**Preliminary Module Description**

Master Artificial Intelligence for Smart Sensors & Actuators

# Modules in the 1st Semester

## Module 1 – Intelligent Systems

MKI11 – Introduction to Artificial Intelligence (2 SWS, 2 CP)

This module elaborates on the fundamental AI concepts and establishes the correlation to intelligent sensor/actuator systems.

- definition AI
- historical Summary
- AI within the process of knowledge management
- software agents
- expert systems
- applications in intelligent sensor/actuator systems
- selection of current publications
- limits of AI

MKI12 – Machine Learning and Deep Learning (4 SWS, 4 CP)

This module introduces Machine Learning. Correspondingly, this module presents a wide spectre of methods ranging from linear models to deep neural networks.

- Fundamentals: prognoses, correlation and causality
- Data collection, data processing and Exploratory Data Analysis
- Operating principle of selected models:
    - linear regression including Maximum Likelihood Estimation, derivation of the error function and derivation of Gradient Descent
    - Feature Space: Feature Engineering and dimensional reduction (principal component analysis)
    - evaluation and tuning of models: selection of metrics, Overfitting/Underfitting, optimisation of hyper parameters
    - Naive Bayes
    - decision trees
    - k-means clustering
- Neural Networks:
    - training with backpropagation
    - selection of a suitable architecture
    - comparison to other (traditional) models
    - efficient training on GPUs
- Applications in intelligent sensor/actuator systems

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# Module 2 – Smart Sensors and Actuators

MKI21 – Microsystems and Physical Crosscoupling (4 SWS, 4 CP)

This module establishes the fundamental interactions between the different physical areas (domain) of mechanics, thermodynamics as well as electromagnetism. As a result, smart sensor and actuator technology is deduced.

- intensive and extensive dimensions of physics
- crystalline structures
- thermodynamic base equations
- mechanical base equations
- electromagnetical base equations
- tensorial dimensions and cross coupling
- microsystems technology
- MEMS sensors
- MEMS actuators

MKI22 – Data Acquisition and Control (4 SWS, 4 CP)

This module illustrates the conceptual signal paths ranging from the raw signal acquisition of sensory input variables to the functional use of AI-based software modules.

- sensory raw signal acquisition
- signal processing
- wireless and grid-bound signal transmission
- electronical µC input structures for the analogue/digital conversion
- A/D conversion by means of successive approximation
- the Delta-sigma modulation
- control strategies for smart sensors
- pilot-control strategy for smart actuators
- electronical power stages for PWM (Pulse-width modulation)
- H-bridge

# Module 3 – Case Study Sensors and Actuators

MKI31 – Case Study Sensors and Actuators (4 SWS, 6 CP)

This case study takes up current case examples related to the application of smart sensors and actuators. Furthermore, students are given the opportunity to deal with these topics independently and creatively.

Working Methods

- Literature research

- Simulations
- Application of evaluation techniques

The case studies are tested as a so-called student research report instead of a classical written examination.

## Module 4 – Embedded Control Solutions

MKI41 – Microcontroller Architectures (2 SWS, 2 CP)

This module examines microcontroller architectures in view of their features for signal processing and the creation of actuator signals. The following topics are treated:

- Computer architecture/ instruction sets (RISC, CISC)
- Internal function units
- Real-time characteristics

MKI42 – Modell-Based Function Engineering (4 SWS, 4 CP)

The construction of complex technical systems or products requires a systematic approach, which can be supported decisively by the application of models in the product lifecycle.

Relevant topics include:

- Models in the product lifecycle
- Process descriptions
- Introduction and application of SysML as a formal modelling language
- Integration of modelling tools (e.g. Matlab) into the development process

## Module 5 – Case Study Embedded Control Solutions

MKI31 – Case Study Embedded Control Solutions (4 SWS, 6 CP)

This case study takes up current case examples related to the application of embedded control systems and their application within the area of AI. Furthermore, students are given the opportunity to deal with these topics independently and creatively. Edge Computing, for instance, is a potential topic focused upon.

Working Methods

- Literature research
- Simulations
- Application of evaluation techniques

# Modules in the 2nd Semester

## Module 6 – Advanced Intelligent Systems

MKI61 – Big Data (4 SWS, 4 CP)

This module introduces how to save and process big data quantities efficiently within the context of intelligent sensor/actuator systems.

Fundamentals: 3 Vs, historical summary of Big Data, selected applications of Big Data
- Fundamentals of databases: ER diagrams, relational databases, database management systems, enquiries, indices, normalisation, transactions
- Big Data architectures: distributed systems, MapReduce, CAP theorem, acceleration by GPUs and FPGAs
- Big Data, Small Data, All Data: data quality, Biase in Big Data, Small Sample Size issues
- Infrastructures, frameworks, libraries and tools of Big Data selected
- Cloud Computing and Edge Computing
- Applications in intelligent sensor/actuator systems

MKI62 – Computer Vision (2 SWS, 2 CP)

This module explains how computer image and video data is processed so we can see it.

Fundamentals: representations of images and videos

- Pre-processing of data using filters
- Determination of features
- Segmentation
- Convolutional Neural Networks (CNNs)
- Selection of current CNN architectures
- Applications in intelligent sensor/actuator systems

## Module 7 – Case Study Intelligent Systems

MKI71 – Case Study Intelligent Systems (4 SWS, 6 CP)

On the basis of an application example, in groups, students independently work on a coherent tasks taken from the area of intelligent sensor and actuator systems in order to practise the content of previous or parallel lectures on the area of intelligent systems. Contributions from industry experts can deepen special topics further.

**Preliminary Module Description**

Master Artificial Intelligence for Smart Sensors & Actuators

# Module 8 – Autonomous Systems

MKI81 – Algorithms of Autonomous Systems (4 SWS, 4 CP)

This module presents the fundamental algorithms in terms of the development of autonomous mechatronic & cyber-physical systems. Application does not only focus on operating autonomous vehicles as well as autonomous robotics but also encompasses the areas of industrial production, smart home, application in environments damaging to humankind, medical technology, agriculture, energy production and distribution. This results in several relevant subject areas, such as:

- Modelling of dynamic systems
- innovative automation methods
- Machine Learning
- Optimisation methods
- Mapping and navigation
- Sensor fusion

MKI82 – Autonomous Robotics (4 SS, 4 CP)

This module addresses on the application of autonomous systems relevant to the industry and delves further into the content of mobile and collaborative robotics.

Relevant subject areas:

- 3D obstacle and object recognition
- Real-time image processing
- Cognitive systems
- Specific application of Machine Learning

# Module 9 – Case Study Autonomous Systems

MKI91 – Case Study Autonomous Systems (4 SWS, 6 CP)

On the basis of an application example selected, students need to conduct literature research and, if applicable, independently work on the topic with small sub-tasks. Within an introductory part, the over-arching topic will be explained and sub-tasks defined.

Example: Autonomous Driving

- Features of necessary networked systems
- Aspects of functional safety for autonomous vehicles
- Sensor/actuator technology for the vehicle control system
- Autonomous driving and mobility concepts

- (legal/ organisational framework conditions )
- ……
- The case studies are tested as a so-called student research report instead of a classical written examination.

# Module 10 – FWP Module

M101 – FWP subject (4 SWS, 4 CP)

Selection from a subject catalogue based on related studies at the DIT as well as subjects provided by the Virtual University of Bavaria (VHB), for instance.

- Advanced Modelling and Simulation (MMC)
- Data Security and Data Protection (Master Medical Informatics)
- Collaborative Systems (Master Medical Informatics)

# Modules in the 3rd Semester

## Module 11 – System Design

MKI111– Systems Design (2 SWS, 2 CP)

The module "System Design" provides insight into the organizational and technical approaches to develop sensor systems starting with the customer requirements and project setup through system design and requirement monitoring up to the realization of the system, including proof of fulfillment of functional and reliability requirements. Customer requirements as well as production capabilities are the basis of the requirements definition process.

Based on the actual system development process of major sensor producing companies, the students shall gain an in-depth knowledge of the complete system design process. After completion of this module, the student has achieved the following learning objectives:

**Professional competence:**

- Understand requirements management as basis of customer -oriented and capability-driven system development
- Understand basic requirements and methods of functional safety for sensors in specific fields of application
- Understand system concept and circuit design
- Understand methods of planning and verifying system functionality and reliability performance

**Methodological competence:**

- Knowledge of roles and responsibilities within a technically oriented project team
- Setting, monitoring and realization of project objectives
- Ability to understand and phrase requirements and transfer those into a data sheet (exercise)

MKI112– Systems Intercommunication (4 SWS, 4 CP)

Content key points:

- system networking/ system fusion
- construction and operating principle of prompt, serial communication systems
- cyber security

# Module 12 – Master Module

MKI121– Master Thesis (22 CP)

completion of the master thesis

MKI122– Master Seminar (2 CP)

Master Seminar