Module Guide
Künstliche Intelligenz für smarte Sensorik / Aktorik

Faculty Applied Natural Sciences and Industrial Engineering
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Table of Contents

MSS-01 AI and Machine Learning

Module code	MSS-01
Module coordination	Prof. Dr. Josef Schmid
Course number and name	MSS1101 AI and Machine Learning
Lecturer	Tobias Schaffer
Semester	1
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 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.

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

- Fundamentals of programming e.g. in Python
- Basic knowledge of statistics
- Basic knowledge of data management

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

MSS-02 Advanced Sensor Technology and Functionality

Module code	MSS-02
Module coordination	Prof. Jürgen Wittmann
Course number and name	MSS1102 Advanced Sensor Technology and Functionality
Lecturer	Prof. Jürgen Wittmann
Semester	1
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

This module 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 sensors 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 sensors/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 performance
- 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

- Fundamentals of electrical engineering
- Fundamentals of metrology

- Basic knowledge of physical principles

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 feature 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

MSS-03 Model-Based Function Engineering

Module code	MSS-03
Module coordination	Prof. Dr. Roland Platz
Course number and name	MSS1103 Model-Based Function Engineering
Lecturer	Prof. Dr. Roland Platz
Semester	1
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

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 definition and specification, concept, optimization via verification, design, realization, and test via validation. The course discusses conceptual approaches to evaluate uncertainty and reliability of the product design. Computational tools like the modeling language Object-Process CASE Tool (OPCAT) and numerical computing environment Matlab, Matlab-Simulink and Matlab-Simscape support the modelling process.

Professional competence:

- In depth knowledge of system engineering processes for mechatronic and cyber-physical Systems.
- Knowledge and practical experience systems performance evaluation, e.g. reliability, remaining life testing.

Methodological competence:

- Hands-on experience in mathematical modeling and numerical simulation of mechatronic systems.
- Conducting model-based design of embedded systems.

Personal competence:

- Moderating and solving complex tasks in teams during assignments during class.
- Analysing, synthesing, evaluating, discussing, and presenting results of tasks with and in front of fellow students during class.

Social competence:

- Communicating and exchanging ideas on a factual ground with students with diverse backgrounds.
- Taking ownership of responsibility when presenting results and findings to fellow students during class.

Applicability in this and other Programs

The students learn about systematic design approach for mechatronic and cyber-physical systems.

Entrance Requirements

- Basic principles of physics (axioms of technical mechanics) and mathematics (differential equations, statistics)
- Fundamentals of mechanical engineering (mechanics, electronics, design concepts)
- Fundamentals of metrology (conversions of physical units)
- Basics for mathematical modeling for numerical simulation

Learning Content

Introduction Mechatronic Systems

VDI 2206 Mechatronic and Cyber-Physical Systems

Product Development Process (PDP) and Product Life Cycle (PLC)

Systems Engineering

System Modeling Language, Software Tools SysML and OPCAT

Generic Life Cycle Stages, Technology Readiness Level TRL, Basic Linear Control Concepts

Model-Based Design of Embedded Systems

Modeling Physical Systems using Matlab/Simulink/Simscape

HIL-Simulation and Test

Design of Experiments (DoE)

Reliability Evaluation Tools in Early Development Stage
- Failure Mode and Effects Analysis (FMEA) / Fault, Error, Failure
- Faults, Fault Tree Analysis (FTA)

Bayesian Statistics, Maximum Likelihood Estimation, Markov Chains, Stochastics

Durability/Life Tests

Dealing with Uncertainty, Functional Safety

Teaching Methods

Class in lecture format with:

- slides and handwritten derivations,
- quizzes,
- group assignments and discussions,
- time for questions.

Remarks

- Online class with three in-person classes during the semester.
- Interactive class with group assigments and live discussions.

Recommended Literature

Bertsche, Bernd; Göhner, Peter; Jensen, Uwe; Schinköthe, Wolfgang; Wunderlich, Hans-Joachim (2009): Zuverlässigkeit mechatronischer Systeme. Berlin, Heidelberg: Springer Berlin Heidelberg, checked on 4/18/2021.

Dori, Dov; Renick, Aharon; Wengrowicz, Niva (2016): When quantitative meets qualitative: enhancing OPM conceptual systems modeling with MATLAB computational capabilities. In Res Eng Design 27 (2), pp. 141164. DOI: 10.1007/s00163-015-0209-9.

Gausemeier, Jürgen; Dumitrescu, Roman; Steffen, Daniel; Czaja, Anja; Wiederkehr, Olga; Tschirner, Christian (2015): Systems Engineering. in industrial practice. With assistance of Heinz Nixdorf Institute, University of Paderborn, Faculty of Product Engineering, Fraunhofer Institute for Production Technology IPT Project Group Mechatronic Systems Design, UNITY AG.

Lavi, Rea; Dori, Yehudit Judy; Wengrowicz, Niva; Dori, Dov (2020): Model-Based Systems Thinking: Assessing Engineering Student Teams. In IEEE Trans. Educ. 63 (1), pp. 3947. DOI: 10.1109/TE.2019.2948807.

Schwer, L. E. (2006): Guide for Verification and Validation in Computational Solid Mechanics. Reprinted by permission of The American Society of Mechanical Engineers.

U.S. Nuclear Regulatory Commission (1981): Fault Tree Handbook,

Walden, David D. (2015): INCOSE Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities, checked on 3/29/2021Jensen, Jeff C. (2010): Elements of Model-Based Design (Technical Report No. UCB/EECS-2010-19). Available online at http://www.eecs.berkeley.edu/Pubs/TechRpts/2010/EECS-2010-19.html, checked on 5/23/2021.

2004: VDI 2206 Design methodology for mechatronic systems.

2021: VDI 2206 - Development of mechatronic and cyber-physical systems.

MSS-04 Advanced Programming

Module code	MSS-04
Module coordination	Prof. Dr. Josef Schmid
Course number and name	MSS1104 Advanced Programming
Lecturer	Tobias Schaffer
Semester	1
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	Portfolio
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

This module is for students who have basic programming knowledge and aim to specialize in machine learning. The course is designed to teach complex machine learning algorithms and techniques, utilizing popular frameworks such as Scikit-Learn, TensorFlow and PyTorch. The course emphasizes practical applications and real-world problem-solving through comprehensive case studies.

Participants will learn to build, train, and deploy machine learning models effectively. The course will cover advanced topics in deep learning, neural networks, and computational methods essential for modern machine learning applications. The students will learn how to design, implement, and deploy scalable applications and machine learning models using various cloud platforms. Additionally, they will acquire skills in managing code and projects using Git.

Applicability in this and other Programs

The module provides the necessary knowledge for AI and Machine Learning and Deep Learning and Computer Vision.

Entrance Requirements

Students should have a solid understanding of basic programming concepts, data structures, and algorithms, preferably with some prior knowledge of basic machine learning concepts and Python programming.

Learning Content

- Develop expertise in using Scikit-Learn, TensorFlow and PyTorch for various machine learning tasks
- Apply advanced machine learning algorithms to real-world problems through detailed case studies
- Build and optimize neural network architectures for tasks such as image recognition, natural language processing, predictive analytics, generative applications
- Implement best practices in version control and project management using Git
- Gain proficiency in cloud computing platforms such as AWS, Azure, or Google Cloud, focusing on services related to computing, storage, and machine learning.
- Learn to construct and deploy machine learning pipelines for data collection and preprocessing

Teaching Methods

The course includes lectures, hands-on programming, and project work. Students will actively engage in implementing and refining machine learning code, guided by case studies that demonstrate theoretical concepts in practical scenarios. Grading will be based on case study submissions and practical coding exercises.

MSS-05 Edge Device Architectures

Module code	MSS-05
Module coordination	Prof. Dr. Josef Schmid
Course number and name	MSS 1105 Edge Device Architectures
Lecturer	Prof. Dr. Josef Schmid
Semester	1
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

The module takes up current examples of edge devices related to the application of embedded systems and their application within the area of AI. Furthermore, students are given the opportunity to have a in deep look into computing architectures and concepts. 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 Edge Device Architectures

- 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

Personal competence:

- The lecture "Edge Device Architectures" teaches students how the architecures of edge devicese are working. The students learn to analyse, synthesise and evaluate a task in relation to embedded control and edge device in an application-related manner.

Social competence:

- 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

- Fundamentals of embedded programming
- Fundamentals of electrical engineering
- Fundamentals of mechanical engineering

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

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

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.

MSS-06 System Design

Module code	MSS-06
Module coordination	Prof. Dr. Matthias Górka
Course number and name	MSS 1106 System Design
Lecturers	Ginu Paul Alunkal Prof. Dr. Matthias Górka
Semester	1
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

After finishing the module **"System Design" ,** the students have reached the following targets:

The participants in the module learn the principles of system development. The foundations are laid to identify customer requirements and convert them into technical requirements. Considering possible risks is also part of system development.

Professional competence:

- Capture and update requirements [4 - In-depth knowledge]
- Know and apply the product life cycle [4 - In-depth knowledge]

- Create, maintain and derive measures from D-FMEA [4 - In-depth knowledge]
- Consider safety aspects while design process [2 - basic knowledge]
- Designing systems [5 - Expert knowledge]

Methodological competence:

- Methods for requirements management, FMEA and idea generation.

Personal competence:

- Dealing with complex systems in volatile environments.

Social competence:

- Collaboration in interdisciplinary teams to create optimal systems.

Applicability in this and other Programs

The module provides the necessary theoretical background and transfer possibility for the design of a complete systems and the respective system parts. This includes their interfaces in the domain of mechanics, electric, electronic and computer science. The learned approaches can be used for the case studies and structured working on the master thesis.

Entrance Requirements

Module(s) in this study course: no requirements

other requirements:

- Basic mathematics
- Basic presentation skills

Learning Content

- Requirements management
- Change management
- Product creation process
- Risk management and D-FMEA (design / product)
- Idea generation

Teaching Methods

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

MSS-07 Deep Learning and Computer Vision

Module code	MSS-07
Module coordination	Dr. Sunil Survaiya
Course number and name	MSS 2101 Deep Learning and Computer Vision
Lecturer	Dr. Sunil Survaiya
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

Deep learning (DL) is a subset of machine learning that mimics the intricate decision-making capabilities of the human brain using multilayered neural networks. Deep learning powers most current artificial intelligence (AI) applications in one way or another.

In **computer vision (CV)**, the human visual system is automated using machines or computers to acquire a high degree of comprehension from input digital pictures or videos, extract meaningful information from digital photos, movies, and other visual inputs, and make suggestions or take action when it detects flaws or errors. Semantic segmentation, object detection, and picture classification are a few examples.

Students are exposed to a variety of DL and CV models in this course. They have the ability to comprehend the issue, choose the appropriate models, assess the models, and decide which strategy or solution is optimal for an application.
After completing this module, the students have met the following learning goals:

Professional competence:

- Grasp of computer vision, image processing, and deep learning concepts.
- Understanding different algorithms in deep learning and image processing.
- Realizing the notion of modeling and using it in various application scenarios.

Methodological competence:

- Selecting and setting up the DL architecture.
- Utilization of various methods of image processing in computer vision.
- Blending CV and DL for different application scenarios.

Personal competence:

- The DL and CV module teach and guide students to solve complex tasks and problems.
- The concept creation, modeling, analysis, and evaluation methodologies, as well as the application of computer vision to industrial issue solving, are taught to the students.

Social competence:

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

Applicability in this and other Programs

MSS-07: Deep learning and computer vision

The module provides the necessary theoretical knowledge and transfer possibilities for the application of machine and deep learning in different systems and applications, specifically in production and logistics. Interfaces to mechatronics, electrical engineering, computer engineering and industrial engineering.

Entrance Requirements

Bachelor degree in mechatronics, production engineering, industrial engineering or a closely related field

Learning Content

This module introduces deep learning and computer vision, in particular, as applied to industrial applications. Correspondingly, this module presents a wide spectrum of methods in deep learning and image processing in computer vision.

- Introduction to deep learning network
- Deep learning architectures - ConvNet, RNN, and GAN
- Selection of different architectures.
- Digital image representation
- Human visual and digital imaging systems
- Image processing operations and transformation
- Image enhancement
- Image restoration
- Image segmentation
- Object recognition
- Computer vision appications

Teaching Methods

- Seminar-like teaching with joint exercises as well as presentations to deepen the knowledge achieved through application
- i-Learn (online learning platform)
- Scientific research paper and Seminar
- group project
- Programming

Remarks

Skillset Requirements

- Fundamentals of Intelligent System
- Fundamentals of Python Programming
- Knowledge of Machine Learning

Recommended Literature

Joseph Howse and Joe Minichino, Learning OpenCV 4 Computer Vision with Python 3, third edition, Packt, Birmingham-Mumbai, 2022.

Aurélien Géron, "Hands-On Machine Learning with Scikit-Learn, Kreas, and Tensorflow" O'Reilly, third edition, 2022.

Richard Szeliski, "Computer Vision: Algorithms and Applications", Springer-Verlag London Ltd., 2011

Charu Aggrawal, "Neural Network and Deep Learning", Springer verlag GmbH, third edition, 2018

MSS-08 Big Data

Module code	MSS-08
Module coordination	Dr. Tim Weber
Course number and name	MSS 2102 Big Data
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	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

The module **"Big Data"** 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

- Fundamentals of Intelligent Systems
- Fundamentals of Computer Science
- Knowledge of Machine Learning & Deep Learning

Learning Content

Bascic Concepts:

- Data dredging
- Causal Connection
- Central Limit Theorem, Law of Large Numbers
- History of Big Data
- Big Data Project Models

Data Sources:

- Structure vs. Accessibility
- Databases (RDBM vs. NoSQL)
- File System

- API
- Web Scraping
- Distributed Storage
- Data streaming
- MQTT

Data Quality:

- Top Down or Bottom Up
- The Cathedral and the Bazaar
- Data Quality Standards
- Data Quality Methods (Gage RR)
- Fisher and Xi^2 Distribution
- ANOVA
- Treating Missing Values

Data Bias:

- Types of Biases (Confirmation Biase, Selection Bias, Not Invented Here Bias)
- Bootstrapping
- Bias Variance Trade-Off

crunching Data:

- MapReduce
- Cluster Architecture
- Measures of Central Tendency
- Measures of Spread
- Gradient Descent
- Maximum Likelihood Estimation
- Principal Component Analysis
- Cluster Analysis

showing Data:

- Fundamentals of Data Visualization
- Types of plots
- Raw Data vs. Computed Data

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

Fung, Kaiser. 2013. *Numbersense: How to Use Big Data to Your Advantage* . McGraw Hill Professional.

Herzog, Thomas N., Fritz Scheuren, and William E. Winkler. May. *Data Quality and Record Linkage Techniques* . Springer.

ISO. 2022. *8000-1:2022 Data Quality* . International Standards Organization. https://www.iso.org/standard/81745.html .

Ismay, Chester, and Albert Y. Kim. 2019. *Statistical Inference via Data Science* . Chapman & Hall/CRC: The R Series.

Little, Roderick J. A., and Donald B. Rubin. 2002. *Statistical Analysis with Missing Data* . *Wiley Series in Probability and Statistics* . Wiley. https://doi.org/10.1002/9781119013563 .

Wickham, Hadley, Mine Çetinkaya-Rundel, and Garrett Grolemund. 2023. *R for Data Science* . OReilly Media, Incorporated.

Buuren, Stef van, and Karin Groothuis-Oudshoorn. 2011. Mice: Multivariate Imputation by Chained Equations in r. *Journal of Statistical Software* 45: Not available. https://doi.org/10.18637/jss.v045.i03 .

MSS-09 Case Study Machine Learning and Deep Learning

Module code	MSS-09
Module coordination	Ginu Paul Alunkal
Course number and name	MSS 2103 Case Study Machine Learning and Deep Learning
Lecturer	Ginu Paul Alunkal
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	Portfolio
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

On the basis of an application example in the case study **"Machine Learning and Deep Learning"** , 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 " Machine Learning and Deep Learning " 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

- Fundamentals of Python Programming
- Fundamentals of AI
- Knowledge of Machine Learning & Deep Learning Models

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 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

Janiesch, C., Zschech, P. & Heinrich, K. Machine learning and deep learning. *Electron Markets* **31** , 685695 (2021).

Taye, M.M. Understanding of Machine Learning with Deep Learning: Architectures, Workflow, Applications and Future Directions. *Computers* **2023** , *12* , 91. https://doi.org/10.3390/computers12050091

MSS-10 Autonomous Systems

Module code	MSS-10
Module coordination	Prof. Dr. Dmitrii Dobriborsci
Course number and name	MSS 2104 Autonomous Systems
Lecturer	Prof. Dr. Dmitrii Dobriborsci
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 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
- 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

Basic knowledge and experience in Python are necessary for the second part of the lab-sessions. However, students with prior experience in Matlab, R or other programming languages may be acceptable given an introductory Python tutorial outside of the module. Also knowledge of linear algebra and calculus are expected.

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
- Optimisation methods
- Mapping and navigation
- Sensor fusion
- Motion control
- Path planning

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

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

MSS-11 Case Study Edge Device Architectures

Module code	MSS-11
Module coordination	Prof. Dr. Josef Schmid
Course number and name	MSS 2105 Case Study Edge Device Architectures
Lecturer	Prof. Dr. Josef Schmid
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	Portfolio
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

The case study **"Edge Device Architectures"** 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 Edge Device Architectures
- 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 "Edge Device Architectures" 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 AI solutions in an application-related manner.

Social competence:

- The students are able to consider Edge Device Architectures 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, computer engineering, AI and Machine Learning, Advanced Sensor Technology and Functionality, Advanced Programming, Edge Device Architectures and System Design.

Entrance Requirements

- Fundamentals of control
- Fundamentals of programming e.g. in Python.
- Fundamentals of embedded programming

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

- 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)

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

- Unpingco, José. (2021): Python Programming for Data Analysis. 1st ed. 2021: Springer International Publishing; Imprint Springer (Springer eBook Collection).
- bin Uzayr, Sufyan (2021): Optimizing Visual Studio Code for Python Development. Developing More Efficient and Effective Programs in Python. 1st ed. 2021. Berkeley, CA: Apress; Imprint Apress (Springer eBook Collection). Online verfügbar unter https://link.springer.com/content/pdf/10.1007%2F978-1-4842-7344-9.pdf , zuletzt geprüft am 16.01.2022.
- Raschka, Sebastian (2016): Python machine learning. Unlock deeper insights into machine learning with this vital guide to cutting-edge predictive analytics.

MSS-12 Network Communication

Module code	MSS-12
Module coordination	Prof. Dr. Josef Schmid
Course number and name	MSS2106 Network Communication
Lecturer	Prof. Dr. Josef Schmid
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

After finishing the module **"Network Communication",** the students reach the following targets:

The participants in the module learn the principles of communication used for Internet of things (IoT) and Embedded Systems. The foundations are laid to identify customer requirements and meet them in technical requirements.

Professional competence:

- System components including system communication
- Communication technology and fields of application of Internet of things
- Security in the field of Internet of things communication

Methodological competence:

- Setting, monitoring and realization of IoT projects
- Ability to understand communication technology and fields of application
- Understand IoT fields of application, e.g. smart factory, robotics, autonomous systems
- Understand the importance of security and how to implement state-of-the-art security methods.

Social competence:

- Ability to work on sub-topics towards the overall system functionality.

Applicability in this and other Programs

The module teaches the fundamental principles and methods for designing communication in the field of IoT and its sub-communication systems. Additionally, it covers the basics of data transmission security. This results in interface BigData, Edge Device Architectures and Case Study Edge Device Architectures.

Entrance Requirements

- Fundamentals of Computer Communication
- Edge Device Architectures

Learning Content

The module **"Network Communication"** provides insight into the organizational and technical approaches to develop IoT communication starting with the customer requirements through system design and up to the realization of the system.

In addition, as part of **"Network Communication"** , 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.

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

- IoT Fundamentals
- The Thing in IoT
- Network Fundamentals
- IoT Network Technologies and Standards
- Application Layer Protovols
- IoT Cyber Security

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

Gravina, Raffaele, et al., eds. *Integration, interconnection, and interoperability of IoT systems* . New York, NY, USA:: Springer International Publishing, 2018.

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

Saint-Andre, P., Smith, K., & Tronçon, R. (2009). *XMPP: the definitive guide* . " O'Reilly Media, Inc.".

MSS-13 Subject-Related Elective Course (FWP)

Module code	MSS-13
Module coordination	Prof. Dr. Josef Schmid
Course number and name	Quality Management Methods & Tools Tele-Experiments with Mobile Robots ERP Systems and Digital Transformation Computer Networking and Secure Network Management Interactive Online MSS Quantum Computing
Lecturers	Prof. Dr. Patrick Glauner Prof. Jürgen Wittmann Virtuelles Angebot vhb
Semester	3
Duration of the module	1 semester
Module frequency	each semester
Course type	compulsory course
Level	postgraduate
Semester periods per week (SWS)	0
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written student research project, written ex. 90 min., presentation 15 - 45 min.
Duration of Examination	90 min.
Weighting of the grade	5 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).

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

Bachelor`s degree in mechatronics or a closely related field

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.

Quality Management Methods & Tools

Objectives

The module introduces students to the concept of quality management in engineering with the focus on statistical concepts, high end product quality, supplier quality and technical problem solving. On successful completion of this module, students should be able to understand quality management concepts, methods and tools especially in a technical and/or production environment.

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

Professional competence:

- understand and use statistical methods and concepts to monitor and improve production processes
- understand and use various methods to identify and eliminate technical problem root causes
- methods and concepts of quality management and quality assurance; use of AI in the field of quality

Methodological competence:

- understand and apply quality methods and tools to quality problems
- understand the overall concept of quality management ranging from statistics over organizational requirements up to quality standards and supplier/customer quality management

Personal competence:

- understand product quality as a long-term competitive advantage for companies, especially in the automotive market
- understanding and ability to use methods from different fields to improve and to monitor quality

Social competence:

- Understand quality management as a company objective to support the customer
- Ability to use various methods to achieve company quality targets

Entrance Requirements

Mathematics on a bachelor of engineering graduate level.

Learning Content

The following topics will be covered in class:

1. Statistical methods and probability
2. Capabilities
3. Statistical Process Control
4. Sub dpm Quality
5. Predictive Quality
6. Problem Solving
7. Supplier Quality Management
8. Standards & Certification

Type of Examination

written ex. 90 min.

Methods

seminar-style course with exercises

Recommended Literature

Sondermann, J. P., QM, Beuth Hochschule für Technik Berlin, Fernstudieninstitut, TFH Berlin 2006, MBA Renewable Energies

Wittmann, J., Introduction to Quality Management in the Semiconductor Industry, Vol. 1: General, ISBN-10: 1535046341; ISBN-13: 978-1535046343), CreateSpace Independent Publishing Platform, Auflage 1, Aug 2016)

Brunner F. J. Brunner, K. W. Wagner, Qualitätsmanagement, Leitfaden für Studium und Praxis, 5. Auflage, Hanser, 2011

Linß, G. Qualitätsmanagement für Ingenieure, 2. Auflage, Fachbuchverlag Leipzig, 2005

Masing T. Pfeiffer, R. Schmitt, Masing Handbuch Qualitätsmanagement, Hanser, 6. Aufl.

Wittmann, J., The Safe Launch Concept, in Quality Management in Technology, 2019, Hrsg. J. Wittmann & W. Bergholz, Kindle , Direct Publishing

Tele-Experiments with Mobile Robots

Objectives

The idea of this course is to use modern teleoperation and make robotics more approchable. Experiments part of this course can be performed via internet and these include experiments in robot kinematics, navigation of remote rovers, path planning and sensor data acquisition and processing. The real robot used in the experiments is a four wheeled ackermann steered real wheel driven indoor mobile robot designed and built at our department specifically for remote experiments.

Learning Content

Tele-Experiments with mobile robots" is an attempt to put basic robot theory and its implementation together to bring to students an interesting and practical course. Given that this tele-course is simultaneously used as part of regular on-site lectures, the course contents are kept up-to-date and always accessible. The experiments available here include a carefully selected mixture of real-world and simulation of robotic principles. Various topics in field robotics including kinematics, navigation principles, path planning, theoretical analysis and inverse kinematics, sensor data acquisition and processing are discussed and students are presented with challenging quizzes before beginning the experiments. Sensors are also chosen so that students get confusing results and are supposed to spend time thinking about the acquired sensor values and how to interpret those. Time delay concepts in robot teleoperation on variable bandwidth networks are also transparently presented to users as part of involuntary learning.

Contents:

1) Kinematics of a car-like mobile robot
2) Navigation control of a car-like mobile robot
3) Path planning of a car-like mobile robot

4) Modelling of the forward and inverse kinematics of differential drive robot
5) Sensor data acquisition and processing

Type of Examination

written ex. 90 min.

Methods

Virtual internship

Forms of interaction with the system/lecturer:
e-mail

Forms of interaction with fellow learners:
e-mail

ERP Systems and Digital Transformation

Objectives

Enterprise Resource Planning Systems (ERP systems) are part of the basic equipment of medium-sized companies and global corporations. In the operational environment they are the central application systems for controlling operational processes. As the central control unit and memory of every company, ERP systems support the operational work processes and, among other things, take over the integration task across all departments, from sales and procurement to production and accounting.
The digital transformation is changing work processes and forms of organization (see VDI 2013), which means that companies need to change their competence profiles (Gerholz 2018). Studies indicate that the ability to solve problems in the environment of operational processes and the central application systems (ERP systems), the understanding of new technologies (including the use of IoT, cloud computing, and AI) and monitoring activities (e.g., analysis of the operational databases resulting from the processes; data analytics) are important (IW 2016).
This CLASSIC vhb course addresses these needs and introduces the central, operational application systems (ERP systems). After a theoretical introduction to the topic "ERP Systems" and "Business Processes", the learning environment offers participants the opportunity to deepen their knowledge of two ERP systems (Infor VISUAL ERP and Microsoft Dynamics NAV) and to consolidate the theoretical foundations through practical experience. In the subsequent case studies **"IoT"** , **"Mobile ERP"** , and **"Data Extraction"** , participants are given the opportunity to delve into current key topics in the

field of business digitization processes. As an integrating data hub, ERP systems are the central starting point for implementing these digital trends.
Internet of Things (IoT) offers the technical basis in the production environment to connect machines and material digitally with the business application systems without media discontinuity. With the IoT infrastructure, planning-relevant machine data such as machine running times, downtimes, and rejects can be automatically reported directly from the shop floor up to the strategic planning systems (ERP system). The planning process is further optimized using current and accurate data points. In the case study, Microsoft Azure and a Raspberry simulator are used as basic components to penetrate the basic architecture of IoT solutions.
Mobile ERP is the application of an ERP system on mobile devices such as tablets and mobile phones. This type of application allows data to be created and retrieved in real time regardless of the company's location. In this way, for example, customer requirements can be better met. Ultimately, this leads to an improvement in the flow of information and to an optimization of the process flows. In the case study, the participant gains experience in the application and function of mobile ERP solutions using Microsoft Dynamics NAV as an example.
Data Extraction is the basis of any digitalized system. The exchange and provision of data even across company boundaries and the evaluation of this data by data analysis tools such as Power BI, Qlik, or Tableau form the technical basis of Business Intelligence projects. The case study uses PowerBI to develop basic concepts for connectivity and data presentation.

After successful completion of the module the learner should be able to ...

- identify structural characteristics and functionalities of ERP systems and compare individual ERP systems with each other based on these,
- recognize the integration effect of ERP systems and their architecture,
- assign digital task managers to operational tasks in a targeted manner,
- describe the potential of mobile ERP applications (Mobile ERP),
- describe and implement a basic architecture for the integration of sensor data into an ERP system in the context of the Internet of Things (IoT), and
- know and apply the possibility of data extraction and evaluation in the ERP environment as the basis of Business Intelligence (BI) software.

Learning Content

- Introduction to the field of ERP systems - LEA's DREAM: From industrialization to digitalization
- ERP basic knowledge - THEORY
- ERP application - INFOR VISUAL ERP
- ERP application - MICROSOFT DYNAMICS NAV
- Case study: IOT

- Case study: MOBILE ERP
- Case Study: DATA EXTRACTION

Type of Examination

written student research project

Methods

virtual lecture

Computer Networking and Secure Network Management Interactive Online

Objectives

The course is divided into two parts:
Part I: Fundamentals of Computer Networking
Part II: Secure Computer Network Management
Part I: Fundamentals of Computer Networking

The standard ISO/OSI computer networking model is introduced first and compared with the TCP/IP model based on RFC specifications; the roles and features of each of the layers of both models are presented.

The most important protocols and services of each layer used for networking the local and remote computers are also presented in the form of a top-down approach. All protocols are analyzed hands on using remote virtual labs and analyzer tools such as Wireshark. The roles and the main features of the network components, i.e. hub, switch, router and DNS server are addressed as well. Their operations are shown and tested using the remote virtual labs and experimental virtualized network configurations. There is also a project (programming of a simple application based on TCP and UDP sockets) which is a prerequisite for admission to the final exam.

Teaching resources offered: tutorials, lab instructions, virtualized ready set network configuration (downloadable on students PCs), case studies, forums, exam patterns, student support materials
Part II: Secure Computer Network Management

The role and the objectives of network management (NM) for an organization are initially addressed. Various standard and private Management Information Bases (MIB) and remote MIBs are presented. The different types of network management tools, i.e. OpenNMS, NetFlow Collector, as well as the network management protocols SNMPv2/v3, NetFlow and OpenFlow network management protocols are experienced hands on based on virtualized experimental virtual networks and software tools.

Experiments are also conducted on the fundamentals of the Reconnaissance and DoS network attack types and their effects on network components and network applications to gain hand-on experience. An understanding is gained of the need for protection tools and the various types of tools. Legacy protection tools and other techniques for protecting the network components (FW, IPS, VPN) are addressed. Furthermore, secure management concepts (e.g. migration to NGFW, NGIPS, Sandbox) for the purpose of protecting against new types of attacks (e.g. ransomware, protocol anomalies) are implemented. In addition, awareness is raised of the security assurance requirements of organizations for network protection.

Teaching resources offered: tutorials, lab instructions, virtualized ready set network configuration (downloadable on students PCs), case studies, forums, exam patterns, student support material

Collaborative and cumulative project for Part II: Program and implement a secure Software Defined Network (SDN) using Snort as the intrusion attacks detector. The project is carried out in a collaborative manner by international teams of 2-3 students. The project is cumulative, i.e. each project step is based on the framework provided by the prior steps. The project is mandatory for admittance to the final exam.

Learning Content

Content:

Part I: Fundamentals of Computer Networking

- Computer Networking Terminology
- Computer Networking Architecture
- Application Layer
- Transport Layer
- Network Layer
- Multiprotocol Label Switching (MPLS)
- Data Link Layer wired networks
- Data Link Layer wireless networks
- Multimedia Technology

Part II: Secure Computer Network Management

- Surveys of Fundamentals on Computer Networks
- Network Management (NM) Architecture
- Management Information Bases (MIBs)
- NM Protocols
- Managing Network Security
- Managing Network Protection

Detailed content:

Part I: Fundamentals of Computer Networking

- Computer Networking Terminology
- Computer Networking Architecture: ISO/OSI versus TCP/IP models, role of the layers, interfaces, and protocols between layers
- Application Layer: services, application protocols (HTTP, FTP, E-Mail, DNS)
- Transport Layer: TCP protocol (sockets, analyze, error cases), UDP protocol (analyze), application programming using TCP/UDP Sockets
- Network Layer: addressing in global networks, subnetting, routing in Internet, routing algorithms, routing protocols (RIPV2 & OSPF), routing tables, ICMP protocol, protocol analyses, router operation
- Multiprotocol Label Switching (MPLS)
- Data Link Layer wired networks: CSMA/CD protocol, Ethernet versions, Ethernet analyses, VLAN principle, WAN protocols, switch operation
- Data Link Layer wireless networks: CSMA/CA protocol according to IEEE 802.11, message analyzes, access point operation
- Multimedia Technology: VoIP operation, RTP, RTCP, SIP, G.711, G.723 protocols, analyses of VoIP protocols

Part II: Secure Computer Network Management

- Surveys of Fundamentals on Computer Networks: MAC Control, TCP/IP Stack, STP protocol, VLANs, subnetting, routing algorithms, routing protocols, routing tables, QoS, CoS
- Network Management (NM) Architecture: reference model, legacy NM functionalities, proxy architecture, policy governed architecture, EVAS NM architecture (Endpoint Visualization, Access and Security), Software Defined Networks architecture (SDN), Mininet
- Management Information Bases (MIBs): standard and private MIBs (MIB II, RMON1, RMON2, ASN.1), language, Structure of Management Information (SMI), Basic Encoding Rules (BER), NM Systems (OpenNMS, NetFlow Collector)
- NM Protocols: SNMPv2, Secure SNMPv3, NetFlow, NetCONF, OpenFlow for SDNs, Case Study based on Mininet
- Managing Network Security: Confidentiality-Integrity-Availability-Model, managing Network Access Control (NAC), legacy NAC using Std. IEEE 802.1X and RADIUS; Case Study: NAC using Policy Governed Network CISCO-ISE; managing Transport Layer Secure Connections (SSL, TSL); managing Network Layer Security (IPSec and VPNs); managing Network Access Decision Control using Policy Engines
- Managing Network Protection: Type of Attacks (Reconnaissance, Denial of Service (DoS), DDoS), case studies of network attacks, managing protection methods (packet filtering, ACL, PAT/NAT, FW, VLAN, Honeypots, next generation FW (NGFW), next generation IPS (NGIPS), managing Sandboxing Protection)

Lab assignments:

1. Managing Static/RIPv2/OSPF routing
2. Monitoring/controlling CNs using SNMP v2 & v3 and MIBII technology
3. Monitoring the CN Security using OpenNMS and SNMP
4. Monitoring the CN Security using NetFlow Prot. and NetFlow Collector
5. Configuring/analyzing CN protection using FW and NAT tools
6. Programming, deploying, and analyzing various CN attacks (Reconnaissance, DoS)
7. Configuring/analyzing VPN based traffic protection using OpenVPN
8. Configuring/analyzing IPS protection using Snort
9. Configuring/analyzing network attacks using Cuckoo Sandbox
10. Monitoring/controlling SDN-based CNs using Mininet

All assignments are carried out using the virtual lab container with network components and software packages already installed. The network components are based on virtual machines and open source software tools such as Wireshark, Vyos Router supporting MIBII and SNMPv2&3, NetFlow Agents, OpenNMS, NetFlow Collector, Snort, OpenVPN, Mininet, and OpenvSwitch. All assignments are mandatory for admittance to the exam.

Type of Examination

written ex. 90 min.

Methods

Virtual seminar

Forms of interaction with the system/lecturer:
e-mail, cooperation between learner and supervisor during task processing, exercises for self-study

Forms of interaction with fellow learners:
e-mail, forum

MSS Quantum Computing

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.

MSS-14 Master's Module

Module code	MSS-14
Module coordination	Prof. Dr. Josef Schmid
Course number and name	MSS 3102 Master`s thesis MSS 3103 Master seminar
Semester	3
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	0
ECTS	25
Workload	Time of attendance: 0 hours self-study: 750 hours Total: 750 hours
Type of Examination	colloquium, master thesis
Weighting of the grade	25 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's 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's thesis (20 ECTS), the Master's seminar (5 ECTS) is also part of this module. The master's seminar consists of two parts that must be passed to successfully complete the module. To prepare for the master's thesis, participation in the seminar series "Career Start into German Technology Companies" is mandatory. The seminars / workshops are offered as block events 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 application processes and the general conditions of the German labour market and its entry after graduation. The second part of the Master's seminar consists of the colloquium. After submitting the Master's thesis, it is presented in a presentation of about 15 minutes and then defended. The colloquium is assessed with 5 ECTS.

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 40 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.