bioelectronics, flexible electronics, electronics textile integration, multiprocess additive manufacturing. On the system functional level, frequent sensor and actuators and their designs for on-body and implantable systems are discussed. Powering and energy management concepts will be detailed, including processing and task scheduling, sparse sampling and sparse sample signal processing. Energy harvesting methods for wearable and implantable systems are analyzed. Principles of biocompatibility and system validation for remote health monitoring are covered. Concrete design problems related to context awareness, energy-efficient context recognition, and mechanical design in medical applications are demonstrated, prototypes realized and discussed in mini-projects.

Learning outcomes and competencies:
Students

- gain overview on context awareness, sensors and actuators for context management in digital health.
- understand design concepts and apply/analyse wearable and implantable system design methods for accessories, smart textiles, skin-attachables using soft substrates, and encapsulation.
- analyse the electrical and physical principles, select and optimize on-body energy harvesting and power management techniques.
- apply system evaluation methods, assess and design for biocompatibility.
- create continuous context recognition and energy-efficient processing using sparse sampling, related signal and pattern processing methods.
- create digital models of wearable systems.

Literature: /

Keywords: wearables, digital health

4.2.2 Biomedical Signal Analysis

Responsible lecturer: Prof. Dr. Björn Eskofier
ECTS: 5
Course type and weekly hours: lecture (2 hours), exercise class (2 hours)
Exam type: written exam (90 min.)

Contents:
The lecture content explains and outlines (a) basics for the generation of important biosignals of the human body, (b) measurement of biosignals, and (c) methods for biosignals analysis.
Considered biosignals are among others action potential (AP), electrocardiogram (ECG), electromyogram (EMG), electroencephalogram (EEG), or mechanomyogram (MMG). The focus during the measurement part is for example the measurement technology or the correct sensor and electrode placement. The main part of the lecture is the analysis part. In this part, concepts like filtering for artifact reduction, wavelet analysis, event detection or waveform analysis are covered. In the end, an insight into pattern recognition methods is gained.

Learning outcomes and competencies:
Students

- reproduce the generation and measurement of important biosignals of the human body
- recognize relations between the generation of biosignals and the measured signal
- understand the importance of biosignal analysis for medical engineering
- analyze and provide solutions to the key causes for artifacts in biosignals
- apply gained knowledge independently to interdisciplinary research questions of medicine and engineering science
- acquire competences between medicine and engineering science
- learn how to reproduce and argumentatively present subject-related content
- understand the structure of systems for automatic classification of simple patterns
- work cooperatively and act responsibly in groups
- implement biosignal processing algorithms in MATLAB
- solve classification problems in MATLAB

Literature:

- R.M. Rangayyan, Biomedical Signal Analysis: A case-study approach. 1st ed., 2002, New York, NY: John Wiley & Sons.
- E.N. Bruce, Biomedical Signal Processing and Signal Modeling. 1st ed., 2001, New York, NY: John Wiley & Sons.

4.2.3 Diagnostic Medical Image Processing

Responsible Lecturer: Prof. Dr.-Ing. Andreas Maier
ECTS: 5
Course type and weekly hours: online course (2 hours) and online exercises (2 hours)
Exam type: written exam (60 min.)

Contents:
The contents of the lecture comprise basics about medical imaging modalities and acquisition hardware. Furthermore, details on acquisition-dependent preprocessing are covered for image intensifiers, flat-panel detectors, and MR. The fundamentals of 3D reconstruction from parallel-beam

to cone-beam reconstruction are also covered. In the last chapter, rigid registration for image fusion is explained. In the exercises, algorithms that were presented in the lecture are implemented in Java.

Learning outcomes and competencies:
The participants

- understand the challenges in interdisciplinary work between engineers and medical practitioners.
- develop understanding of algorithms and math for diagnostic medical image processing.
- learn that creative adaptation of known algorithms to new problems is key for their future career.
- develop the ability to adapt algorithms to different problems.
- are able to explain algorithms and concepts of the lecture to other engineers.

Literature: /

4.2.4 Interventional Medical Image Processing

Responsible Lecturer: Prof. Dr.-Ing. Andreas Maier
ECTS: 5
Course type and weekly hours: online course (4 hours)
Exam type: written exam (60 min.)

Contents:
This lecture focuses on recent developments in image processing driven by medical applications. All algorithms are motivated by practical problems. The mathematical tools required to solve the considered image processing tasks will be introduced.
The lecture starts with an overview on preprocessing algorithms such as scatter correction for x-ray images, edge detection, super-resolution and edge-preserving noise reduction. The second chapter describes automatic image analysis using feature descriptors, key point detection, and segmentation using bottom-up algorithms such as the random walker or top-down approaches such as active shape models. Furthermore, the lecture covers geometric calibration algorithms for single view calibration, epipolar geometry, and factorization. The last part of the lecture covers non-rigid registration based on variational methods and motion-compensated image reconstruction.

Learning outcomes and competencies:
The participants

- summarize the contents of the lecture.
- apply pre-processing algorithms such as scatter correction and edge-preserving filtering.
- extract information from images automatically by image analysis methods such as key point detectors and segmentation algorithms.
- calibrate projection geometries for single images and image sequences using the described methods.
- develop non-rigid registration methods using variational calculus and different regularizes.
- adopt algorithms to new domains by appropriate modifications.

Literature: /

4.2.5 Multidimensional Signals and Systems (may be subject to changes)

Responsible lecturer: Prof. Dr.-Ing. Rudolf Rabenstein
ECTS: 5
Course type and weekly hours: lecture (4 hours)
Exam type: oral exam (30 min.)

Contents:

Properties of multidimensional signals

- separability, symmetry, etc.

2D signals and systems

- convolution
- delta impulse
- Fourier transformation
- FIR and IIR systems
- state space representation

Wave propagation in 2D and 3D

- wave equation,
- Fourier transformation and decomposition into plane waves and circular and spherical harmonics
- Green's function
- Kirchhoff-Helmholtz integral equation

Applications

- imaging with the pin hole camera model
- principle of computer tomography
- subpixel rendering
- iterative solution of systems of linear equations
- room acoustics
- sound field reproduction with wave field synthesis and Ambisonics

Learning outcomes and competencies:

The students

- classify multidimensional signals and systems,
- assess multidimensional sampling schemes in the space domain and in the wave-number domain,
- evaluate the properties of multidimensional FIR and IIR systems,
- discuss the advantages and disadvantages of wave representations in different spatial domains and in the corresponding coordinate systems,
- solve the acoustical wave equation in two and three spatial dimensions,
- design systems for spatial audio reproduction (Ambisonics)
- evaluate the implementation of systems for spatial audio reproduction (wave-field synthesis).

Literature: /

Keywords: human-computer- interface

4.2.6 Visual Computing in Medicine

Responsible Lecturer: Peter Hastreiter
ECTS: 5
Course type and weekly hours: online course (4 hours)
Exam type: oral exam (30 min.)

Contents:
The flood and complexity of medical image data as well as the clinical need for accuracy and efficiency require powerful and robust concepts of medical data processing. Due to the diversity of image information and their clinical relevance the transition from imaging to medical analysis and interpretation plays an important role. The visual representation of abstract data allows understanding both technical and medical aspects in a comprehensive and intuitive way.

Learning outcomes and competencies:
Based on a processing pipeline for medical image data an overview of the characteristics of medical image data as well as fundamental methods and procedures for medical image analysis and visualization is given. Examples of clinical practice show the relation to the medical application:

- Overview of imaging techniques in medicine
- Grid structures, data types, image formats
- Preprocessing, filtering and interpolation
- Fundamental approaches of segmentation
- Explicit and implicit methods of registration
- Medical visualization (2D, 3D, 4D) of scalar-, vector-, tensor data
- Practical demonstrations in the labs and in the clinics

Literature:
- B. Preim, C. Botha: Visual Computing for Medicine, Morgan Kaufmann Verlag, 2013
- B. Preim, D. Bartz: Visualization in Medicine - Theory, Algorithms, and Applications, Morgan Kaufmann Verlag, 2007
- H. Handels: Medizinische Bildverarbeitung, Bildanalyse, Mustererkennung und Visualisierung für die computergestützte ärztliche Diagnostik und Therapie, Vieweg und Teubner Verlag, 2009
- P.M. Schlag, S. Eulenstein, Th. Lange: Computerassistierte Chirurgie, Elsevier Verlag, 2010
- E. Neri, D. Caramella, C. Bartolozzi: Image Processing in Radiology, Springer Verlag, 2008

5 2nd year, 2nd semester (spring/summer semester):

5.1 Master’s thesis in collaboration with industry partner or hospital

Supervisors: 1 academic supervisor, 1 technical supervisor (industry partner), 1 medical supervisor (physician or member of the Faculty of Medicine)
ECTS: 30
Exam type: written thesis and oral presentation

By writing the Master´s thesis, students should learn to execute scientific research in the field of medical engineering. To get familiar with the concept of scientific work, the FAU offers the course “Nailing your Thesis” in summer semester.
The topic is issued and supervised by a cooperation of a fulltime university teacher and a non-academic business partner. The thesis results out of a previous internship to combine the technical research with study tract distinctive business and entrepreneurship components.
It is recommended to start looking for a final thesis subject in the second year of study. This way, students have time to take matching study modules to acquire specialized knowledge.
Registration is possible for all students, that have completed all mandatory modules and have acquired at least 75 ECTS credits. From there on, the thesis is limited to 6 months, which correspond to 30 ECTS or 900 hours of work.
Within the deadline, the thesis paper must be handed in at the supervising lab. The thesis presentation and the grading can take place after the deadline.