# Publication of the updated module handbook FAU

## 20337 – EIT Health Master in Health and Medical Data Analytics

EIT Health

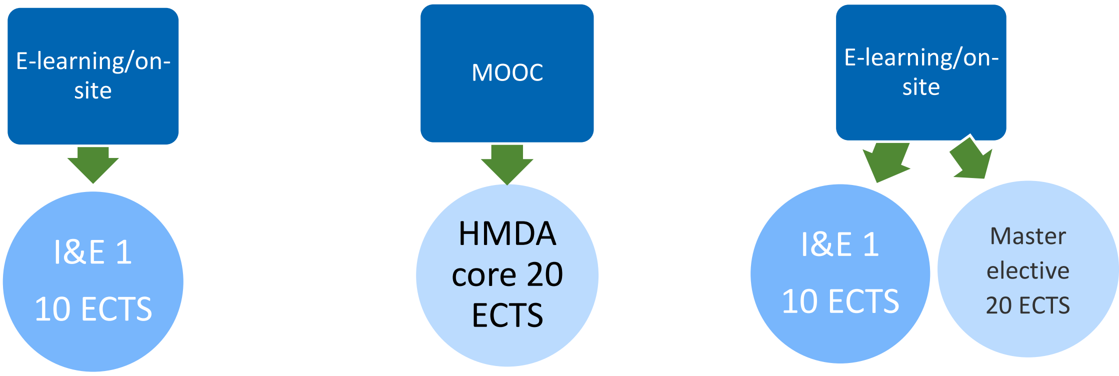
Erlangen | 21 July 2022

# Contents

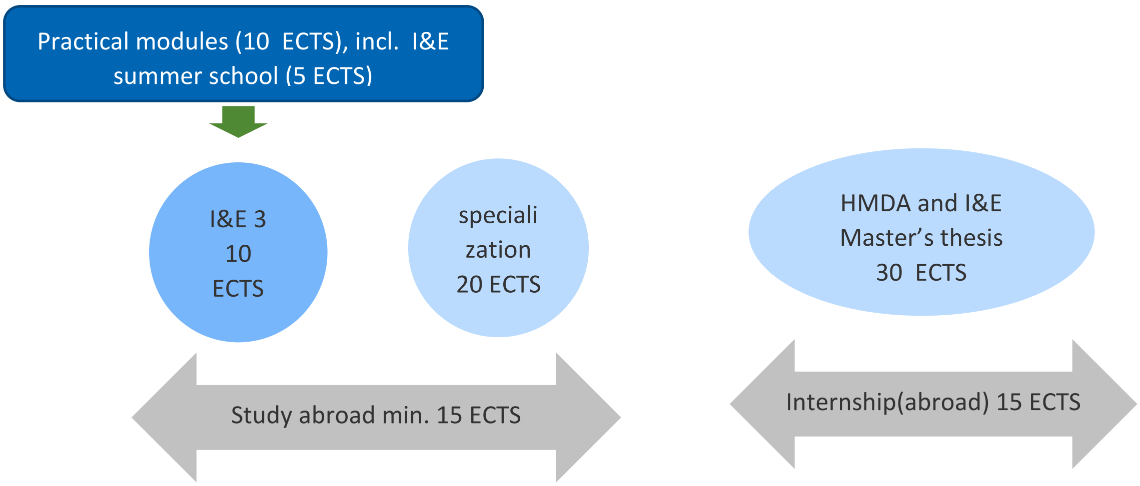
# Study track at the FAU

## Alignment

1st year




2nd year



# 1st year, 1st semester (autumn/winter semester)

## Innovation and Entrepreneurship 1 (10 ECTS)

### INNOVATION AND LEADERSHIP (WS)

Responsible lecturer: Prof. Dr. Kathrin Möslein
Chair of Information Systems I, Innovation and Value Creation (Prof. Dr. Möslein)
ECTS: 5
Course type and weekly hours: lecture (4 hours)
Exam type: presentation, project report
FAU Module Catalog: 7

**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 behavior 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

## DESIGNING TECHNOLOGY (WS)

Responsible lecturer: Prof. Dr. Kathrin Möslein
Chair of Information Systems I, Innovation and Value Creation (Prof. Dr. Möslein)
ECTS: 5
Course type and weekly hours: lecture (4 hours)
Exam type: Research project and written assignments
FAU Module Catalog: 7

**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 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 sociotechnical 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

## BECOMING AN INNOVATIVE ENGINEER (INNOENG) (WS & SS)

Responsible lecturer: Prof. Dr. Björn Eskofier, Marlies Nitschke
Lehrstuhl für Maschinelles Lernen und Datenanalytik (MaD)
ECTS: 2,5
Course type and weekly hours: self-study & pace course (2,5 per / week)
Exam type: online test
FAU Module Catalog: 7

**Contents:**
The online course "Becoming an innovative engineer" will complement the technical knowledge which you gained in other courses. It therefore gives you a broad overview about various topics and empowers you to make use of your technical background to become an innovative engineer. The course comprises seven topics to fulfill the learning objectives descripted below:

- Empowerment and Teamwork:
  Theory of enterprise content management which is fundamental for successful teamwork.
- Organizational Creativity:
  Individual creativity, team creativity, and organizational creativity since innovation requires creativity.
- Business Design:
  Insights into what must be considered when founding a business.
- Prototyping:
  Basics of prototyping as it is key for fast and efficient development.
- Agile Development:
  Agile development methods empowering them to manage their development workflow.
- Source Control via Git:
  How source code can be efficiently controlled using git.
- Testing of Software Systems:
  Fundamentals and principles of software testing which is necessary for every successful software product.

This course is a shared online course of the HMDA partner universities and was created at the FAU with support of EIT Health.
Please join the following StudOn course if you want to take the course (WS2021/22):
https://www.studon.fau.de/crs3248090.html

### 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:** t.b.d.
**Learning outcomes and competencies:** t.b.d.
**Literature:** t.b.d.
**Keywords:** innovation, entrepreneurship

## HMDA Common core (20 ECTS)

### PATTERN RECOGNITION (WS)

Responsible lecturer: Prof. Dr.-Ing. Andreas Maier
Chair of Computer Science 5 (Pattern Recognition)
ECTS: 5
Course type and weekly hours: lecture (3 hours), exercise class (1 hour)
Exam type: oral exam (90 min.)
FAU Modul Catalog: 2

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

- Bayesian classifier
- Logistic Regression
- Naïve 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 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

## MACHINE LEARNING FOR TIME SERIES (WS)

Responsible lecturer: Prof. Dr. Björn Eskofier, Prof. Dr. Oliver Amft
Lehrstuhl für Maschinelles Lernen und Datenanalytik (MaD)
ECTS: 5
Course type and weekly hours: lecture (2 hours), exercise class (2 hours)
Exam type: oral exam (30 min.)
FAU Modul Catalog: 2

**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 toolboxes 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

## DEEP LEARNING (WS)

Responsible lecturer: Prof. Dr.-Ing. Andreas Maier
Chair of Computer Science 5 (Pattern Recognition)
ECTS: 5
Course type and weekly hours: lecture (2 hours), exercise class (2 hours)
Exam type: oral exam (30 min.)
FAU Modul Catalog: 2

**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)

- weekly 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

## 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-omicdata 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

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 omicdata and master principles on how to learn from heterogeneous multi-omic data.

**Literature:** /

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

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

## HMDA Common Core continuation:

### PATTERN ANALYSIS (SS)

Responsible lecturer: Prof. Dr.-Ing. Andreas Maier
Chair of Computer Science 5 (Pattern Recognition)
ECTS: 5
Course type and weekly hours: lecture (3 hours), exercise class (1 hour)
Exam type: oral exam (30 min.)
FAU Modul Catalog: 2

**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

# Innovation and Entrepreneurship 2 (10 ECTS)

## TECHNOLOGY AND INNOVATION MANAGEMENT (SS)

Responsible lecturer: Prof. Dr. Kai-Ingo Voigt
Chair of Business Administration (Industrial Management) (Prof. Dr. Voigt)
ECTS: 5
Course type and weekly hours: lecture (attendance: 45h, self-study: 105h)
Exam type: tbd
FAU Module Catalog: 7

**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:** t.b.d.

## SERVICE INNOVATION (SS)

Responsible lecturer: Prof. Dr. Kathrin Möslein
Chair of Information Systems I, Innovation and Value Creation (Prof. Dr. Möslein)
ECTS: 5
Course type and weekly hours: seminar (contact hours: 30h, independent study: 120h)
Exam type: Written assignments
FAU Module Catalog: 7

**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 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 specialties 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

## FUNDAMENTALS IN ANATOMY AND PHYSIOLOGY FOR ENGINEERS (ANATOMY & PHYSIOLOGY) (SS)

Responsible lecturer: Dr. med. Benedikt Kleinsasser, Prof. Dr. med. Friedrich Paulsen, Prof. Dr. Michael Eichhorn, Prof. Dr. Clemens Forster
Chair of Anatomy II (Prof. Dr. Paulsen)
ECTS: 5
Course type and weekly hours: lecture (2 hours)
Exam type: /
FAU Modul Catalog: 1

**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.

## MEDICAL BIOTECHNOLOGY (SS)

Responsible Lecturer: Oliver Friedrich
Chair of Medical Biotechnology
ECTS: 5
Course type: lecture (3 hours/week) + exercise (1 hours/week)
Exam type: written exam (120minutes)
FAU Modul Catalog: 1

**Contents:**

Focus on scientific procedures, techniques and technologies:

- cellular ion channels (patch clamp, voltage clamp)
- molecular, dynamic protein interactions (molecular motors, motility assays)

- muscle performance diagnostics, biomechanical/biomechatronics procedures
- cellular fluorescence microscopy, multiphoton microscopy, image processing of cellular image data, information extraction, cell signalling
- methods to estimate muscle performance and training
- cellular mechanisms of malaria and malaria biotechnology
- high pressure bioscience and biology of excitable cells, high pressure biotechnology
- prosthetics of the musculo-skeletal apparatus

- Methods of intraoperative monitoring and telemetry
- Development of alternatives for animal experiments for industrial applications

**Learning objectives and competencies:**

- analyse specific questions within the topics and to apply the appropriate technologies to answer scientific problems by dissecting sub-solutions and develop process-oriented strategies
- extract evidence-based information and contexts from scientific publications related to a focussed problem within the topics, to transfer the concepts to more general questions in the field and to assess advantages and limitations of techniques
- develop strategies for the conception of new and combined processes within the discussed topics
- aquire and apply soft skills (UE); to independently extract information from specialised scientific papers and to prepare the contents in a short-presentation in front of the course group
- evaluate and assess experimental results in scientific publications and to critically question conclusions drawn from experiments

**Literature: /**

## LAB CLASS ON MEDICAL PHYSICS IN RADIATION THERAPY (SS)

Responsible Lecturer: Christoph Bert
Chair of Radiation Therapy
ECTS: 5
Course type: exercise (2 hours/week)
Exam type: tbd
FAU Modul Catalog: 1

This lab class can only be taken if the introductory lecture "Introduction to medical physics in radiation therapy" has been passed successfully.

**Content:**

The lab class consists of 5 lab sessions using the medical devices of the Department of Radiation Oncology of the University Clinic (Strahlenklinik, Universitätsklinikum Erlangen). The devices (medical linear accelerator, imaging such as CT or MRT, quality assurance equipment, …) are used for patient treatment each day. In the lab (typically starting late afternoon due to the patient treatments) the devices will be used to perform typical workflows and/or quality assurance procedures. Each lab session is performed in a group of 2-3 students.

**Learning objectives and competencies:**

Students …

- … operate medical devices such as linear accelerators or CTs to acquire data as part of quality assurance routines or of phantoms
- … analyse the measured data by applying the knowledge they gained by preparing for the lab and/or the lecture of MEDPHYS-I
- … report their findings in a structured lab report

**Literatur:**

Hoisak et al. Surface Guided Radiation Therapy, CRC Press AAPM Task Group 142 report: Quality assurance of medical accelerators (2009) INTERNATIONAL ATOMIC ENERGY AGENCY, Absorbed Dose Determination in External Beam Radiotherapy: An international Code of Practice for Dosimetry Based Standards of Absorbed Dose to Water, Technical Reports Series No. 398, IAEA, Vienna (2000) Schlegel, Karger, Jäkel: Medizinische Physi, Springer 2018.

## SPECIAL TOPICS OF MEDICAL PHYSICS IN RADIATION THERAPY (SS)

Responsible Lecturer: Christoph Bert
Chair of Radiation Therapy
ECTS: 2,5
Course type: lecture (2 hours/week)
Exam type: written exam (60 minutes)
FAU Modul Catalog: 1

**Content:**

The lecture within the module focuses on special subjects of medical physics in radiation oncology. Among them are management of organ motion (focusing on respiratory motion) in imaging and treatment, brachytherapy, i.e. treatment based on sealed radioactive materials that are inserted into/close to the target volume, and ion beam therapy, i.e. the treatment using protons or carbon ions which required a dedicated infrastructure w.r.t. treatment delivery but also treatment planning.

**Learning objectives and competencies:**

Students can…

- can explain the main challenges related to organ motion in planning and delivery of radiation therapy
- can explain and sketch the main technical and medical physics workflow of an ion beam therapy
- transfer the knowledge gained of organ motion in photon therapy to ion beam therapy
- report the workflow and the medical physics principles of brachytherapy

**Literatur: /**

## ADVANCES IN MEDICAL SYSTEMS BIOLOGY (SS)

Responsible Lecturer: Prof. Dr. Julio Vera-Gonzalez
ECTS: 2,5
Course type: seminar (3 hours/week)
Exam type: written exam (30minutes)
FAU Modul Catalog: 1

**Content:**

In this subject the students will be introduced to new approaches in medical systems biology. Medical systems biology aims to simulate, to analyse and to discuss biomedical mathematical models. This is a multidisciplinary approach to understand biomedical systems. The following skills are expected from a student that has accomplished this subject.

- Literature research and discussion as well as performing a critical view of a topic.
- The ability to summarize and simplify broad biological information into a theoretical framework.
- To create and to simulate a mathematical model.
- To discuss the results from an in silico exercise and conclude biological insights from the model.

We evaluate these skills applying the principles of learning-by-doing.

**Learning objectives and competencies:**

The students are faced to a real problem in biomedicine that they should solve and discuss in a report. The following learning goals should be satisfied to perform this exercise.

- Learning the basic concepts of molecular biology.
- Understanding the principles of systems biology and mathematical modeling.
- Applying the concepts of molecular biology to a specific biomedical problem to propose a theoretical framework.
- Analyse a real problem in biomedicine and propose a workflow to solve it.
- Evaluate the literature to enrich the biomedical knowledge of the theoretical framework.
- Create a mathematical model out of the theoretical framework to solve a biomedical problem

**Literature: /**

# Master's electives (20 ECTS)

**5 ECTS** to be chosen from the seminar catalogue. (FAU Modul Catalog 4: "Advanced Seminar Medical Engineering")

Further information, M4:
https://www.medizintechnik.studium.fau.de/files/2020/12/mt_seminarkatalog_allefpos_aktuell.pdf

**5 ECTS** to be chosen from the FAU modul Catalogs M8 “Free Choice Uni”
**10 ECTS** to be chosen from the FAU modul Catalogs M5 “Medical Engineering Specialisation Modules”Further information, M5 & M8:
https://www.medizintechnik.studium.fau.de/files/2020/12/ma_mt_modulecatalog_hmda_fpo-2019_aktuell.pdf

**The following modules represent an example of selectable option.**

## MEDICAL IMAGING SYSTEM TECHNOLOGY (SS)

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. Overtime, 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:**

- know the basics of physics and technology of X-ray systems, nuclear medical imaging, sonography, X-ray computer tomography and magnetic resonance technology.
- can describe and explain the functioning of medical imaging systems.
- are familiar with the application spectrum and can discuss advantages and disadvantages of the various modalities.

**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

## VOICE-ENABLED HEALTHCARE (WS & SS)

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

**Contents**:
Voice recognition, speech synthesis, sentiment analysis and natural language processing are groundbreaking technologies for improved human machine interactions. This seminar intends to give students the opportunity to get in touch with the latest technologies in this space and venture out on a literature review or prototype building journey to improve healthcare applications. The seminar features a lecture part where participants are introduced to the algorithmic background of voice and natural language processing. You are enabled to analyze literature and / or develop own prototypes of voice-enabled healthcare applications. Potential fields of application include e.g. voice-controlled interventional devices and sentiment analysis for psychiatric diseases.

**Learning outcomes and competencies:**

- Understand science of voice recognition and natural language processing
- Understand medical human interactions and medical needs
- Analyze combinations of voice technologies and potential applications in medicine
- Algorithmic background of voice recognition and NLP
- Literature analysis and prototype building
- Advanced knowledge: Medical technology
- Basic knowledge: Medicine

**Literature: /**

## HUMAN COMPUTER INTERACTION (SS)

Responsible lecturer: Prof. Dr. Björn Eskofier, Wolfgang Mehringer
Lehrstuhl für Maschinelles Lernen und Datenanalytik (MaD)
ECTS: 5
Course type and weekly hours: lecture (3 hours), exercise class (1,5 hour)
Exam type: written exam (90 min.)
FAU Modul Catalog: 5

**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

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

## Innovation and Entrepreneurship 3 (10 ECTS)

### THE HMDA´S SCHOOL ON LEARNING FROM HEALTH DATA

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:**
With its yet unfulfilled promise to revolutionize the healthcare economy and save billions of euros in the process, Artificial Intelligence (AI) and health data management in general are exploding in popularity. Indeed, the growth of the global AI health market is expected to reach US$6.6 billion by 2021.

But can AI and data-driven technologies truly live up to expectations in the field of health?

Over 5 demanding days at this exciting bioHealth Computing school, graduate students (Master & PhD) and early career professionals in science, informatics and healthcare are immersed in a challenging mix of theoretical and practical sessions on AI technology and innovation and coached to develop business models of market-acceptable products and services using AI technologies.

*Learning from Health Data* is an accelerated learning programme proposed by a consortium of EIT-Health partner universities and co-organised by the Université Grenoble-Alpes and ESI-Archamps.

The school is fully in line with EU goals to deliver innovation-led solutions enabling European citizens to live longer, healthier lives. The school adheres to the 2030 Agenda for Sustainable Development of the UN, and in particular to the objectives of the UHC2030 programme whose mission is to create a movement for accelerating equitable and sustainable progress towards universal health coverage (UHC).

The application form includes a section where candidates should provide a 50 to 200-word outline of an innovative idea or project related to health and medical data analytics. This might be expressed in terms of:

- An unmet need in healthcare which could benefit from the development of data-driven products or services.
- The (re)deployment of an existing technology to provide an innovative product or service for healthcare.
- A currently unavailable but potentially marketable product or service involving data-driven technology for healthcare.

The best ideas may serve as the basis for a group project in the Business Development & Innovation component of the school.

**Learning outcomes and competencies:**
Students can

- 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.
- develop world-class solutions in the field of IT and health technologies, address societal challenges, contribute to the competitiveness of Europe,
- focus on unmet needs in healthcare, AI candidate technologies, experienced-based co-design, business creation, health assessment and regulatory affairs.
- participate a series of advanced courses and hands-on activities on IT proposed by experts from partner universities, hospitals, and industries. One breakout session on advanced application in health
- will examine several uses of machine learning, big data and internet of things presented by leaders in Health Research and Development, reviewing the latest techniques.
- develop innovative ideas in multidisciplinary teams translating them into value creation through a business model and under the health regulation framework.

## INNOVATION LAB FOR WEARABLE AND UBIQUITOUS COMPUTING (WS & SS)

Responsible lecturer: Prof. Dr. Björn Eskofier
ECTS: 10
Course type and weekly hours: internship (4 hours)
Exam type: internship, graded certificate
FAU Modul Catalog: 6

**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: /**

## THE AMOS PROJECT (SS)

Responsible lecturer: Prof. Dr. Dirk Riehle
Professur für Open Source Software
ECTS: 10
Course type and weekly hours: lecture (2 SWS) & exercise
Exam type: /
FAU Modul Catalog: 6

**Contents:**

- Agile methods and related software development processes
- Scrum roles, process practices, including product and engineering management
- Technical practices like refactoring, continuous integration, and test-driven development
- Principles and best practices of open source software development

The project is a software development project in which student teams work with an industry partner who provides the idea for the project. This is a practical hands-on experience. Students can play one of two primary roles:

- Product owner. In this function, a student defines, prioritizes, communicates, and reviews requirements. The total effort adds up to 5 ECTS.
- Software developer. In this function, a student estimates their effort for requirements and implements them. The total effort adds up to 10 ECTS.

Students will be organized into teams of 5-7 people, combining product owners with software developers. An industry partner will provide requirements to be worked out in detail by the product owners and to be realized by the software developers. The available projects will be presented at the beginning of the course.

**Learning Outcomes:**

- Students learn about software products and software development in an industry context
- Students learn about agile methods, in particular, Scrum and Extreme Programming
- Students learn about open source software development and its underlying principles
- Students gain practical hands-on experience with a Scrum process and XP technical practices

**Literature: /**

## PROJECT BIOMEDICAL NETWORK SCIENCE (WS & SS)

Responsible Lecturer: Prof. Dr. David B. Blumenthal
Juniorprofessur für Daten, Sensoren und Geräte / Digitale Transformation
ECTS: 10
Course type and weekly hours: Project Seminar (4r hours/week)
Exam type: Working prototype of a software tool (40% of grade), 20 min demonstration with the lecturers (20% of grade) and a short scientific paper which describing the developed methodologies (40% of grade, 4 pages ACM style excluding references).
FAU Modul Catalog: 6

**Content:**
The Biomedical Network Science (BIONETS) lab investigates molecular disease mechanisms using techniques from combinatorial optimization, network science, and artificial intelligence. We also develop privacy-preserving decentralized biomedical AI solutions, which enable cross-institutional studies on sensitive data. Students will work on individual research topics within these field and develop prototypes of software tools to solve the addressed problems.

**Competences & Learning Outcomes:**

Students will …

- develop and implement an algorithm for a problem within the field of biomedical networks science which, in certain respects, improves upon the state-of-the-art,
- acquire hands-on experience in an emerging research field,
- learn best practices in software development and documentation,
- gain first experience in academic writing.

**Literatur:**
All relevant research literature will be made available in StudOn

## PROJECT REPRESENTATION LEARNING (WS & SS)

Responsible Lecturer: Prof. Dr. Bernhard Kainz
Professur für Daten, Sensoren und Geräte
ECTS: 10
Course type: tbd

**Content:**
Different projects in the area of (deep) representation learning are on offer. These reach from theoretical exploration of new data representation methods to practical evaluation of applications in, e.g., medical image analysis. Example projects will be made available on the website of the chair for health data science. Students may also propose their own projects, which will be coordinated and refined with the module lead during preliminary discussions.

# HMDA Specialization (20 ECTS)

## WEARABLE AND IMPLANTABLE COMPUTING (WS & SS)

Responsible lecturer: Prof. Dr. Oliver Amft
Lehrstuhl für eHealth/mHealth
ECTS: 5
Course type and weekly hours: lecture (2 hours), exercise class (2 hours)
Exam type: written exam (60 min.)
FAU Modul Catalog: 3

**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-attachable 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

## BIOMEDICAL SIGNAL ANALYSIS (WS)

Responsible lecturer: Prof. Dr. Björn Eskofier
Lehrstuhl für Maschinelles Lernen und Datenanalytik (MaD)
ECTS: 5

Course type and weekly hours: lecture (2 hours), exercise class (2 hours)
Exam type: written exam (90 min.)
FAU Modul Catalog: 3

**Contents:**
The lecture content explains and outlines (a) basics for the generation of important bio signals of the human body, (b) measurement of bio signals, and (c) methods for bio signals analysis. Considered bio signals 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 bio signals of the human body.
- recognize relations between the generation of bio signals and the measured signal.
- understand the importance of bio signal analysis for medical engineering.
- analyze and provide solutions to the key causes for artifacts in bio signals.
- 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 bio signal 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.

## DIAGNOSTIC MEDICAL IMAGE PROCESSING (WS & SS)

Responsible Lecturer: Prof. Dr.-Ing. Andreas Maier
Virtuelle Hochschule Bayern (VHB)
ECTS: 5
Course type and weekly hours: online course (2 hours) and online exercises (2 hours)
Exam type: written exam (60 min.)
FAU Modul Catalog: 3

**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: /**

## INTERVENTIONAL MEDICAL IMAGE PROCESSING (WS & SS)

Responsible Lecturer: Prof. Dr.-Ing. Andreas Maier
Virtuelle Hochschule Bayern (VHB)
ECTS: 5
Course type and weekly hours: online course (4 hours)
Exam type: written exam (60 min.)
FAU Modul Catalog: 3

**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: /**

## VISUAL COMPUTING IN MEDICINE (WS & SS)

Responsible Lecturer: PD Dr.-Ing. Peter Hastreiter
Chair of Computer Science 9 (Computer Graphics)
ECTS: 5
Course type and weekly hours: online course (4 hours)
Exam type: oral exam (30 min.)
FAU Modul Catalog: 3

**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 KaufmannVerlag, 2007
- H. Handels: Medizinische Bildverarbeitung, Bildanalyse, Mustererkennung und Visualisierung für diecomputergestützte 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

# 2nd year, 2nd semester (spring/summer semester)

## 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.

As FAU student, please check the information under this link:
https://www.medical-engineering.study.fau.eu/current-students/thesis-paper/

www.eithealth.eu

## Authors

Dr. Felix Schmutterer FAU

Daniel Garza Reyna FAU

Mariana Mejica FAU