Module Guide
Künstliche Intelligenz für smarte Sensorik / Aktorik

Faculty Applied Natural Sciences and Industrial Engineering
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Table of Contents

MKI-1 Intelligent Systems

Module code	MKI-1
Module coordination	Prof. Jürgen Wittmann
Course number and name	MKI11 Introduction to Artificial Intelligence MKI12 Machine Learning and Deep Learning
Lecturers	Prof. Dr. Christina Bauer Prof. Dr. Roland Platz Prof. Jürgen Wittmann
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	6
ECTS	6
Workload	Time of attendance: 90 hours self-study: 90 hours Total: 180 hours
Type of Examination	written ex. 120 min.
Duration of Examination	120 min.
Weight	6 out of 90 ECTS
Language of Instruction	English

Module Objective

Artificial Intelligence (AI) is a general term that describes the combination of all necessary methodological and technological tools needed for autonomous systems, such as autonomous vehicles or robots. This course gives an overview about what AI is, its historical background, what AI can do, and cannot do. At the end of the course, the students will be able to distinguish between methodological concepts and tools about how autonomous systems gain knowledge, evolve reasoning, and keep learning.

In the module **"Intelligent Systems"**, basic concepts of artificial intelligence are explained and the connection to intelligent sensor/actuator systems is established. Students are introduced to machine learning and deep learning as sub-fields of artificial intelligence. They are able to evaluate and select the best solution / approach regarding artificial intelligence for a specific application.

Upon completion of this module, the student has achieved the following learning objectives:

Professional competence:

- understanding history approaches and methods of artificial intelligence in general
- understanding various methods of machine learning
- understanding modelling and applying of deep learning to various fields of application

Methodological competence:

- application of different data collection and preprocessing methods
- application of various machine learning techniques, such as regression
- setting up deep learning models including various numbers of layers and hyperparameters

Personal competence:

- The module Intelligent Systems teaches students how to solve complex tasks and problems in establishing and application of artificial intelligence in products and systems
- The students learn how to analyze and evaluate a problem and how to apply artificial intelligence to solve it

Social competence:

- Students are able to reflect on the requirements in the field of intelligent systems and transfer them to relevant application scenarios.

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and transfer possibility for the application of artificial intelligence in different systems and applications, specifically in sensors and actuators. Interfaces to mechatronics, electrical engineering and computer engineering.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field

Learning Content

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

- definition AI
- historical background
- AI within the process of knowledge management
- software agents
- knowledge managment & expert systems
- applications in intelligent sensor/actuator systems for Mechanical Engineering
- selection of current publications
- limits of AI
- logic
- reasoning with uncertainty
- reinforcement learning
- neural networks

Furthermore, 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

Teaching Methods

- Seminar-like teaching with joint exercises as well as presentations to deepen the knowledge achieved through application

- i-Learn (online learning platform)

Recommended Literature

Trevor Hastie, Robert Tibshirani, Jerome Friedman (2009): The Elements of Statistical Learning, Springer, New York

Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani (2017): An Introduction to Statistical Learning: with Applications in R. Springer, New York

Thomas Dean, James Allen, Yiannis Aloimonos, "Artificial Intelligence: Theory and Practice", Addison Wesley

Stuart Russel, Peter Norvig, "Artificial Intelligence - a modern approach", Prentice Hall New Jersey

MKI-2 Smart Sensors and Actuators

Module code	MKI-2
Module coordination	Prof. Jürgen Wittmann
Course number and name	MKI21 Microsystems and Physical Crosscoupling MKI22 Data Aquisition and Control
Lecturers	Dr. Tim Weber Prof. Jürgen Wittmann
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	6
ECTS	6
Workload	Time of attendance: 90 hours self-study: 90 hours Total: 180 hours
Type of Examination	written ex. 120 min.
Duration of Examination	120 min.
Weight	6 out of 90 ECTS
Language of Instruction	English

Module Objective

The module **"Smart Sensors and Actuators"** introduces to sensor/actuator technology starting from the crystal through various semiconductor manufacturing disciplines such as lithography or etch up to integration to complete devices. It also focuses on various sensor principles for the conversion of signals of different physical domains into an electrical sensor output, e.g. magnetic-electric conversion. These fundamental aspects are the composed to smart sensor and actuators.

In addition, 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.

Upon completion of this module, the student has achieved the following learning objectives:

Professional competence:

- Crystal growth and properties including impact on devices
- Manufacturing technology of MEMS sensor/actuators
- Sensor technology and sensor principles
- Understanding of smart sensors & actuators
- Signal processing
- Feature extraction, processing & statistical evaluation of data
- Sensor Reliability

Methodological competence:

- understanding the interdependencies of technology with product performmance
- understanding the principles and limitations of sensors and actuators
- discussion of intelligence as part of sensor/actuator design
- understand analogue and digital sensor signals including respective signal processing

Personal competence:

- analysis and discussion of technical issues in production and operation of sensors and actuators
- students learn what to focus on when evaluating or selecting a sensor
- students learn limits and opportunities of various sensor interfaces (e.g. PWM) and various signal processing techniques

Social competence:

- The students use their competences acquired in the lectures and are able to discuss advantages and disadvantages of various sensor technologies and principles as well as the respective signal processing

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and transfer possibility for the application of sensors and actuators in various application scenarios. It creates interfaces to courses of study such as mechatronics, computer science or electrical engineering.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field

Learning Content

This module establishes the fundamental technology aspects as well as interactions between the different physical areas (domain), e.g. the conversion from non-electrical to electrical signals:

- crystal technology, structures and properties
- microsystems manufacturing technology
- integration technology
- sensor principles & signal conversion
- MEMS smart sensors and actuators
- Sensor Reliability

Furthermore, 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.

- data types and short introduction to data
- sensory raw signal acquisition including images and data from various sources
- signal processing and signal featur 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
- Kalman Filter
- statistical concepts to evaluate data (parameter space, design of experiments)
- feature extraction from data for further use in AI and machine learning

Teaching Methods

- Seminar-like teaching with joint exercises as well as presentations to deepen the knowledge achieved through application
- i-Learn (online learning platform)

Recommended Literature

Klös, A. "Nanoelektronik - Bauelemente der Zukunft", Hanser, 2018

Ohring, M. "Reliability and Failure of Electronic Materials and Devices, Academic Press, 2014

Czichos, H. "Measurement, Testing and Sensor Technology", Springer International Publishing, 2018

MKI-3 Case Study Sensors and Actuators

Module code	MKI-3
Module coordination	Prof. Jürgen Wittmann
Course number and name	MKI31 Case Study Sensors and Actuators
Lecturer	Prof. Jürgen Wittmann
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	6
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written student research project
Weight	6 out of 90 ECTS
Language of Instruction	English

Module Objective

The case study **"Sensors and Actuators"** 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. The intention of this case study is to introduce the students to a practical and industry-oriented way of technical problem solving.

Upon completion of this module, depending on a more theoretical or more practical focus, students will be able to identify limitations and opportunities of sensors and actuators in their specific field of application.

Professional competence:

- in depth knowledge of a specific subarea of sensors, actuators or the respective technology

- practical experience in construction and set up of sensor/actuator systems
- knowledge and practical experience in sensor/actuator performance evaluation

Methodological competence:

- Students are able to execute a literature search in a specific sensor or actuator related subarea
- Students are able to evaluate and assess sensor principles for specific fields of application

Personal competence:

- Case Study Sensors and Actuators teaches students how to solve complex tasks in teams with distributed task areas. The students learn to analyse, synthesise and evaluate a task in relation to smart sensors and actuators in an application-related manner.
- Students are required to present the progress of their respective project in regular meetings

Social competence:

- The students are able to consider questions in the area of smart sensors and actuators on the basis of case studies and to deepen their competences acquired in the module in group work and to use them in a prepared manner.
- The students are able to consider the problems from different perspectives and to use their competences acquired in the module appropriately and situation-based in individual and group discussions.

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and the transfer capability to gain a deeper understanding of sensor/actuator principles and the capability to apply and to evaluate sensors/actuator in and for a specific area of application. This creates interfaces to courses of study such as mechanical engineering, mechatronics, electrical engineering.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field

Learning Content

On the basis of a selected application example, the students should explore and work on the topic themselves by means of literature research, independent sub-tasks, etc. The topics of the case studies can be chosen from any subject area.

The topics of the case studies can vary each semester.

Teaching Methods

- Literature research
- Simulations
- Construction
- Application of evaluation techniques
- Guided work on seminar topics in working groups. Accompanying events / presentations by external speakers depending on the selected topic area

Remarks

The case studies are examined as a so-called "Prüfungsstudienarbeit" (student research report) and are therefore not a classic examination.

The theoretical knowledge acquired by the students is specifically applied in practice in the case study topics so that students analyse problems independently and apply proposed solutions. This intensifies the transfer of knowledge into practice and the targeted deepening of the acquired technical and methodological competences by recognising connections and evaluating them.

Recommended Literature

Rupitsch, S. "Piezoelectric Sensors and Actuators: Fundamentals and Applications", Springer, 2018

Gusev, E. et al. "Advanced Materials and Technologies for Micro/Nano Devices, Sensors and Actuators", Springer, 2010

Klös, A. "Nanoelektronik - Bauelemente der Zukunft", Hanser, 2018

Ohring, M. " Reliability and Failure of Electronic Materials and Devices", Academic Press, 2014

Czichos, H. "Measurement, Testing and Sensor Technology", Springer International Publishing, 2018

MKI-4 Embedded Control Solutions

Module code	MKI-4
Module coordination	Prof. Jürgen Wittmann
Course number and name	MKI41 Microcontroller Architectures MKI42 Model Based Function Engineering
Lecturers	Prof. Dr. Robert Bösnecker Prof. Dr. Roland Platz
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	6
ECTS	6
Workload	Time of attendance: 90 hours self-study: 90 hours Total: 180 hours
Type of Examination	written ex. 120 min.
Duration of Examination	120 min.
Weight	6 out of 90 ECTS
Language of Instruction	English

Module Objective

The module **"Embedded Control Solutions"** examines microcontroller architectures in view of their features for signal processing and the creation of actuator signals. In addition, 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.

Model based Function Engineering focus is put on the importance of a systematic approach for a successful design of complex technical systems. Virtual conceptual models support and evaluate the design process in all stages in the product life cycle - from the first idea to serial production. This course introduces the modeling of the main design stages, such as definition and specification, concept, optimization via verification, design, realization and test via validation. The course further discusses conceptual approaches to evaluate uncertainty and reliability of the product design. Computational tools like SysML and Matlab support the modeling process.

Upon completion of this module, the student has achieved the following learning objectives:

Professional competence:

- understanding microcontroller architectures in view of their features for signal processing
- understand virtual conceptual modeling tools in the design process
- understand the complete product design process from a modeling perspective

Methodological competence:

- apply microcontroller signal processing in real systems and learn to create actuator signals
- apply computational tools like SysML and Matlab to support the modeling process
- use and apply design relevant methods, such as Design of Experiments (DoE)

Personal competence:

- The studens learn, how to analyze and evaluate a task in relation to microcontroller and microcontroller architectures
- They understand and learn to apply modeling methods in the design process

Social competence:

- Students are able to reflect on the requirements in the field of embedded control solutions and transfer them to relevant application scenarios.

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and transfer possibility for microcontroller architectures and model based function engineering. Interfaces to mechatronics, electrical engineering and computer engineering.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field

Learning Content

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

In addition, 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:

- definition of the product lifecycle
- description and virtual models of stages and processes in the Product Life Cycle
- applicable software as modeling language and virtual design tools
- identification, quantification and evaluation of data and model uncertainty
- design of experiments (DoE)
- statistical evaluation of failure and functional degradation
- reliability evaluation tools like Prognostics and Health Management (PHM), Failure Mode and Effects Analysis (FMEA), Functional Safety, etc.

Teaching Methods

- Seminar-like teaching with joint exercises as well as presentations to deepen the knowledge achieved through application
- i-Learn (online learning platform)

MKI-5 Case Study Embedded Control Solutions

Module code	MKI-5
Module coordination	Prof. Jürgen Wittmann
Course number and name	MKI51 Case Study Embedded Control Solutions
Lecturer	Johann Brunner
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	6
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written student research project
Weight	6 out of 90 ECTS
Language of Instruction	English

Module Objective

The case study **"Embedded Control Solutions"** 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.

Upon completion of this module, students will have achieved the following learning outcomes:

Professional competence:

- The module provides in depth knowledge of a specific subarea of embedded control solutions
- provides practical experience in this field

Methodological competence:

- Students are able to execute a topic related literature search in this field
- Students are able to evaluate and assess microcontroller architectures and respective signals
- Students are able to apply design modeling techniques

Personal competence:

- The Case Study "Embedded Control Solutions" teaches students how to solve complex tasks in teams with distributed task areas. The students learn to analyse, synthesise and evaluate a task in relation to embedded control solutions in an application-related manner.

Social competence:

- The students are able to consider embedded control solutions on the basis of case studies and to deepen their competences acquired in the module in group work and to use them in a prepared manner.
- The students are able to consider the problems from different perspectives and to use their competences acquired in the module appropriately and situation-based in individual and group discussions.

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and transfer capability to gain a deeper understanding of microcontroller architecture, their relevant signals and the entire product design process from a modeling perspective. This creates interfaces to courses of study such ase electrical engineering, mechatronics and computer engineering.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field

Learning Content

On the basis of a selected application example, the students should explore and work on the topic themselves by means of literature research, independent sub-tasks, etc. The topics of the case studies can be chosen from any subject area.

The topics of the case studies can vary each semester.

Teaching Methods

- Literature research
- Simulations
- Application of evaluation techniques

- Guided work on seminar topics in working groups. Accompanying events / presentations by external speakers depending on the selected topic area

Remarks

The case studies are examined as a so-called "Prüfungsstudienarbeit" (student research report) and are therefore not a classic examination.

The theoretical knowledge acquired by the students is specifically applied in practice in the case study topics so that students analyse problems independently and apply proposed solutions. This intensifies the transfer of knowledge into practice and the targeted deepening of the acquired technical and methodological competences by recognising connections and evaluating them.

MKI-6 Advanced Intelligent Systems

Module code	MKI-6
Module coordination	Prof. Jürgen Wittmann
Course number and name	MKI61 Big Data MKI62 Computer Vision
Lecturers	Prof. Dr. Patrick Glauner Prof. Jürgen Wittmann
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	6
ECTS	6
Workload	Time of attendance: 90 hours self-study: 90 hours Total: 180 hours
Type of Examination	written ex. 120 min.
Duration of Examination	120 min.
Weight	6 out of 90 ECTS
Language of Instruction	English

Module Objective

The module **"Advanced Intelligent Systems"** imparts knowledge on how to save and process big data quantities efficiently within the context of intelligent sensor/actuator systems. The students learn to develop and implement Big Data systems including the use of large sets of data for learning of deep learning models. They will be able to identify typical problems related to big data, such as data quality and bias, and how to solve those problems. In addition, this module explains how computer image and video data is processed so that data becomes "visible". Upon completion of this module, the student has achieved the following learning objectives:

Professional competence:
- the students understand the concepts of the most popular approaches in big data and deep learning
- they know and understand basic concepts of computer vision, such as filter techniques and convolutional neural networks

Methodological competence:
- students have the capability to develop big data and deep learning related programs
- they know how to use CV techniques to identify and/or intensify features in images

Personal competence:
- the students are able to implement their own methods and approaches and can argue against competing methods

Social competence:
- Students are able to view the problems from the field of advanced intelligent systems from the meta level and to use their competences acquired in the module appropriately and situation-based in individual and group discussions.

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and transfer possibility for the application of big data and computer vision in different systems and applications, specifically in sensors and actuators. Interfaces to mechatronics, electrical engineering and computer engineering.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field

Learning Content

This module introduces how to save and process big data sets efficiently.
- Introduction: 3 Vs, history of big data, selected big data use cases
- Complexity analysis: time complexity, O, Omega, Theta, o, and O tilde notations, space complexity, recurrence relations, master theorem, dynamic programming
- Multithreading: parallelism and concurrency, creating threads, global interpreter lock (GIL)
- Databases: ER diagrams, relational databases, database management systems, queries, indexes, normalization, transactions

- Big data architectures: distributed systems, MapReduce, CAP theorem, speedup through GPUs and FPGAs
- Big data, small data, all data: data quality, biases in data sets, small sample size problems
- MLOps: project lifecycle, challenges, operations, principal components, pipelines, best practices
- Quantum computing: qubits, quantum logic gates, quantum computers, quantum algorithms
- Selected big data infrastructures, frameworks, libraries and tools

In addition, this module explains how computer image and video data is processed so that data becomes "visible".

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

Teaching Methods

- Seminar-like teaching with joint exercises as well as presentations to deepen the knowledge achieved through application
- i-Learn (online learning platform)

Recommended Literature

A. Petrov, "Database Internals: A Deep Dive into How Distributed Data Systems Work", O'Reilly Media, 2019.

M. Goodrich, et al., "Data Structures and Algorithms in Python", John Wiley & Sons, 2013.

E. Raj, "Engineering MLOps: Rapidly build, test, and manage production-ready machine learning life cycles at scale", Packt, 2021.

S. Ranjan, S. Applied Deep Learning and Computer Vision for Self-Driving Cars, Packt Birmingham ? Mumbai, S. Ranjan, S. Senthamilarasu, 2020

C. Wagner, Kantenextraktion, Klassische Verfahren, Christoph Wagner, Vortrag, 2006 , ildsegmentierung und Computer Vision?

S. Winter, Digitale Bildverarbeitung, Skript zur Vorlesung, SS 2014, Institut für Neuroinformatik, Ruhr-Universität Bochum, Susanne Winter

E. Venkat, Digital Image Processing, EC2029 / IT6007, Anna University, Assistant Professor at VSA Group of Institutions

MKI-7 Case Study Intelligent Systems

Module code	MKI-7
Module coordination	Prof. Jürgen Wittmann
Course number and name	MKI71 Case Study Intelligent Systems
Lecturer	Prof. Jürgen Wittmann
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	6
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written student research project
Weight	6 out of 90 ECTS
Language of Instruction	English

Module Objective

On the basis of an application example in the case study **"Intelligent Systems"**, students independently work in groups on a coherent task taken from the area of intelligent 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. The intention of this case study is to introduce the students to a practical and industry-oriented way of technical problem solving.

Upon completion of this module, students will have achieved the following learning outcomes:

Professional competence:

- understanding and applying methods of development, construction, testing & assessing intelligent systems such as intelligent sensors or sensor systems etc.
- understanding and applying methods, e.g. software, as part of an intelligent mechatronic or cyberphysical system
- understanding different approaches to machine learning and/or more specifically deep learning in various field of application

Methodological competence:

- application of different approaches to add intelligence to a product or system
- identify opportunities and limits of intelligent systems in development and during operation

Personal competence:

- The Case Study "Intelligent Systems" teaches students how to solve complex tasks in teams with distributed task areas. The students learn to analyse, synthesise and evaluate a task in relation to intelligent systems in an application-related manner.
- Students are required to present the progress of their respective project in regular meetings.

Social competence:

- The students are able to consider intelligent systems on the basis of case studies as well as to deepen their competences acquired in the module in group work and to use them in a prepared manner.
- The students are able to consider the problems from different perspectives and to use their competences acquired in the module appropriately and situation-based in individual and group discussions.

Applicability in this and other Programs

Based on the lectures of this course, the module provided additional specific knowledge in the respective field and the transfer capability to understand intelligence in systems and to apply intelligent systems in various fields of application. This creates interfaces to courses of study such as electrical engineering, mechatronics and computer engineering.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field

Learning Content

On the basis of a selected application example, the students should explore and work on the topic themselves by means of literature research, independent sub-tasks, etc. The topics of the case studies can be chosen from any subject area.

The topics of the case studies can vary each semester.

Teaching Methods

- i-Learn (online learning platform)
- Literature research
- Simulations
- Development, construction and building of intelligent systems
- Application of assessment techniques
- Guided work on seminar topics in working groups. Accompanying events / presentations by external speakers depending on the selected topic area

Remarks

The case studies are examined as a so-called "Prüfungsstudienarbeit" (student research report) and are therefore not a classic examination.

The theoretical knowledge acquired by the students is specifically applied in practice in the case study topics so that students analyse problems independently and apply proposed solutions. This intensifies the transfer of knowledge into practice and the targeted deepening of the acquired technical and methodological competences by recognising connections and evaluating them.

Recommended Literature

"Intelligent Systems Design and Applications", 18th International conference on Intelligent Systems Design and Applications (ISDA2018), held in Vellore, India, Dec 6-8, 2018, Vol. 2

"Intelligent Systems and Applications", Proceedings of the 2019 Intelligent Systems Conference (IntelliSys) Vol. 1; Y. Bi, S. Kapoor, R. Bhatia (eds.), Springer, EAN: 9783030295165

MKI-8 Autonomous Systems

Module code	MKI-8
Module coordination	Prof. Jürgen Wittmann
Course number and name	MKI81 Algorithms of Autonomous Systems MKI82 Autonomous Robotics
Lecturers	Tobias Schaffer Prof. Jürgen Wittmann
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	8
ECTS	8
Workload	Time of attendance: 120 hours self-study: 120 hours Total: 240 hours
Type of Examination	written ex. 150 min.
Duration of Examination	150 min.
Weight	8 out of 90 ECTS
Language of Instruction	English

Module Objective

The module **"Autonomous Systems"** imparts knowledge on 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. Furthermore, this module addresses on the application of autonomous systems relevant to the industry and delves further into the content of mobile and collaborative robotics.

Upon completion of this module, the student has achieved the following learning objectives:

Professional competence:

- Coordinates & Maneuverability
- Vehicle Dynamic Kinematic
- Navigation, Localization and Mapping
- Neural network design for applications in autonomous systems
- Object detection and recognition (vehicles, road marking, traffic sign)
- Segmentation for self driving cars
- Decision making

Methodological competence:

- Application of neural nets and deep learning to autonomous systems
- Application of orientation, navigation and localization

Personal competence:

- The students learn how to analyze, apply and evaluate a task in relation to autonomous systems. They understand and learn to apply the algorithms used for self driving cars and, in general, autonomous systems

Social competence:

- The module Autonomous Systems teaches students how to solve complex problems in this field. In particular the case study provides opportunities to work in teams to work on larger scale projects. Students learn to work together and to defend their way of problem solving.

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and transfer possibility for the application of autonomous robotics and algorithms for autonomous systems in different systems and applications. Interfaces to mechatronics, electrical engineering and computer engineering.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field

Learning Content

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

Furthermore, this module addresses the application of autonomous systems relevant to the industry and delves further into the content of mobile and collaborative robotics.

Relevant subject areas:

- Semantic Segmentation
- Lane & Road Sign detection & general object detection
- Convolutional Neural Network architectures
- Specific application of Machine Learning

Teaching Methods

- Seminar-like teaching with joint exercises as well as presentations to deepen the knowledge achieved through application
- i-Learn (online learning platform)

Recommended Literature

D. Ahlers, "Lane Detection for Intelligent Cars", University of Hamburg, Faculty of Mathematics, Informatics and Natural Sciences, Department of Informatics, Technical Aspects of Multimodal Systems, 05. December 2016

M. Bojarski et al., "End to end learning for self-driving cars", arXiv preprint arXiv:1604.07316 (2016).

V. Chen, E. Chou, ,,Practical Object Detection and Segmentation"

F. Chollet, "Deep Learning mit Python und Keras", mitp, 2018

S. Kuutti et al., "Deep Learning for Autonomous Vehicle Control, Algorithms, State-of-the-Art and Future Prospects, in Synthesis Lectures on Advances in Automotive Technology, Series Editor: A. Khajepour, University of Waterloo, Morgan & Claypol Publishers, 2019

S. Ranjan, "Applied Deep Learning and Computer Vision for Self-Driving-Cars, Packt Birmingham-Mumbai, S. Ranjan, S. Senthamilarasu, 2020

MKI-9 Case Study Autonomous Systems

Module code	MKI-9
Module coordination	Prof. Jürgen Wittmann
Course number and name	MKI91 Case Study Autonomous Systems
Lecturer	Dr. Tim Weber
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	4
Workload	Time of attendance: 60 hours self-study: 60 hours Total: 120 hours
Type of Examination	written student research project
Weight	6 out of 90 ECTS
Language of Instruction	English

Module Objective

The Case Study **"Autonomous Systems"** addresses current questions in this area and gives students the opportunity to engage with these topics independently and creatively. Furthermore, students are given the opportunity to deal with these topics independently and creatively. Upon completion of this module, depending on a more theoretical or more practical focus, students will be able to identify limitations and opportunities algorithms and application of autonomous systems their specific field of application.

Professional competence:

- in depth knowledge of a specific subarea of autonomous systems and their related algorithms
- practical experience in construction and set up of autonomous systems

- knowledge and practical experience in autonomous systems performance evaluation (e.g. life test)

Methodological competence:

- Students are able to execute a literature search in a specific subareas of autonomous systems
- Students are able to evaluate and assess various algorithms used for autonomous systems

Personal competence:

- Case Study Autonomous Systems teaches students how to solve complex tasks in teams with distributed task areas. The students learn to analyse, synthesise and evaluate a task in relation to algorithms, construction and implementation in an application-related manner.

Social competence:

- The students are able to consider questions in the area of autonomous systems on the basis of case studies and to deepen their competences acquired in the module in group work and to use them in a prepared manner.
- The students are able to consider the problems from different perspectives and to use their competences acquired in the module appropriately and situation-based in individual and group discussions.

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and the transfer capability to gain a deeper understanding of autonomous system construction, implementation and related software principles and the capability to apply and to evaluate autonomous systems in and for a specific area of application. This creates interfaces to courses of study such as mechanical engineering, mechatronics, electrical engineering.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field

Learning Content

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
- Development and implementation of algorithms in autonomous systems
- Construction, implementation and test of autonomous systems

The topics of the case studies can vary each semester.

Teaching Methods

- Guided work on seminar topics in working groups. Accompanying events / presentations by external speakers depending on the selected topic area
- i-learn (Online learning platform)
- Literature research

Remarks

The case studies are examined as so-called Prüfungsstudienarbeit and are therefore not a classic examination.

The theoretical knowledge acquired by the students is specifically applied in practice in the case study topics so that students analyse problems independently and apply proposed solutions. This intensifies the transfer of knowledge into practice and the targeted deepening of the acquired technical and methodological competences by recognising connections and evaluating them.

Recommended Literature

D. Ahlers, "Lane Detection for Intelligent Cars", University of Hamburg, Faculty of Mathematics, Informatics and Natural Sciences, Department of Informatics, Technical Aspects of Multimodal Systems, 05. December 2016

M. Bojarski et al., "End to end learning for self-driving cars", arXiv preprint arXiv:1604.07316 (2016).

V. Chen, E. Chou, ,,Practical Object Detection and Segmentation"

F. Chollet, "Deep Learning mit Python und Keras", mitp, 2018

S. Kuutti et al., "Deep Learning for Autonomous Vehicle Control, Algorithms, State-of-the-Art and Future Prospects, in Synthesis Lectures on Advances in Automotive Technology, Series Editor: A. Khajepour, University of Waterloo, Morgan & Claypol Publishers, 2019

S. Ranjan, "Applied Deep Learning and Computer Vision for Self-Driving-Cars, Packt Birmingham-Mumbai, S. Ranjan, S. Senthamilarasu, 2020

MKI-10 Subject-related elective course (FWP)

Module code	MKI-10
Module coordination	Prof. Jürgen Wittmann
Course number and name	Python
Lecturers	Prof. Dr. Patrick Glauner Johannes Kigele Prof. Dr. Horst Kunhardt
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	compulsory course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	4
Workload	Time of attendance: 60 hours self-study: 60 hours Total: 120 hours
Type of Examination	Examination form of the chose module
Weight	4 out of 90 ECTS
Language of Instruction	English

Module Objective

Students can choose from a range of FWP subjects as part of the compulsory elective subject module.

Students are offered, among other things, the opportunity to work on a technical project in which they are highly self-responsible and self-organized, yet work on a topic related to artificial intelligence for smart sensors and actuators under the guidance of the lecturer.

Furthermore, courses from a subject catalogue of related studies are offered at the DIT and, if applicable, the Virtual University of Bavaria (VHB), e.g.

- Advanced Modelling and Simulation (Master Mechatronic and Cyber-Physical Systems)
- Data Security and Data Protection (Master Medical Informatics)
- Collaborative Systems (Master Medical Informatics)

Further courses deepen scientific topics in the field of artificial intelligence for smart sensors and actuators.

The offer is reviewed every semester and updated if necessary.

After completing the FWP module, the students have achieved the learning goals defined in the sub-module.

In the FWP module, the following competences are to be taught:

Professional competence:

The competences result from the chosen FWP subject.

Methodological competence:

The competences result from the chosen FWP subject.

Personal competence:

The competences result from the chosen FWP subject.

Social competence:

The competences result from the chosen FWP subject.

Applicability in this and other Programs

All Master's programmes in which technical knowledge is required to solve complex problems.

Entrance Requirements

Learning Content

The contents result from the respective FWP subject.

Teaching Methods

The didactic methods result from the respective FWP subject.

Remarks

The FWP range of subjects includes courses with different ECTS values. Students are advised to take courses with at least 4 ECTS values.

The type of examination conducted for FWP courses is subject to the currently valid study regulations.

Recommended Literature

The literature results from the respective FWP subject.

Python

Objectives

The lecture Python conveys basic and advanced knowledge about the programming language Python. Python is already widely used and spread in the industry.

After completion of this module, the student will have achieved the following learning objectives:

Professional competences:

- Programming language Python
- Typical expressions in programming

Methodical Expertise:

- Understand, analyze and alter existing programming code
- Error analysis and handling

Personal competences:

- Construct simple Python applications
- Understand other Python-based programs and their functionality

Social competences:

- Working in a team through a project

Entrance Requirements

Bachelor's degree in mechatronics or a closely related field

Learning Content

- Variables
- If-Clauses
- Loops
- Functions
- Classes
- Inputs

- Exceptions
- GUIs
- Documentation
- Projects
- Decorators

Type of Examination

written ex. 90 min.

Methods

During the lectures, relevant theoretical knowledge will be taught. Through specific examples the students will be able to apply this knowledge to programming exercises. Here, the method of problem-based learning is centralised and is meant to promote the ability for independent acquisition of knowledge and problem-solving skills among students.

Recommended Literature

Romano, Fabrizio: Learning Python; Packt Publishing (2018)

Objectives

This class provides students with an introduction to Quantum Computing (QC), which looks promising to solve certain computational problems substantially faster than classical computers. QC began in the early 1980s and in recent years, investment into QC research has increased in both the public and private sectors. Students will acquire knowledge in QC and its applications in various domains such as machine learning and cryptography. They will also be able to elaborate it further in the future, for example in projects or further studies. Overall, QC is a cutting-edge eld, with many high-pay opportunities for graduates.

Upon completion of this module, the student has achieved the following learning objectives:

Professional competence:

- understanding of QC and its application

Methodological competence:

- elaboration of application scenarios

Personal competence:

- The students learn how to analyze and evaluate a problem and how QC can help to solve it

Social competence:

- Students are able to reflect on the requirements in the field of QC and transfer them to relevant application scenarios.

Learning Content

The following topics will be discussed in class:

- Introduction: history, comparison to traditional computing, applications, business potentials
- Foundations: complex numbers, complex vector spaces
- Systems: deterministic systems, probabilistic systems, quantum systems, assembling systems
- Quantum theory: states, superposition, observables, measuring, dynamics, assembling quantum
- systems, entanglement
- Architecture: bits and qubits, classical gates, reversible gates, quantum gates, no-cloning theorem
- Selected algorithms: Deutsch's, Deutsch-Jozsa, Simon's, Grover's, Shor's
- Theoretical computer science: limits of quantum computing, complexity classes
- Quantum computers and programming: goals and challenges, decoherence, physical realizations,
- quantum annealing, adiabatic quantum computing
- Applications: quantum machine learning, quantum cryptography, quantum information theory

Type of Examination

presentation 15 - 45 min.

Methods

This course is taught 180 minutes a week, which include lectures, laboratory sessions, seminar sessions and guest lectures. Towards the end of the term, students give a graded presentation on a selected topic related to quantum computing.

Recommended Literature

P. Glauner and P. Plugmann (Eds.), \Innovative Technologies for Market Leadership: Investing in the Future", Springer, 2020.

N. S. Yanofsky and M. A. Manucci, \Quantum Computing for Computer Scientists", Cambridge University Press, 2008.

MKI-11 Systems Design

Module code	MKI-11
Module coordination	Prof. Jürgen Wittmann
Course number and name	MKI111 Systems Design MKI112 Systems Intercommunication
Lecturer	Prof. Jürgen Wittmann
Semester	3
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	6
ECTS	6
Workload	Time of attendance: 90 hours self-study: 90 hours Total: 180 hours
Type of Examination	written ex. 120 min.
Duration of Examination	120 min.
Weight	6 out of 90 ECTS
Language of Instruction	English

Module Objective

The module **"Systems 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, students shall gain in-depth knowledge of the complete system design process.

In addition, as part of Systems Intercommunication, students learn about cyberphysical networks, system and network communication. A major focus is given to various aspects of Internet of Things (IoT) where physical objects are connected which are embedded with sensors and software etc. and which exchange a large amount of data over the internet or other means.

After completion of this module, the student has achieved the following learning objectives:

Professional competence:

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

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)
- Understanding and capability to develop and setup cyberphysical system communication and data exchange in an IoT environment
- Understand IoT fields of application, e.g. smart factory, robotics, autonomous systems

Personal competence:

- understand system design as part of a major project
- ability to penetrate a complex system and break it down to sub-topics including their interrelationships

Social competence:

- Understand systems as complex entities. Ability to work on sub-topics towards the overall system functionality.

Applicability in this and other Programs

The module provides the necessary theoretical background and transfer possibility for the design of systems and the respective system parts intercommunication. Interfaces to mechatronics, electrical engineering and computer science.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field

Learning Content

The lecture "**Systems 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, students shall gain in-depth knowledge of the complete system design process.

In addition, the following topics are also covered in this module:

- system networking / system fusion
- construction and operating principle of prompt, serial communication systems
- cyber security
- technology, market and applications of the Internet of Things (IoT)

Teaching Methods

- Seminar-like teaching with joint exercises as well as presentations to deepen the knowledge achieved through application
- i-Learn (online learning platform)

Recommended Literature

Bühne, "Handbuch Requirements Management nach IREB Standard, Aus- und Weiterbildung zum IREB Certified Professional for Requirements Engineering Advance Level "Requirements Management", Vers. 1.0.1

DIN ISO 26261

Firouzi, F., Chakrabarty, K., Nassif, S., "Intelligent Internet of Things: From Device to Fog and Cloud, 2020, Springer, Switzerland

Kuster, J. et al. (2019), Handbuch Projektmanagement, 4. Aufl., Springer, Berlin

MKI-12 Master module

Module code	MKI-12
Module coordination	Prof. Jürgen Wittmann
Course number and name	Master`s thesis Master seminar
Semester	3
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	0
ECTS	24
Workload	Time of attendance: 0 hours self-study: 720 hours Total: 720 hours
Type of Examination	, master thesis, written examination
Weight	24 out of 90 ECTS
Language of Instruction	English

Module Objective

The master's programme "**Artificial Intelligence for Smart Sensors and Actuators"** is concluded with a master thesis. Students are expected to prove that they can independently and successfully complete a certain task within a given period of time and that they can apply scientifically-founded theoretical and practical knowledge to solve a problem. After successful completion of the master thesis, students are able to work independently on complex scientific/technical tasks. They solve problems using digital methods as well as tools and find answers to current questions in the field of artificial intelligence for smart sensors and actuators.

The teaching content taught during the course of studies is applied in the form of a scientific paper. The problem is to be independently analysed, structured and processed within a given time frame. This trains the ability to independently work on technical problems of a larger related topic and to process the results in scientific form. The aim is, among other things, to deepen and apply the ability to document the results transparently.

In addition to the master thesis (22 ECTS), the master seminar (2 ECTS) is also part of this module. The master seminar consists of two parts, which must be passed to successfully complete the module. In preparation for the master thesis, participation in the seminar series "Career Start into German Technology Companies" is mandatory. The seminars / workshops are offered as block courses during the first two semesters of study. The events cover a variety of topics that are of great importance for the preparation of the master's thesis. In addition to scientific working methods, students are also introduced to the general conditions of the German job market and application processes. In order to pass this seminar, a written examination has to be passed. The second part of the master seminar consists of the colloquium. After handing in the master thesis, students have to present their thesis in a presentation of about 15 minutes and defended it afterwards. The weighting of the two parts of the master seminar is 1 ECTS seminar series "Career Start into German Technology Companies" and 1 ECTS colloquium.

Professional competence

Students are enabled to familiarise themselves with technical tasks, to analyse problems independently and to solve them.

After completing the module, students are able to work on a problem from the broad field of artificial intelligence for smart sensor and actuator technology in a scientifically sound manner.

Methodological Competence

The ability to independently work on and solve a comprehensive problem from the engineering sciences on a scientific basis is the overriding goal of methodological competence.

Personal competence

Independent, autonomous and self-disciplinary scientific, methodical processing of a practice-relevant, delimitable (sub-)project in a study programme-related environment as well as written, independent documentation in the form of a scientific paper and require personal skills.

Social competence

The students improve their social and interface competence through intensive communication with the supervisors at the Deggendorf Institute of Technology and in the cooperating industrial company.

Applicability in this and other Programs

The Master's programme "**Artificial Intelligence for Smart Sensors and Actuators** enables students to work scientifically. The Master's degree entitles the holder to a subsequent doctorate.

Entrance Requirements

Admission requirements are the successfully completed case studies including the scientific elaboration of the project topics.

The registration for the master thesis requires that at least 30 ECTS credits have been achieved (cf. study and examination regulations (SPO).

Learning Content

The topic of the master thesis will be set by a professor of the participating universities or by a cooperating company. In addition, the students are entitled to propose their own topics. A DIT professor is responsible for supervision and content support.

The master thesis includes:

- Presentation of the state-of-the art in science and technology of the topic being worked on
- Description of the methodology and the course of the own theoretical and experimental procedure including concept development
- Decision-making regarding the most favourable problem solution
- The integration of the own work into the work of the supervising institutes/ faculties and possible industry partners.
- Report on own publications
- Report on the applications/possible applications for funding within the scope of the topic
- Creation of test setups and programs
- Execution of measurements and test runs including their evaluation
- Scientific documentation of the technical results achieved and their evaluation
- Study of literature

By writing a master thesis, students should demonstrate their ability to apply the knowledge and skills acquired during their studies to an independent scientific thesis.

The master thesis is followed by a colloquium as an oral examination. The students present their master thesis and defend it.

Teaching Methods

Guidance to independent work according to scientific methods by the respective supervisor.

seminars, workshops,

colloquium

Remarks

The subject content of the master thesis can be chosen freely and individually by students. The topic must be recognised by the supervising professor. Furthermore, it is possible to work on a topic in cooperation with a company and to work on a research topic at the faculty.

Recommended Literature

Literature selected by the student for the specific subject area.

Support for scientific work:

Eco, Umberto: How to write a scientific thesis; 13th edition; UTB Verlag; Vienna; 2010.

Scheld, Guido: Instructions for the preparation of internship, seminar and diploma theses as well as bachelor and master theses; 7th edition; Fachbibliothek Verlag; Büren; 2008.

Rossig, Wolfram; Prätsch, Joachim: Scientific works: Guidelines for term papers, bachelor's and master's theses, diploma and master's theses, dissertations; 7th edition; team printing; Weyhe; 2008.

Standop, Ewald; Meyer, Matthias: The form of scientific work; 18th edition; Quelle & Meyer; Wiebelsheim; 2008.