Module Guide
Mechatronic and Cyber-Physical Systems

Faculty Applied Natural Sciences and Industrial Engineering
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MCS-1 Cyber Physical Systems

Module code	MCS-1
Module coordination	Prof. Dr. Frank Denk
Course number and name	MCS1101 Structure and Functions of Cyber Physical Systems MCS1102 Business Models for CPS
Lecturer	Prof. Dr. Frank Denk
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	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. 90 min.
Duration of Examination	90 min.
Weight	6 out of 90 ECTS
Language of Instruction	English

Module Objective

Structures and Functions of Cyber-Physical Systems

New business models of cyber-physical systems

Intelligent, self-regulating, sensor-supported and networked production systems will make "intelligent factories" possible in the near future. At the other end of the spectrum, the industrial Internet of Things (IIOT) has become relevant in the social sphere.

The main objective of the module is the basic understanding, analysis and recognition of the different functionalities of the system components within a cyberphysical system structure.

The development of IT technology has influenced the global business landscape. Customers change from traditional roles, in relation to the company and in interactions with each other in connection with the social networks. Supply chains are being reinvented, setting new standards in terms of time and space. Risk, opportunity, innovation and capital must all be redefined. Simultaneous management within an organisation and coexistence with external ecosystem partners requires new instruments and new attitudes. Business models are being reinvented in a fascinating way. Strategic agility has, to some extent, been forced upon us by the economic situation.

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

Professional competence:

- Embedded systems and applications;
- Wireless technologies in industry and household;
- Intelligent systems for sensor and actuator applications;
- Concept of IT-controlled business models;
- Factors that determine customer value;
- Barriers and enabling factors for modern business models;

Methodological competence:

- Understanding, analyzing and synthesizing information about Internet technologies of embedded computer systems;
- Communication with suppliers of intelligent system components, such as intelligent sensors and actuators;
- Discussion of important cyber-technical issues, such as the robustness and feasibility of communication interfaces.
- Understanding of different business concepts of cyber-physical systems;
- Identification and analysis of the different forms of technical business solutions;
- Synthesis of customer values;

Personal competence:

- Create simple descriptions of the structure and functions of cyber-phyiscal systems.
- Acquisition and transfer of system terminology
- Construction of simple business models of a cyber-physical system.
- Capturing and communicating customer needs

Social competence:

- Work in small groups to discuss and present the overview.
- Presentation and discussion of realized business models for different business concepts.

Applicability in this and other Programs

Structures and Functions of Cyber Physical Systems:

The module provides a basis for embedded system and IT-related modules in all study programs of the Faculty of Applied Natural Sciences and Industrial Engineering;.

New Business Models for Cyber Physical Systems:

Can be used in any other study program in the field of New Economics.

Entrance Requirements

Bachelor's degree in mechatronics, mechanical engineering, electrical engineering or bachelor's degree in industrial engineering, technical physics or computer engineering.

Learning Content

Structures and Functions of Cyber-Physical Systems:

- Design of Embedded Computer Systems
- CPS Applications
- Internet of Things
- Ubiquitous Computing
- Industry 4.0 - Digital Manufacturing
- Sensors and Actuators
- RFID
- IPv4 and IPv6
- International Standard OPC-UA
- Safety

New Business Models of Cyber-Physical Systems:

- Customer Value from the Customer Process
- More Customers and More for the Customer
- Innovation and Personalization
- Silent Commerce
- Examples of New Business Models
- Analyzing
- Economics Calculations

Teaching Methods

Lectures / tutorials / home work / group activities

Whiteboard, visualizer online learning portal (iLearn).

Recommended Literature

Structures and Functions of Cyber-Physical Systems:

- DietmarP.F.Möller: Guide to Computing Fundamentals in Cyber-Physical Systems; Concepts, Design Methods, and Applications; Springer-Verlag;
- Eva Geisberger/Manfred Broy: Living in a networked world; acatech STUDY 2015;
- Acatech: Cyber-Physical Systems; acatech POSITION PAPER 2011

New Business Models of Cyber-Physical Systems:

- Henning Kagermann: IT Driven Business Models; Global Case Studies in Transformation; Wiley 2011
- Gassmann, Frankenberger: The St. Gallen Business Model Navigator; University of St. Gallen

MCS-2 Cooperative and autonomous systems

Module code	MCS-2
Module coordination	Prof. Dr. Wolfgang Aumer
Course number and name	MCS1103 Advanced Robotics MCS1104 Autonomous systems MCS1105 Case Study Cooperative and autonomous systems
Lecturers	Maximilian Apfelbeck Prof. Dr. Wolfgang Aumer Prof. Dr. Gökçe Aydos Achim Kämmler
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	postgraduate
Semester periods per week (SWS)	12
ECTS	14
Workload	Time of attendance: 180 hours self-study: 240 hours Total: 420 hours
Type of Examination	written student research project, written ex. 120 min.
Duration of Examination	120 min.
Weight	14 out of 90 ECTS
Language of Instruction	English

Module Objective

The contents of the module **Cooperative and Autonomous Aystems** enable the students to apply advanced knowledge in robotics based on the basics of robotics. Networking with autonomous systems supports the application-oriented teaching of the methodology and professional competence of robotics. The case study supports the independent deepening of the analysis and utilization of autonomous systems and robotics within a team.

After completing the Cooperative and Autonomous Systems module, students will be able to

- Develop application-oriented solutions from the acquired methods for autonomous systems with regard to localization, navigation, route planning, obstacle recognition and tracking.
- Analyze and apply robotic methods in a targeted manner
- Using the generated methods in simulation models

In the module **Cooperative and Autonomous Systems** the following competences are to be taught:

Professional competence:

Professional competencies are acquired in the sub-module Cooperative and autonomous systems:

- Understanding and applying methods of autonomous systems
- Modelling of environmental conditions and vehicle relations
- Apply the methods for the localization of vehicles in space
- Application of methods for obstacle recognition and route planning
- Analysis of control loops for autonomous systems
- Understanding and Applying Denavit-Hartenberg Relationships
- Understanding and applying forward and inverse kinematics
- Application of robot simulations and programming of robots
- Understand and apply the functions for joint collaboration between robots and humans.
- Understanding and applying methods of machine learning, in particular artificial intelligence
- Understanding different approaches to building assembly lines

Methodological competence:

Methodological competencies are acquired in the submodule Cooperative and Autonomous Systems:

- Application of robot programming
- Verification (evaluation) of robot movements
- Application of localization, navigation, route planning, and obstacle detection of autonomous systems
- Application of calculated robot relations in suitable simulation systems

Personal competence:

The Case Study Cooperative and Autonomous Systems teaches students how to solve complex robotic problems and how to use them as autonomous systems in groups with distributed tasks. The students learn how to analyze, apply and evaluate a task in relation to autonomous systems.

Social competence:

The students are able to view autonomous systems on the basis of case studies and to deepen and use their competences acquired from the module in group work.

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and transfer possibility for the application of autonomous system to provide irrespectively of the mobility platform for different application scenarios. Interfaces to mechatronics, control engineering, electrical engineering and computer science result.

Entrance Requirements

Bachelor's degree in mechatronics, mechanical engineering, electrical engineering, industrial engineering, technical physics or computer science

Learning Content

Within the framework of the lecture "Advanced Robotics" knowledge about essential topics of autonomous robot systems will be imparted. The focus is on assistance, service and mobile robots. In this context, guidelines for collaborative robots and mobile robots will be discussed. In addition, robot system architectures and path planning are the topics of the lecture.

The subject "Autonomous Systems" deals with in-depth contents of mobile and collaborative robotics. 3D obstacle / object recognition, localization and map generation, as well as navigation and route planning play a decisive role. Cognitive systems, machine learning and artificial intelligence are also addressed.

On the basis of a selected application example, the students are supposed to carry out independ literature research, if necessary independent small subtasks,etc. and work on the topic themselves by means of literature research.

Sample Autonomous Systems

Characteristics of the required control loops of networked systems

Sensors / actuators for vehicle control

Localization and Mapping

Route planning, tracking and obstacle detection

……

The case studies are examined as so-called examination papers, i.e. no classical examination.

Teaching Methods

Advanced Robotics and Autonomous Systems

Seminaristic teaching with joint exercises to deepen the theory learned through application

Case Study Cooperative and Autonomous systems

Guided processing of seminar topics in study groups. Accompanying events / presentations depending on the selected topic area.

Remarks

The students learn to analyze and apply theoretical knowledge about the topics of the case study independently. This intensifies the transfer of knowledge into practice and the targeted deepening of the acquired technical and methodological competencies by recognizing contexts and evaluating them.

Recommended Literature

- Siciliano B., Khatib O.: Handbook of Robotics. Springer.
- Corke P.: Robotics, Vision and Control. Springer.
- Craig J. J.: Introduction to Robotics. Pearson Education.
- Spong M. W.: Robot Modeling and Control. Wiley.
- Siegert H. J., Bocionek S.: Robotik: Programmierung intelligenter Roboter. Springer.
- Brillowski Klaus: Einführung in die Robotik - Auslegung und Steuerung serieller Roboter. Shaker-Verlag.

MCS-3 Advanced Simulation Systems

Module code	MCS-3
Module coordination	Prof. Dr. Peter Firsching
Course number and name	MCS1106 Advanced Modeling and Simulation MCS1107 Case Study Mechatronic System Simulation
Lecturers	Prof. Dr. Gökçe Aydos Prof. Dr. Peter Firsching
Semester	1
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	postgraduate
Semester periods per week (SWS)	16
ECTS	10
Workload	Time of attendance: 120 hours self-study: 180 hours Total: 300 hours
Type of Examination	written student research project, written ex. 90 min.
Duration of Examination	90 min.
Weight	10 out of 90 ECTS
Language of Instruction	English

Module Objective

The contents of the module "Advanced Modelling and Simulation" enable students to increasingly design virtual product development processes and to use specifically selected and designed models. In addition to the application-oriented teaching of methodology and professional competence with regard to parametric and non-parametric model development as well as the generation of process-oriented process descriptions, the so-called Case Study Mechatronic System Simulation supports the independent deepening of the analysis, synthesis and evaluation of modelling and simulation tasks in the team.

After completing the Advanced Modelling and Simulation module, students will be able to

- select the required methods from the learned methods for experimental modelling and to introduce them into a modelling process.

- apply methods for the experimental generation of models of dynamic systems and analyze the model results in a targeted manner,

- assign and use the generated models in a suitable way to simulation tools.

In the module Advanced Modelling and Simulation, the following competences are to be taught:

Professional competence:

- Understanding and applying methods of experimental modelling of dynamic systems
- Consolidation (synthesis) of the model-building methods to complex overall models
- Understanding and applying methods of machine learning, especially artificial neural networks in the modelling process
- Understanding different approaches to the design of simulation systems

Methodological competence:

- Application of state machines for the modelling of event-driven systems
- Verification (evaluation) of modelling results
- Application of generated models in suitable simulation systems
- Assessment of the suitability of models for the phases of a product development process.

Personal competence:

The case study Mechatronic System Simulation teaches future graduates how to solve complex modeling and simulation tasks in teams with distributed task areas. The students learn how to analyze, synthesize and evaluate a task in relation to mechatronic systems.

Social competence:

The students are able to look at the problems from different perspectives and to use their competences acquired in the module situation appropriately in individual and group discussions.

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and the transfer capability to provide technical systems in the form of suitable models for different simulation scenarios. This creates interfaces to courses of study, such as mechanical engineering, mechatronics and computer engineering.

Entrance Requirements

Bachelor's degree in mechatronics, mechanical engineering, electrical engineering or bachelor's degree in industrial engineering, technical physics or computer engineering.

Learning Content

I – sub-module Advanced Modelling and Simulation

1. Mathematical Models of Physical Systems
1.1. Differential Equations of Physical Systems
1.2 Linear Approximation of nonlinear System Equations
1.3 Signal flow charts
1.4 Transfer function of Linear Systems
1.5 State space models of Linear Systems
1.6 Discrete time systems
2. System identification by parameter identification
2.1. Theoretical and experimental system analysis
2.2 Parameter identification in time domain
2.3 Parameters of 2^{nd} and n^{th} order time delay systems
2.4 Parameter identification in frequency domain
3. Parameter estimation
3.1. Principles of parameter estimation
3.2 Least squares method
3.3 Steepest descend method
3.4 Parameter estimation of dynamic systems
3.5 System models based on artificial neural networks
4. Event driven systems
4.1. Introduction – concepts of finite state machines
4.2 Application examples – sequential function chart
5. Mathematical Models of Physical Systems

5.1 The concept of analogue computing
5.2 Simulation scenarios and process models
5.3 Block oriented vs. object oriented simulation
5.4 Simulation systems overview

II – sub-module Case Study Mechatronic System Simulation

1. Introduction
1.1 Project management of a working group
1.2 Introduction working topics
2. Periodic reports of the working groups
3. Presentation of project results
3.1 Mid-term presentation
3.2 Final presentation and written report

Teaching Methods

Advanced Modelling and Simulation

Seminaristic teaching with group work and joint exercises as well as presentations to deepen the knowledge achieved through application

Case Study Mechatronic system simulation

Guided processing of seminar topics in working groups. Accompanying events / presentations of external lecturers depending on the selected topic area.

Remarks

It is particularly important that students apply the theoretical knowledge gained in the Advanced Modelling and Simulation sub-module to the topics of the case study independently. This intensifies the transfer of knowledge into practice and the targeted deepening of the acquired technical and methodological competencies through the recognition of contexts and their evaluation.

Recommended Literature

Robert L. Woods, Kent L. Lawrence: Modeling and Simulation of Dynamic Systems. Prentice Hall, 1997

Isermann R.: Identification of dynamic systems. Springer-Verlag, 2011.

Ljung L., Glad T.: Modeling of dynamic systems. Prentice Hall, 1994

Dorf R. C., Bishop R. K.: Modern Control Systems. Pearson Educational International, 2017.

Kröse B., van der Smagt P.: An introduction to Neural Networks (PDF). 1996

Litz L.: Grundlagen der Automatisierungstechnik. Oldenbourg-Verlag, 2013.

Wernstedt J.: Experimentelle Prozeßanalyse. Oldenbourg-Verlag, 1989.

MCS-4 Human Machine Interfaces

Module code	MCS-4
Module coordination	Prof. Dr. Frank Denk
Course number and name	MCS2101 Virtual Reality / Augmented Reality MCS2102 Mobile and adaptive HMI MCS2103 Case Study VR/AR in System Engineering
Lecturers	Prof. Dr. Marcus Barkowsky Prof. Dr. Frank Denk
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	postgraduate
Semester periods per week (SWS)	10
ECTS	12
Workload	Time of attendance: 150 hours self-study: 210 hours Total: 360 hours
Type of Examination	written student research project, written ex. 120 min.
Duration of Examination	120 min.
Weight	12 out of 90 ECTS
Language of Instruction	English

Module Objective

The lectures `'Virtual Reality / Augmented Reality', 'Mobile and Adaptive HMI' and the corresponding case study impart basic knowledge about the essential topics of the digital extension possibilities - the "Extended Reality" - of technically real solutions in the field of system engineering development. In the foreground are software applications for the realization of the HMI - Human Machine Interface - via different sensory perceptions and the technical concepts for the implementation of the corresponding content by controllers, such as an HMD - Head Mounted Display. In this context, the different digital extensions and definitions are discussed. Furthermore, the conceptual planning and implementation of VR/AR projects are covered in the byway of the lecture.

In the case study, the students will work on selected examples thematically a project team with differently defined roles and work packages. In a first review, the topic will be explained through research and existing solutions will be pointed out. The overall process of the machining process by way of a "value chain" is realized through research - synthesis - design - prototype and evaluation.

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

Professional competence:

- Virtual and Augmented Reality systems and applications;
- Applied technologies in the field of Virtual and Augmented Reality;
- Current topics of the first generation for Extended Reality applications;
- Students can design, criticize, and implement mobile human-machine interfaces that meet the guidelines for usability, user experience, and experience quality.
- Students understand the visual perception and haptics of people with regard to the development of efficient graphical user interfaces.
- Students can analyze a defined and realized topic in the AR or VR-project area;
- Role definition according to the domain hardware, software or system within a group;
- Creation of a case study: final report of all group members with defined generation process;

Methodological competence:

- Understand, analyze and synthesize information about Extended Reality-system technologies;
- Communicate with vendors of AR and VR-system components, such as headsets;
- Discussion of important technical issues, such as controller, field of view and inside-outside tracking.
- Collection of initial experience in the design process, including background information such as passport law.
- Students are able to create personas, scribbles and wireframes.
- Students know how to implement their design with web technology, progressive web applications and native Android programming.

Personal competence:

- Construct simple AR/VR applications
- Acquisition and transfer of system terminology

- The exercises will be carried out in small groups of 4 students each and a support and peer review process will be set up between the groups.

Social competence:

- Presentation of individual technology solutions and limitations of announced AR/VR projects.
- Improving team and communication skills, including fair and productive criticism of other groups' work.

Applicability in this and other Programs

Virtual and Augmented Reality:

The module provides a basis for HMI modules in all study programs of the Faculty of Applied Natural Sciences and Industrial Engineering;.

Mobile and Adaptive HMI:

Generic and basic topics are included and represent use cases for all study programs of the Faculty of Applied Natural Sciences and Industrial Engineering;.

Entrance Requirements

Bachelor's degree in mechatronics, mechanical engineering, electrical engineering or bachelor's degree in industrial engineering, technical physics or computer engineering.

Learning Content

Virtual and Augmented Reality:

- History in context
- VR and AR Technology
- Used form factor in AR and VR
- Current state of the first generation AR and VR
- Current issues in AR and VR
- Consuming Content in AR and VR
- Projects` creation

Mobile and Adaptive HMI:

Perception:

- The human eye
- Human visual perception
- Higher cognitive processes
- Gestalt Theory

Human-Machine interaction concepts:

- Cognitive background

- Utility, Usability, User Experience
- Quality of Experience

Designing for User Experience:

- 4 Steps of the design process
- Specific considerations for design on mobile devices
- Design principles for interactive Web applications using HTML, CSS, Javascript

Exercise on User Experience Design:

- Designing a sample application
- Refreshing HTML, CSS, Javascript
- Frameworks for Mobile Application Development
- Understanding Cordova and implementing the sample application

Native Application development with Android:

- Understanding the application life cycle
- Tools of Android development
- Guidelines for material design usage
- Implementing a sample application

Case Study for Virtual and Augmented Reality in System Engineering:

- Project aquisition
- Role definition
- Preperation of summarized report
- Presentation

Teaching Methods

VR/AR:

Lectures / tutorials / home work / group activities

Whiteboard, visualizer online learning portal (iLearn).

HMI:

The course uses a seminar style alternating between lectures and exercise phases.

The design and implementation part is done in groups of 4 students which hones team working and constructive criticism skills.

Case Study for Virtual and Augmented Reality in System Engineering:

- Self-study based on theme paper
- Project Team work

Recommended Literature

Virtual and Augmented Reality:

- Paul Mealy: Virtual & Augmented Reality for dummies; John Wiley;
- Gartner: Hype Cycle Report 2018
- German Patent Search: https://www.dpma.de
- European Patent Search: https://epo.org
- US-Search: http:// patft.uspto.gov

Mobile and Adaptive HMI:

- Bruce Goldstein, “Sensation and Perception”, 10. Auflage, 2016, Cengage Learning, 10th edition, ISBN: 978-1305580299
- Jens Jacobsen, Lorena Meyer, “Praxisbuch Usability und UX”, Rheinwerk Computing, ISBN: 978-8362-4423-7
- Jan Semler, “App-Design”, Rheinwerk Design, 2016, ISBN: 978-3-8362-3453-5
- W3schools, Tutorials on HTML, CSS, Javascript, available online: https:// www.w3schools.com
- Android, “Up and Running with Material Design”, online: https:// developer.android.com/design/index.html
- iOS, “Human Interface Guidelines, iOS Design Themes”, online: https:// developer.apple.com/ios/human-interface-guidelines/overview/themes/

Case Study for Virtual and Augmented Reality in System Engineering:

- Paul Mealy: Virtual & Augmented Reality for dummies; John Wiley;

MCS-5 Additive Manufacturing (AM)

Module code	MCS-5
Module coordination	Prof. Dr. Stefan Scherbarth
Course number and name	MCS2104 Technologies of Additive Manufacturing MCS2105 AM production processes MCS2106 Case Study Cyberphysical production systems using AM
Lecturers	Matthias Hien Fabian Pacher Prof. Dr. Stefan Scherbarth Maximilian Stöckl
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	postgraduate
Semester periods per week (SWS)	12
ECTS	14
Workload	Time of attendance: 120 hours self-study: 180 hours Total: 300 hours
Type of Examination	written student research project, written ex. 150 min.
Duration of Examination	150 min.
Weight	14 out of 90 ECTS
Language of Instruction	English

Module Objective

The module has the following learning objectives:

- The students understand the Additive Manufacturing (AM) production process in detail.
- They can name and transparently describe the common AM technologies.
- The students can explain the AM process chain.
- The students can describe the advantages and disadvantages of the AM-technology in detail.
- The students can calculate the major economical process key values of the AM-technology.
- The students know the keystones for a successful implementation of metal based AM-technologies.
- The students can apply the basic design rules for a metal based AM process.
- The students have an understanding of the future perspective of the AM-technology.

Applicability in this and other Programs

Inside program: MCS-8 Master Module: Masterthesis, Masterseminar

Continuing: PhD work or PhD studies

Entrance Requirements

Bachelor's degree according to examination study regulations.

Learning Content

Additive Manufacturing in accordance with 3D-print based on a concatenation of innovative technical sub-disciplines. These are illustrated along the whole manufacturing process and discussed in appropriate professional manner.

- Acquisition and processing of 3D-data
- Detailed procedure of selected additive production processes
- Production-ready design (selection of forms and structures, support structures, bionic approaches)
- Materials (plastics, metals, binder, classification, characteristics)
- Production process

Additive respectively with 3D-print manufactured products do not only replace conventional products. The special characteristics of the production process enable new and process specific product features. Thereof again specific business models or process subsequences can be revealed, which are only applicable in additive manufacturing. The following topics outline these specific processes:

- Additive Manufacturing Production Process: Introduction, Classification and Definition
- Characteristics of AM Technology
- Technology Overview and Application Examples
- Economic Significance of Additive Manufacturing Technology
- Economic Calculation of the Additive Manufacturing Process
- Motivation for Additive Manufacturing beyond Economic Benefits
- Metal Additive Manufacturing Getting Started
- Design for Metal Additive Manufacturing
- Future Perspective of Additive Manufacturing

Topics which can be covered within the framework of the case study:

- development supporting use
- decentralized spare part production
- food-printing
- medical technological application
- bioprint technology
- reverse engineering
- tooling

Contributions from experts based in the industry can deepen the understanding of specific topics.

Case studies are so-called “Prüfungsstudienarbeit” (student research projects), there will be no classic exam at the end of the semester.

Teaching Methods

Type of teaching: Seminaristic instruction / exercise, home exercises

Media form: presentation with projector, blackboard, videos, exhibits, additional documents about iLearn drive

Remarks

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Recommended Literature

Additive Manufacturing Technologies

Gibson, Ian; 2014; (459 pages)

Springer publishing house; 2014

Additive manufacturing: 3D printing for prototyping and manufacturing

Gebhardt, Andreas; (611 pages)

Carl Hanser publishing house; 2016

Detailed script and selected scientific publications about ilearn platform

MCS-6 Fachwissenschaftliches Wahlpflichtfach (FWP)

Module code	MCS-6
Module coordination	Prof. Dr. Peter Firsching
Course number and name	Python FWP-Project Integrated Production Systems Programming in C++ Career start into German technology companies Automotive Drive Systems
Lecturers	Prof. Dr. Peter Firsching Björn Franken Daniel Maier Ulrike Sauckel Lisa Werner Virtuelles Angebot vhb
Semester	2
Duration of the module	1 semester
Module frequency	annually
Course type	compulsory course
Niveau	postgraduate
Semester periods per week (SWS)	40
ECTS	4
Workload	Time of attendance: 60 hours self-study: 60 hours Total: 120 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weight	4 out of 90 ECTS

Language of Instruction	English, German

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 nevertheless work on a topic related to mechatronic / cyberphysical systems under the guidance of the lecturer.

Furthermore, courses are offered in which students can learn or deepen their knowledge of the current programming languages, for example Python or C++.

Further courses deepen scientific topics in the field of mechatronic and cyber-physical systems.

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.

Recommended Literature

The literature results from the respective FWP subject.

Python

Objectives

The lecture „Python Basics Course“ conveys basic 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

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 basic 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)

FWP-Project

Objectives

Within the framework of the module "Fachwissenschaftliches Wahlpflichtfach", students are offered the opportunity to work on a technical project in which they are highly self-responsible and self-organized, but nevertheless guided by the lecturer on a topic related to mechatronic / cyber-physical systems. The following projects have already been carried out:

1. integration of optical surface analytics in a CNC machine

2. RoboCup 2020

After completing the project, the students have achieved the following learning objectives:

- Classification of the project topic into the overall topic of mechatronic and cyber-physical systems
- Development of a project organization for the successful implementation of the project
- Apply acquired knowledge from already completed modules of the Master's programme to the specific solution of the project task

The following competences are to be taught in the project:

Professional competence:

The required professional competencies are oriented towards the project topic.

Project 1 focused on the following areas of expertise

- Software development for embedded control
- Application of specialist knowledge from the field of drive technology and measurement technology

In project 2, the focus was on technical expertise:

- Application of knowledge about collaborative robots
- Implementation of the principles of cyber-physical systems on a mobile robot system

Methodological competence:

The students understand the combination of methods from different subject areas to a complex overall result.

Personal competence:

The students deal with methods of project organization. They recognize problems within the project and learn to work on solutions in a team structure with distributed tasks.

Social competence:

Students are enabled to deal with team structures beyond technical problems.

Learning Content

The contents result from the respective project topic.

Type of Examination

written ex. 90 min.

Methods

Guided teamwork

Seminaristic transfer of specialist knowledge which is not available to the required extent in the project team (example: special knowledge of PLC or microcontroller programming, use of industrial bus systems)

Recommended Literature

The specific literature results from the respective project topic.

Integrated Production Systems

Objectives

Participants of this course receive an overview of the tasks of a production manager in an international company:

- Motivation, philosophy, and objectives
- Methods and tools
- Experiences from industrial practice
- Overview of the current situation in terms of production systems of global acting companies

After having completed the course **'Integrated Production Systems'** students …

- understand the essential characteristics of the Lean Concept,
- know and interiorized the meaning of the existing Lean Principles,
- understand the principles and objectives of the continuous process of improvement and are able to apply the most important corresponding methods and techniques,
- understand the difference between technology- and process-orientated production,
- know the reasons for as well as possible structures and main principles of global production and corresponding supply chains,
- comprehend principles and goals of the TQM approach and are able to apply the most important corresponding methods and techniques,
- understand the Jidoka principle and resulting potential benefits,
- understand and are able to apply the TPM concept together with its eight pillars,
- comprehend and are able to quantify the material and energy flows of manufacturing companies as well as influencing factors,

- understand the meaning of information in production processes,
- know the terminology and the essentials of Lean Development and Lean Administration.

Entrance Requirements

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Learning Content

1 Historical derivation, definition, and fundamental terms of traditional and integrated production systems (Taylorism and its realization by Henry Ford); critical analysis of the classical methods of division of responsibilities/work; Lean Production as a solution approach for the problems demonstrated
2 Description of basic pillars of integrated production systems (continuous process of improvement, Total Quality Management, value stream method, flow principle, the role of employees in the context of Lean Management)
3 Methods und tools of the continuous process of improvement: Ishikawa diagram, Pareto Analysis, A3 report, 5-W
4 Process-oriented production: differentiation to technology-orientated production, description of the key elements of flow-orientated production: Kanban, Just in Time, One Piece Flow, Heijunka
5 Global production networks in the context of Supply Chain Management: fundamentals of Supply Chain Management, supply chain structures, supply chain strategies
6 Fundamentals, elements, and tools of Total Quality Management (TQM): client orientation in the light of globalization, staff retention und assistance, risks associated with the implementation of TQM, Overall Equipment Efficiency (OEE) as a measuring instrument
7 Jidoka and Low Cost Automation (LCA): explanation of the Jidoka principle and associated tools (Poka Yoke, Andon), description of the LCA philosophy (five-levels concept), guidelines and checklists for the introduction of LCA systems
8 Total Productive Maintenance (TPM): description of seven steps for the realization of TPM, overview of TPM tools: Makigami, value stream method etc., transfer of the TPM concept into practice
9 Material and energy efficiency: measurement methods for the determination of consumptions, strategies for consumption reduction, methods for tapping the potentials of energy savings in practice, transfer of the Lean Concept to the energy value stream

10 Transfer of the Lean Concept to information provision and distribution, CAD/ CAM methods, Product Lifecycle Management (PLM), Enterprise Resource Planning (ERP)
11 Lean Development: introduction to product development according to the Lean Concept, methods and tools supporting the product development process, outcome measurement instruments
12 Lean Administration: transfer of the Lean Methods to administrative and management processes, identification of administrative processes and corresponding wastage rates
13 Repetition of the contents and preparation of the written exam

Type of Examination

written ex. 90 min.

Methods

Virtual Lecture

Cooperation between learner and supervisor in task processing, exercises, exercises for self-learning, e-mail

Programming in C++

Objectives

This course teaches the fundamentals of the programming language C/C ++ in 2 parts of the course. Part 1 is suitable for beginners and participants with basic C / C ++ knowledge. Part 2 deals above all with dynamic objects and C ++ special concepts and turns to advanced users. The two parts of the course can be worked on independently from each other, or even in one semester.

The focus of the course is on the practical application of the programming concepts and syntax elements for solving problems in business informatics.

Qualification Goals:

In Part 1 (Fundamentals), the participants are enabled to learn the basics of an procedural programming language (C) and an object-oriented programming language (C++) in theory and practice to solve simple application problems of business informatics.

Part 2 introduces advanced programming concepts of an object-oriented programming language. The students acquire the skills and experience needed to solve complex application problems.

Learning Content

Part 1: C ++ for Beginners (static concepts)
1.1 Introduction to Programming
1.2 Variables, data types, operators, in-/output
1.3 Functions
1.4 Control Structures
1.5 Arrays / Sample application procedural programming
1.6 Paradigms of object orientation (OO)
1.7 Classes and objects
1.8 Constructor, member initialization list, overloading, destructor, static member variables
1.9 Inheritance / Sample application object-oriented programming
Part 2: Advanced C ++ (Dynamic concepts)
2.1 File Processing & Exception Handling
2.2 Pointers
2.3 Dynamic objects
2.4 Linked lists / Sample application file processing & error handling with linked lists
2.5 Polymorphism, virtual functions, abstract classes
2.6 Operator overloading
2.7 Templates

Type of Examination

written ex. 90 min.

Methods

Virtual lecture
Exercises, exercises for self-learning operation, e-mail
The students are offered intensive support by e-tutors.
Each part of the course includes a script with many practical examples. Each chapter also includes video tutorials, self-test tutorials and programming tutorials.

In each part of the course, two programming exercises must be prepared and delivered by the students by individual work. The timely delivered programming solutions are evaluated by e-tutors. A successful result is the precondition for attending the exam. Depending on successful exam-results, students will receive a certificate with their grade and ECTS-credit points.

Career start into German technology companies

Objectives

The students participate in a range of lectures, workshops and seminars that will provide them with the skills to successfully find working student positions or a company collaboration for their master thesis and later professional full time employment in Germany.

The module has the following learning objectives:

- The students get to know the German culture.
- They can apply to German companies in an appropriate way.
- The students learn more about the visa regulations and their importance for daily life.
- The students can apply the basics of scientific methods.
- The students are able to write an application for a job in Germany.
- The students know how to convince in a job interview.
- The students acquire basic knowledge of German labor law.
- The students are prepared for working life in Germany.

Entrance Requirements

Bachelor's degree according to examination study regulations and English skills' level B2.

Learning Content

The programme consists of three different levels, each contains various seminars the students have to participate in.

Level 1:

- How to apply to German companies
- Intercultural training
- Visa regulations and their importance in daily life

Level 2:

- How to convince in a job interview

- Individual CV check
- Scientific methods

Level 3:

- Introduction to German labor law (Rights and obligations in the German employment contract)
- Preparing for working life in Germany

Type of Examination

written ex. 60 min.

Methods

Type of teaching: Seminaristic instruction / exercise
Media form: presentation with projector, blackboard, additional documents

Recommended Literature

iLearn course “International Career Service”
The CV Book: your definitive guide to writing the perfect CV Innes, James (290 p.)
Pearson; 2012
The cover letter book; your definitive guide to writing the perfect cover letter
Innes, James (246 p.)
Pearson; 2012
The interview book. Your definitive guide to the perfect interview
Innes, James (298 p.)
Pearson; 2018
Detailed script and selected scientific publications about ilearn platform

Automotive Drive Systems

Objectives

The module Automotive and Industrial Drive Systems introduces diverse electrical drive systems, teaches the typical methods of control and shows the special requirements in an automotive or industrial environment, respectively. The subject offers an overview of electrical drive systems for industrial applications and in vehicles and introduces further sustainable drive concepts.

The students achieve the following learning objectives:

Professional competence:

- Special subject Automobile Electrical Drive Systems
- Students can list components of an electrical power train
- They know how to calculate the pulse patterns of a space-vector modulation
- They can describe the electro-chemical processes in batteries and can explain their behaviour
- They can oppose advantages and disadvantages of an electrical power train to a conventional combustion engine-driven car
- They can name hybrid vehicle concepts and alternative combustion engines
- They can analyse alternative fuels for their applicability in cars
- They can assess different power train concepts for their application
- Special subject Industrial Electrical Drive Systems
- Students understand the structure of a multi-axle motion control system

Methodological competence:

- They master the mathematical methods of a field-oriented description of three-phase electrical machines
- They can describe the dynamic behaviour of three-phase synchronous and asynchronous machines
- They can name different design approaches for speed control systems of electrical drives
- They can design speed control systems for electrical drives

Personal competence:

- Capture and transmit the system terminology

Social competence:

- Students work out contents within groups

Entrance Requirements

Formally: none

Learning Content

Special subject Automobile Electrical Drive Systems

1. Electrical Power Train

1.1. Motors

1.2. Inverter Control with Space Vector Modulation

1.3. Batteries

1.4. Charging Concepts

2. Fuel-assisted Electric Cars

2.1. Fuel-Cells

2.2. Hybrid Vehicles

3. Sustainable Combustion Engine Concepts

3.1. Alternative Fuels

3.2. Alternative Combustion Engines

Special subject Industrial Electrical Drive Systems

1. Industrial drives

1.1. General properties

1.2. Energy efficiency classes

1.3. Motion control

1.4. Charging Concepts

2. Dynamic models of electric machines

2.1. Modelling of the dynamic behaviour of electric machines

2.2. Clark / Park transformation

2.3. Dynamic model synchronous machine

2.4. Dynamic model asynchronous machine

3. Closed loop control of electric devices

3.1. General control system design

3.2. Speed control for DC machines

3.3. Control system design for 3~ machines

3.4. Direct torque control

Type of Examination

written ex. 90 min.

Methods

Seminaristic lessons, group work

Recommended Literature

R. Jurgen: Electric and Hybrid-Electric Vehicles. SAE international 2011.

J. Beretta: Automotive Electricity. Wiley 2010.

M. Ehsani / Y. Gao / S. Longo/ K. Ebrahimi: Modern Electric, Hybrid Electric and Fuel Cell Vehicle, 3. edition. CRC-Press 2019.

A. Emadi: Advanced Electric Drive Vehicles. CRC-Press 2015.

J. Erjavec: Hybrid Electric & Fuel Cell Vehicles, 2. edition. Delmar 2013.

I. Husain: Electric and Hybrid Vehicles, 2. edition. CRC-Press 2011.

A. Khajepour / S. Fallah / A. Goodarzi: Electric and Hybrid Vehicles. Wiley 2014.

B. Bose: Modern Power Electronics and AC Drives. Prentice Hall 2002.

G. Henneberger: Electrical Machines I. Lecture notes. Technical University Aachen 2002.

R. Dorf / R. Bishop: Modern Control Systems, 13. edition. Pearson Prentice Hall 2017.

Different journals

Application notes

MCS-7 Functional Safety

Module code	MCS-7
Module coordination	Prof. Dr. Peter Firsching
Course number and name	MCS3101 Principles of Functional Safety MCS3102 Design of safe Systems
Lecturers	Alexander Grosch Georg Zembacher
Semester	3
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Niveau	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. 90 min.
Duration of Examination	90 min.
Weight	6 out of 90 ECTS
Language of Instruction	English

Module Objective

In the module '**Principles of Functional Safety**' students learn to follow developments in the areas of operational safety and occupational safety over the course of time. Functional safety is classified in the comprehensive field of process and machine safety. The students work out general objectives and influencing factors for the application of safety technology.

Students learn about European treaties as the basis for directives, harmonized standards and occupational safety. In this context, the European legislative procedure, with regard to the development of technical guidelines and standards, will be presented.

Within the framework of this module, the students will become familiar with relevant technical guidelines with regard to the development of safe machines and processes.

A detailed examination of the Machinery Directive provides students with the necessary basic knowledge. Students learn about current developments in existing safety standards and guidelines. This results from the strong overlapping of IT security and machine security in the future in terms of industry 4.0, with the use of cyber-physical systems.

The students can understand the processes involved in the development of standards. They recognize the importance of harmonizing standards that should be applied with regard to the development of processes/machines in order to achieve conformity with European safety directives.

The learning section also introduces national and international organizations for standardization. In the course of a standards research, relevant standards from the areas of safety and functional safety are identified.

The students learn the meaning and the procedure for a CE-certification. In the context of the explanation of the CE certification process, the detailed consideration of risk analysis and risk reduction takes place on the basis of relevant, international standards EN ISO 12100 and EN ISO13849 at selected study examples. In the course of this work, the use of special software for the systematic evaluation of safety functions will be presented.

The participants of the module gain an insight into the application of statistical methods in the fields of safety engineering and reliability analyses. An overview of relevant parameters and distribution functions is given by the analysis of exemplary data sets.

In the lecture Design of Safe Systems, the students work out general objectives and influencing factors in the application of safety engineering.

Using an example project along ISO 26262, the students learn how to apply a product in consideration of the prescribed methods.

Within the framework of this module, students are introduced to relevant technical guidelines with regard to the development of safe products and their development processes and tools.

Students learn about current developments in existing safety standards and guidelines. This results from the future strong overlap of IT security and product security in the course of industry 4.0, when using cyber-physical systems.

The students learn the meaning and the procedure with a development tool certification.

The participants of the module gain an insight into the application of methods in the areas of security technology. An overview of relevant parameters and distribution functions is given by analyzing exemplary data sets.

After completing the module Functional Safety, the students have achieved the following learning objectives.

Professional competence:

- The students have built up a sound basic knowledge in the field of safety engineering, in particular functional safety.
- The students know and apply the legal framework and processes with regard to the creation of technical guidelines and the resulting harmonized standards, as well as the implementation of the European requirements at national level.
- The students are familiar with the current European directives (Machinery Directive, Low Voltage Directive and Electromagnetic Compatibility Directive) and understand their influence on development work and plant procurement.
- Students are familiar with the basic technical standards that must be taken into account when integrating safety functions. In this context, the EN ISO 12100 and EN ISO 13849 standards play a particularly important role in the module.
- The students are familiar with the technical process of CE-certification and understand the effects on the development process and machine procurement. They are aware of the legal obligations that apply in the course of CE-certification.
- The students know and understand the legal framework and processes related to the creation of technical products.
- The students are familiar with the basic technical standards that must be taken into account when integrating safety functions. In this context, the ISO 26262 standards play a particularly important role in the module.
- The students know the technical process of a safety-relevant development and understand the effects on the development process and the responsibility of customers and suppliers. They are aware of the legal obligations
- Students have a basic knowledge of statistical analysis of data sets in the field of safety engineering and reliability analysis.

Methodological competence:

- The students acquire the ability to conduct a targeted research of standards and guidelines.
- With their basic knowledge of directives, standardization and CE-certification, students are able to carry out a basic risk analysis in accordance with the EN ISO 12100 standard. In addition, the students have the methodological competence to design safety-related parts of control

systems (SRP/CS) according to the required performance level PLr using appropriate safety software (SISTEMA).
- With the technical basic knowledge about guidelines and standards it is possible for the students to implement the methodical competence of the safety-related parts of control systems.

Personal competence:

- The students acquire skills and strategies with which they can constantly update their knowledge with regard to safety technology in the rapid technological upheaval in the course of Industrialization 4.0.
- In the course of the module, students will be able to reflect on their responsibilities, which must be taken into account when designing new processes, machines or products with regard to safety aspects.

Social competence:

- Students acquire the ability to work together in mixed development teams, with special emphasis on clear communication and conflict management.

Applicability in this and other Programs

- Knowledge of standardization and standards research
- Statistical methods
- Methods for designing safe machines and processes

Entrance Requirements

none

Learning Content

Principles of Functional Safety

- Safety technology and occupational safety in the course of time
- Basics and terms of safety engineering
  - Distinction between system and functional safety
  - Goals and influencing factors in the development of safety concepts
- Legal framework in Europe with regard to safety technology
- Safety and health at work on the basis of European treaties
- Development of safety standards on the basis of European directives
- Future developments regarding the combination of IT security and functional security
- European directives for the development of safe machines
- Relevant Functional Safety Guidelines

- Machinery Directive 2006/42/EC
- Standards for safety technology
- Historical development in the field of standardization
- Definitions and terms from the field of standardization
- Significance, application and development of standards
- Harmonized standards
- International and national standard organizations
- Hierarchies and groupings of standards
- Presentation and comparison of standards in the field of functional safety.
- Practical approach to standards research. Exercises
- CE-certification
- CE-certification process
- Effects and influence of CE-certification on the development process and machine procurement
- Legal liabilities due to CE-certification and advantages of the CE-certification process at a glance
- Risk analysis according to the EN ISO 12100 standard using examples
- Risk reduction and design of safety functions in accordance with the EN ISO 13849 standard on the basis of examples
- Statistical methods in the field of safety engineering and reliability analysis

Design of Safe Systems

- Utilisation of a project example: Electrical steering without a redundant mechanical gear
- Functional Safety vocabulary
- Management of functional safety
  - Project independent safety management
  - Safety management during concept phase and development
  - Safety management activities after start of production
- Concept phase
  - Item definition
  - Initialisation of the safety life cycle
  - Safety integrity level analysis and risk assessment
  - Functional safety concept

- System product development
  - System development and integration
  - Product development hardware
  - Start of hardware development
  - Hardware safety requirements analysis
  - Hardware design
  - Quantitative requirements for random errors
  - Evaluation of random error effects on the safety goals
  - Hardware integration and test
  - Product development software
  - Start of software development
  - Software safety requirements specification
  - Software architecture and design
  - Software implementation
  - Software module test
  - Software integration and test
  - Software validation against the safety requirements
- Production and use
  - Production
  - Use, service and end of useful life
- Supporting processes
  - Interfaces
  - Specification of safety requirements
  - Configuration and change management
  - Verification
  - Documentation
  - Software tools qualification
  - Qualification of hardware components
  - Qualification of software components
- ASIL and SIL – safety-oriented analysis
  - Decomposition and tailoring
  - Co-existence criteria
  - Error dependencies
  - Safety analysis
- Guideline support to use for ISO 262626 based on ISO/TS 16949 and IEC 61508.

Teaching Methods

The module provides a framework for self-organized learning to help students develop their professional and methodological skills.

In addition to theoretical inputs, interaction exercises and problem-solving tasks are used as central methods. Through guided work assignments, students are actively involved in the development of learning content. Practical exercises and the presentation of the results enable the students to understand topics in depth. In addition, their communication and team skills are promoted.

Remarks

Exercises on risk analysis and the design of safety functions are intended to deepen the knowledge acquired in the lecture and to apply newly acquired skills in a practical manner. Tasks are developed in working groups and then presented.

The presentation of solutions and the discussion of the results impart skills which are indispensable to the modern working environment of an engineer.

Recommended Literature

- Funktionale Sicherheit von Maschinen : praktische Anwendung der DIN EN ISO 13849 praktische Anwendung der DIN EN ISO 13849; Gregorius, Carsten; Berlin; Beuth Verlag; 2016; ISBN: 9783410252498
- Zertifizierung im Rahmen der CE Kennzeichnung Konformitätsbewertung und Risikobeurteilung nach der Maschinenrichtlinie 2006/42/EG und anderen europäischen Richtlinien; Schneider Andre; Berlin; VDE Verlag; 2018; ISBN 978-3-8007-4473
- Funktionale Sicherheit von Maschinen und Anlagen : Umsetzung der Europäischen Maschinenrichtlinie in der Praxis ; [Inhalt: ISO 13849-1, IEC 62061]; Gehlen; Erlangen; Publicis Publ.; 2010; ISBN: 9783895783661
- Handbook of reliability, availability, maintainability and safety in engineering design; Stapelberg; London; Springer; 2009; ISBN: 9781848001749
- Reliability engineering; Rao, Singiresu; Boston; Pearson; 2015 ; ISBN: 9780136015727
- Automotive SPICE® in der Praxis: Interpretationshilfe für Anwender und Assessoren von Markus Müller (Autor), Klaus Hörmann (Autor), Lars Dittmann (Autor), Jörg Zimmer (Autor), ISBN-13: 978-3864903267
- ISO 26262
- IEC 61508
- Norm EN ISO12100
- Norm EN ISO 13849
- Maschinenrichtlinie 2006/42/EC

MCS-8 Mastermodul

Module code	MCS-8
Module coordination	Prof. Dr. Peter Firsching
Course number and name	MCS3103 Masterthesis MCS3104 Masterseminar
Semester	3
Duration of the module	1 semester
Module frequency	
Course type	required course
Niveau	postgraduate
Semester periods per week (SWS)	0
ECTS	24
Workload	Time of attendance: 60 hours self-study: 660 hours Total: 720 hours
Type of Examination	master thesis
Weight	24 out of 90 ECTS
Language of Instruction	English

Module Objective

The Master's programme Mechatronic and Cyber-Physical Systems is completed with a Master' thesis. The students have to prove that they can work on a certain task independently and successfully 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, the students are able to independently work on complex scientific/technical tasks. They solve problems with the help of digital methods and tools and master networked, cyberphysical systems.

The module content taught during the course of study is applied in the form of scientific work. The problem has to be analyzed, structured and worked on independently within a given time frame. This trains the ability to independently work on technical problems of a larger coherent topic and to prepare the results in scientific form. The aim is, among other things, to deepen and apply the ability to document the results transparently.

Professional competence

The students are enabled to familiarize themselves with technical tasks in depth, to analyze problems independently and to solve them.

After completing the module, students will be able to work on a problem from the extensive field of mechatroic and cyber-physical systems in a scientifically sound manner.

Methodological competence

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

Personal competence

Independent, self-responsible 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 scientific work train and required personal competences.

Social competence

The students improve their social and interface competence through intensive communication with the supervisors at the Technical University and in the cooperating industrial company.

Applicability in this and other Programs

The Master's programme Mechatronic and Cyber-Physical Systems 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's thesis requires that at least 30 ECTS credits have been achieved. See SPO.

Learning Content

The topic of the Master's 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 is included:

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.

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.