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University of Applied Sciences
HOCHSCHULE EMDEN·LEER

Module manual

Study program

Master Industrial Informatics

(PO2024)

Emden/Leer University of Applied Sciences

Department of Technology

Department of Electrical Engineering and Computer Science

(As of May 30, 2024)

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1 Competencies in the Industrial Informatics degree program

The German Society for Computer Science (GI) has carried out extensive practical surveys for computer science degree programs and derived recommendations from them, also taking into account the social mission of universities. The GI's recommendations have been used to design our degree programs for years. The following fields of expertise have been taken from the current recommendations [GI 2005] and adapted for the Industrial Informatics degree program.

The competencies are given names for later, clear comparison with the qualification objectives of the department and the course of study.

The abbreviations introduced below are used in the so-called module competence matrix to illustrate the allocation of the modules to the competences to be taught.

Areas of competence from GI recommendations

BASE	Formal, algorithmic, mathematical basic skills
SYS	Software and system development Analysis, design, implementation and project management skills
TECHCOMP	Technological competencies
FÜSKOMP	Interdisciplinary and key competences: Interdisciplinary competences, methodological competences, social competences and self-competence

These areas of expertise are described in more detail and in brief below. As above, the subcategories are given names.

Basic skills

BASIS.FORMAL	be able to describe formal problems using automata and formal languages
BASIS.ALGO	be able to implement algorithmic requirements into an efficient algorithm and a suitable data structure
BASIS.MATH	be able to design, test and evaluate mathematical algorithms

Software and system development

SYS.ANALYSIS	Ability to deal with unclear requirements and to familiarize yourself with new complex applications and application areas
SYS.DESIGN	Ability to design modularized and ergonomic applications using patterns and libraries for different architectures
SYS.REALISATION	Ability to professionally create larger programs and systems and ensure their quality. This includes experience with development environments and knowledge of configuration, change, release and delivery management.
SYS.PROJMAN	Ability to plan, monitor and control work in projects. This requires knowledge of software scope and effort estimation.

Technological competencies

TECHCOMP.BASIC	have general knowledge of physical systems
TECHCOMP.SPECIAL	Have specialist knowledge of cyber-physical systems
TECH COMPONENTS HARDWARE	Understanding hardware systems
TECHKOMP.HWSW	Understanding the interaction between hardware and software
TECHCOMP.COMPUTATION NETWORKS	Understanding and designing computer networks
TECHCOMP.REALTIME	Understanding and designing real-time systems
TECHKOMP.VERTSYS	Be able to design distributed service-based systems

Interdisciplinary and key competencies

FÜSKOMP.ÜFACH	Basic knowledge of innovation management, documentation and presentation skills
FÜSKOMP.METHKOMP	Methodological skills: ability to apply IT knowledge to new areas of application, ability to expand methods and knowledge
FÜSKOMP.SOZKOMP	Social skills and self-competence: being able to present convincingly, being able to recognize and integrate differing positions, arguing in a goal-oriented manner, dealing with criticism objectively, recognizing and reducing misunderstandings
FÜSKOMP.GESTITUTION	Social and ethical competencies: Being able to assess the impact of digitalization on society, knowing and following ethical guidelines

In order to ensure a clear structure in the module handbook, an attempt was made to limit each module description to one page. The wording on the interdisciplinary and social skills (FÜSKOMP) is therefore rather general. For this reason, some module managers have preferred to describe the other skills in more detail instead. The information on the interdisciplinary and social skills (FÜSKOMP) in the module skills matrix is nevertheless binding. This type of presentation simply avoids redundancies.

2 Module Competence Matrix

The concrete module competence ma trix dit Studien Gnec s wird hhere nthn dokumentated.

Kompetenz / Modulname	BASIS. FORMAL	BASIS.ALGO	BASIS.MATH	SYS.ANALYSIS	SYS.DESIGN	SYS.REALISATION	SYS.PROJMAN	TECHCOMP.BASIC	TECHCOMP.SPECIAL	TECH COMPONENTS HARDWARE	TECHKOMP.HWSW	TECHCOMP.COMPUTATION NETWORK	TECHCOMP.REALTIME	TECHKOMP.VERTSYS	FÜSKOMP.ÜFACH	FÜSKOMP.METHKOMP	FÜSKOMP.SOZKOMP	FÜSKOMP.GESTITUTION
Industrial Cyber-Physical Systems				++ +	+ +	+		+	++ +	+ +	+ +	+ +	+	++		+ +	+	
Industrial Internet of Things		+		+ +	+					+ +	+ ++	+		+				
Digitalization Engineering	+ +		++	+ +	+				++	+ +	+ +		+	++		++		
Group Project				+ +	+ +										+ +	+ +		
Robotic Systems	+ +	+ + +	+			+		++ +	+	+ +	+ + +	+ + +	+					
Data Science and Analytics	++ +		++	+ +	+				+					+		+		
Mathematical modelling of ICPS	++	+	++ +	+ +	+	+		+	++		++	+ +		++	+ +			
Peer Project				+ +	+ + +										+ +	+ + +		
Master's Thesis				+ +	+ +										+ +	+ +		
Elective modules																		
Innovation Engineering	+			+				+ +	+		+ +				+ +	+ + +		
Human Factors and Augmented Reality				+ +	+			+ +	+ + +						+ +	+ +		

Key to symbols:

+ : is supported

+ + : is strongly supported

3 Abbreviations of the study programs of the Department of Technology

Department of Electrical Engineering and Computer Science

BET	Bachelor Electrical Engineering
BETPV	Bachelor of Electrical Engineering in a Practical Combination
BI	Bachelor of Computer Science
BIPV	Bachelor of Computer Science in Practice
BMT	Bachelor Media Technology
BOMI	Bachelor Media Informatics (Online)
BORE	Bachelor Renewable Energies (Online)
BOWI	Bachelor of Business Information Technology (Online)
MII	Master Industrial Informatics
MOMMY	Master Media Informatics (Online)

Department of Mechanical Engineering

BIBS	Bachelor Industrial and Business Systems
BMD	Bachelor Mechanical Engineering and Design
BMDPV	Bachelor of Mechanical Engineering and Design in a Practical Combination
BNPM	Bachelor Sustainable Product Development in Mechanical Engineering
MBIDA	Master Business Intelligence and Data Analytics
MMB	Master Mechanical Engineering
MTM	Master Technical Management

Department of Scientific Technology

BBT	Bachelor Biotechnology
BBTBI	Bachelor Biotechnology/Bioinformatics
BCTUT	Bachelor Chemical Engineering/Environmental Engineering
BEEEEE	Bachelor Renewable Energies and Energy Efficiency
BEP	Bachelor Engineering Physics
BEPPV	Bachelor Engineering Physics in practice
BNPT	Bachelor Sustainable Process Technology
BNPTPV	Bachelor Sustainable Process Technology in Practice
BSES	Bachelor Sustainable Energy Systems
MALS	Master Applied Life Sciences
MEP	Master Engineering Physics
MTCE	Master Technology of Circular Economy

4 Module directory

4.1 Compulsory modules

Module name *Module*(Freestyle zel)	**Digitalization Engineering**(DENG-J24)
Module name (eng.)	Digitalization Engineering
Semester (frequency) *Semester (frequency)*	1 (every winter semester) (*every winter semester*)
ECTS points (duration) *ECTS (duration)*	5 (1 semester)
Type *Method of Examination*	Compulsory module *(compulsory modules)*
Languages) *Language(s)*	English
Student workload *Student Workload*	60 h contact time + 90 h self-study *60 h contact time + 90 h self-study*
Requirements (according to MPO) *Entry Requirements (MPO)*	
Recommended requirements *Recommended Requirements*	
Usability *Applicability*	MII
Type and duration of examination *Type/Duration of Assessment*	Written exam 1.5h or oral exam or creation and documentation of computer programs
Teaching and learning methods *Teaching Method*	Lecture, seminar *(lectures, seminars)*
Module Responsible *Module Coordinator*	AW Colombo

Qualification objectives *Aims and Objectives*

Through the Internet of Services (IoS), both internal and cross-organizational services can be provided and/or used by Industrial Cyber-Physical Systems (ICPS) participants of an entire digitized and networked value chain to conduct innovative value-added businesses. By knowing the technological concepts of ICPS, IoT and IoS, students will understand the steps required to digitize HW and SW components and systems of different ecosystems, e.g. industrial, transport, energy, infrastructure ecosystems

- Systems, etc. Using Asset Administration Shel (AAS) and Digital Twin (DT) technology, both 'physical' and 'cyber' parts of ICPS ('digitized things' or 'I4.0 components') are specified. developed and prototyped for exemplary use cases.

All digital things are represented digitally and are subject to concepts of digital signal processing. The students know the basics of implementing digital signal processing in relation to hardware and software components. They can implement basic algorithms themselves.

Teaching content *Course content*
Acquisition of background knowledge on specifying and implementing service-oriented, edge and cloud-based as well as agent-based business processes. Learning the engineering process for digitizing and networking 'things'/'assets' located within an IEC 62264/IEC 61512 infrastructure and migrating them to ICPS. Learning a set of technologies and architectural patterns to enable digitization and Internet/Ethernet-based networking of ICPS according to DIN SPEC 91345:2016-04 (RAMI 4.0) and Industrial Internet-Reference Architecture (IIRA) standards. Using the Asset Administration Shell (AAS) as a backbone technology, students will learn technical approaches, standards and tools to specify and prototype implementation of the 6 layers of the vertical dimension of RAMI 4.0 in 'things'/'assets' belonging to real-world application scenarios and use cases. 'Things/assets' are treated as signals. Digitization of signals, sampling and interpolation, representation of signals via transformations (DFT, DCT), coding of signals, information theory.
literature *Literature* • Engineering human-focused Industrial Cyber-Physical Systems in Industry 4.0 context, doi:10.1098/rsta.2020.0366. 2021. • Digital Twin and Asset Administration Shell Concepts and Application in the Industrial Internet and Industry 4.0. Industry 4.0 Platform and Industrial Internet Consortium. 2020. • Industrial Cloud-Based Cyber-Physical Systems. The IMC-AESOP Approach, doi:10.1007/978-3-319-05624-1. 2015.

Courses *Courses*		
Lecturer *Lecturer*	**Title of the course** *Course Title*	**SWS** *SPWP*
AW Colombo	Digitalization of ICPS	2
J.-M. Batke	Digital Signal Processing	2

Module name *Module*(Freestyle zel)	**Group Project**(GRPJ-J24)
Module name (eng.)	Group Project
Semester (frequency) *Semester (frequency)*	1 (every winter semester) (*every winter semester*)
ECTS points (duration) *ECTS (duration)*	10 (1 semester)
Type *Method of Examination*	Compulsory module*(compulsory modules)*
Languages) *Language(s)*	English
Student workload *Student Workload*	30 h contact time + 270 h self-study *30 h contact time + 270 h self-study*
Requirements (according to MPO) *Entry Requirements (MPO)*	
Recommended requirements *Recommended Requirements*	
Usability *Applicability*	MII
Type and duration of examination *Type/Duration of Assessment*	Project report
Teaching and learning methods *Teaching Method*	Seminar, Student Work*(seminar, student work)*
Module Responsible *Module Coordinator*	Course spokesperson Industrial Informatics

Qualification objectives *Aims and Objectives*

Students can combine the skills they have learned in different courses in a group under real conditions to solve a complex problem. They can apply project management methods to specific projects and document the project results. Students can independently access scientific literature, derive consequences for their own work from it and implement the knowledge in a goal-oriented manner when solving tasks within the project. By leading project teams, you learn to take on special responsibility. The project topic of the 'Group Project' module is typically an internal university project so that students can acquire the project skills needed in the 'Peer Project' module in a familiar and familiar environment as preparation.

Teaching content *Course content*

Topics according to the selected project. Note:

This module can also be used as practical accompaniment to a module offered in the current semester.

literature *Literature*

Literature specific to the project work

Courses *Courses*		
Lecturer *Lecturer*	**Title of the course** *Course Title*	**SWS** *SPWP*
Authorized examiners according to MPO-A	Group Project	2

Module name *Module*(Freestyle zel)	**Industrial Cyber-Physical Systems**(ICPS-J24)
Module name (eng.)	Industrial Cyber-Physical Systems
Semester (frequency) *Semester (frequency)*	1 (every winter semester) (*every winter semester*)
ECTS points (duration) *ECTS (duration)*	5 (1 semester)
Type *Method of Examination*	Compulsory module*(compulsory modules)*
Languages) *Language(s)*	English
Student workload *Student Workload*	60 h contact time + 90 h self-study *60 h contact time + 90 h self-study*
Requirements (according to MPO) *Entry Requirements (MPO)*	
Recommended requirements *Recommended Requirements*	
Usability *Applicability*	MII
Type and duration of examination *Type/Duration of Assessment*	Written exam 1.5 hours or oral exam
Teaching and learning methods *Teaching Method*	Lecture, seminar*(lectures, seminars)*
Module Responsible *Module Coordinator*	AW Colombo

Qualification objectives *Aims and Objectives*
Within a modularly reconfigurable intelligent industrial environment, Industrial Cyber-Physical Systems (ICPS) manage, control and monitor physical processes, create a digital copy (Cyber-Shadow, Digital Twin (DT)) of the physical world and provide a large, sometimes very large, amount of digitized data and information exposed in an internet-based communication/information network (I4.0, IIoT). Learn a set of technologies and architectural patterns to enable the digitization of industrial cyber-physical systems according to the DIN SPEC 91345:2016-04 (RAMI 4.0) and Industrial Internet-Reference Architecture (IIRA) standards. Students learn (i) how to construct ICPS, deal with a consistent digital data and information model throughout the lifecycle of an ICPS and (ii) how to combine the value chain for types and instances of ICPS in a unique model. Providing the specifications of the corresponding 'Digital Thread'.

Teaching content *Course content*
Positioning of 'Things / Assets' within DIN SPEC 91345 (3D Reference Architecture Model for Industry 4.0 (RAMI 4.0)), the Industrial Internet Reference Architecture (IIRA) and the Smart Grid Reference Architecture (SGAM). Identifying 'Things / Assets' within an IEC 62264 (ISA'95 and PERA) / IEC 61512 (ISA'88 and PWS) infrastructure, positioned at both the Operational and Information Technology (OT-IT) levels of an industrial ecosystem. Applying the 5 Mayer Principles for Systems-of-Systems (SoS) and the IEC 62890 standard, students will learn the lifecycle of the asset with the value streams it contains using examples and case studies from real industrial ICPS. Lifecycles are examined in different dimensions relevant to the development of ICPS, such as: E.g. in an industrial system: (i) product; (ii) production order; (iii) factory: a factory also has a life cycle, it is financed, planned, built and recycled (a factory integrates production systems and machines from different manufacturers); (iv) machine: a machine is ordered, designed, commissioned, operated, maintained, rebuilt and recycled, and (v) machine components.

literature *Literature*
• DIN SPEC 91345: The Reference Architectural Model Industry 4.0 (RAMI 4.0). ZVEI – Platform 4.0. • A Survey on Edge and Edge-Cloud Computing Assisted Cyber-Physical Systems, doi: 10.1109/TII.2021.3073066. • The Industrial Internet of Things, Reference Architecture, Industrial Internet Consortium (IIC); • IEC 62264 / IEC 61512 / IEC 62890 / PERA / SGAM (https://www.iso.org/standard/57308.html).

Courses *Courses*		
Lecturer *Lecturer*	**Title of the course** *Course Title*	**SWS** *SPWP*
AW Colombo	ICPS and Industry 4.0	2
AW Colombo	ICPS Life Cycle Engineering	2

Module name *Module*(Freestyle zel)	**Industrial Internet of Things**(II0T-J24)
Module name (eng.)	Industrial Internet of Things
Semester (frequency) *Semester (frequency)*	1 (every winter semester) (*every winter semester*)
ECTS points (duration) *ECTS (duration)*	5 (1 semester)
Type *Method of Examination*	Compulsory module*(compulsory modules)*
Languages) *Language(s)*	English
Student workload *Student Workload*	60 h contact time + 90 h self-study *60 h contact time + 90 h self-study*
Requirements (according to MPO) *Entry Requirements (MPO)*	
Recommended requirements *Recommended Requirements*	
Usability *Applicability*	MII
Type and duration of examination *Type/Duration of Assessment*	Term paper
Teaching and learning methods *Teaching Method*	Seminar, internship*(seminar, lab course)*
Module Responsible *Module Coordinator*	N. Streekmann

Qualification objectives *Aims and Objectives*

The students create concrete solutions for selected tasks of data transport and data processing in industrial IT by specifically combining existing frameworks and program libraries for the Internet of Things. To do this, they develop their own software project, including documentation and a final demonstration, alongside the course.

Teaching content *Course content*

The development of Industrial Cyber-Physical Systems (ICPS) aims to create an optimal overall package that uses existing technological and economic potentials within the framework of a systematic innovation process. Various integration aspects must be taken into account, which are essentially based on structural connectivity and functional interoperability between ICPS.

The module covers basic concepts and common technologies that can be used to create specific data transport topologies and data processing chains for a wide range of industrial use cases. It is essential to consider end-to-end integration of sensors and actuators at various levels up to the business level of a company. In the context of data transport, concepts and technologies such as IoT protocols, web service technologies, messaging technologies and integration patterns are considered. On the data processing side, the focus is on architectural concepts (e.g. Lambda, Kappa, Dataflow) and frameworks (such as Storm, Spark, Beam and Flink).

literature *Literature*

Kleppmann, M.: Designing Data-Intensive Applications, O'Reilly, 2017.
https://opcfoundation.org/

Courses *Courses*		
Lecturer *Lecturer*	**Title of the course** *Course Title*	**SWS** *SPWP*

O. Bergman	IIoT and Data Transport	2
N. Streekmann	IoT Data Processing	2

Module name *Module*(Freestyle zel)	**Data Science and Analytics**(DSAN-J24)
Module name (eng.)	Data Science and Analytics
Semester (frequency) *Semester (frequency)*	2 (every summer semester) (*every summer semester*)
ECTS points (duration) *ECTS (duration)*	5 (1 semester)
Type *Method of Examination*	Compulsory module*(compulsory modules)*
Languages) *Language(s)*	English
Student workload *Student Workload*	60 h contact time + 90 h self-study *60 h contact time + 90 h self-study*
Requirements (according to MPO) *Entry Requirements (MPO)*	
Recommended requirements *Recommended Requirements*	Mathematics at Bachelor level
Usability *Applicability*	MII
Type and duration of examination *Type/Duration of Assessment*	Course work in the form of a term paper
Teaching and learning methods *Teaching Method*	lecture*(lectures)*
Module Responsible *Module Coordinator*	E. Wings

Qualification objectives *Aims and Objectives*

Students are able to estimate and evaluate the numerical challenge of a large amount of data. With the help of standard software, students should be able to analyze, evaluate and apply selected algorithms for high-dimensional problems using the standard KDD process. After learning the most important features of analytics as part of an Industry 4.0 and/or IIRA-compliant digitized ecosystem, students have the opportunity to investigate and prototype different types of analytics for different application areas.

Teaching content *Course content*

The importance of data analysis, especially of large amounts of data (Big Data), is growing in the fields of science and business. The lecture covers concepts, algorithms and technologies for analyzing large amounts of data. Methods from the field of machine learning, as well as their embedding in the CRISP-DM and KDD processes and their classification in Industry 4.0 standards are covered. Analyses created with digitized data and information provided by industrial cyber-physical systems are an essential part of digitized environments and support decision-making at different levels in the ecosystems of industry, transport, energy and health (or a combination thereof). The lecture offers the opportunity to understand different types of analytics and how they can be integrated into Industry 4.0 (RAMI 4.0) and Industrial Internet Reference Architecture (IIRA) environments.

literature *Literature*
Josh Patterson, Adam Gibson: Deep Learning: A Practitioner's Approach. O'Reilly, 2017 Jörg Frochte: Machine Learning Basics and Algorithms in Python. 3rd edition, Hanser Verlag, 2020 Bühlmann, Peter; Drineas, Petros; Kane, Michael; van der Laan, Mark: Handbook of Big Data. Chapman and Hall/CRC, 2016 The Industrial Internet of Things. Volume T3: Analytics Framework. Industrial Internet Consortium 2017. AI Guide Platform 4.0. 2020.www.plattform-i40.de/IP/Redaktion/EN/Downloads/Publikation/China/ ai-guide.pdf What is data and analytics?www.gartner.com/en/topics/data-and-analytics

Courses *Courses*		
Lecturer *Lecturer*	**Title of the course** *Course Title*	**SWS** *SPWP*
E. Wings	Data Science	2
E. Wings, AW Colombo	Analytics	2

Module name *Module* (Freestyle zel)	**Mathematical Modelling of ICPS** (MMOI-J24)
Module name (eng.)	Mathematical Modelling of ICPS
Semester (frequency) *Semester (frequency)*	2 (every summer semester) (*every summer semester*)
ECTS points (duration) *ECTS (duration)*	5 (1 semester)
Type *Method of Examination*	Compulsory module *(compulsory modules)*
Languages) *Language(s)*	English
Student workload *Student Workload*	60 h contact time + 90 h self-study *60 h contact time + 90 h self-study*
Requirements (according to MPO) *Entry Requirements (MPO)*	
Recommended requirements *Recommended Requirements*	
Usability *Applicability*	MII
Type and duration of examination *Type/Duration of Assessment*	Written exam 1.5h or oral exam
Teaching and learning methods *Teaching Method*	Lecture, seminar *(lectures, seminars)*
Module Responsible *Module Coordinator*	GJ Veltink

Qualification objectives *Aims and Objectives*

The students should be able to understand, analyze, adapt and independently develop formal specifications of ICPS. To do this, they use both model-based methods such as queue theory and Petri nets as well as algebraic methods such as term replacement systems and process algebra. This enables the students to apply formal mathematical modeling techniques for the various phases of the ICPS life cycle: design, development, commissioning, provision, operation and maintenance of the digitized industrial environment in order to be able to analyze and evaluate the behavior of these collaborative distributed systems.

Teaching content *Course content*

Students learn how to use formal methods throughout the life cycle of an ICPS. By applying them to real industrial ICPS case studies, they learn the relevant technical methods. The following methods and tools are covered: queue theory, high-level Petri net theory, functional analysis, process algebra and the specification language mCRL2. It is shown how these methods and tools are used in modeling, qualitative and quantitative analysis, validation and prototype implementation of ICPS.

literature *Literature*

- Adan, I., J. Resing: Queueing Systems. Eindhoven University of Technology, The Netherlands, 2002.
- Reisig, W.: Understanding Petri Nets: Modeling Techniques, Analysis Methods, Case Studies (English Edition). Springer-Verlag, 2013.
- Fokkink, W.: Introduction to Process Algebra. Springer Verlag 2007.
- Groote, JF, MR Mousavi: Modeling and Analysis of Communicating Systems. MIT Press, 2015.

Courses *Courses*

Lecturer *Lecturer*	**Title of the course** *Course Title*	**SWS** *SPWP*
AW Colombo	Model-based Formal Methods and Tools	2
GJ Veltink	Algebraic Formal Methods and Tools	2

Module name*Module*(Freestyle zel)	**Peer Project**(PRPJ-J24)
Module name (eng.)	Peer Project
Semester (frequency) *Semester (frequency)*	2 (every summer semester) (*every summer semester*)
ECTS points (duration) *ECTS (duration)*	10 (1 semester)
Type*Method of Examination*	Compulsory module*(compulsory modules)*
Languages)*Language(s)*	English
Student workload *Student Workload*	6 h contact time + 294 h self-study *6 hours contact time + 294 hours self-study*
Requirements (according to MPO) *Entry Requirements (MPO)*	Group Project
Recommended requirements *Recommended Requirements*	
Usability*Applicability*	MII
Type and duration of examination *Type/Duration of Assessment*	Term paper
Teaching and learning methods *Teaching Method*	Student work*(student work)*
Module Responsible *Module Coordinator*	Course spokesperson Industrial Informatics

Qualification objectives*Aims and Objectives*
The students can combine the skills they have learned separately in different courses in a group of two under real conditions to solve a complex problem. They can apply project management methods in concrete projects and document the project results. The students can independently access scientific literature, derive consequences for their own work from it and implement the knowledge in a goal-oriented manner when solving the tasks within the project. They also learn to document and present their research results in the form of a print-ready contribution for a conference or journal. The project topic of the 'Peer Project' module is typically an external project at the university so that the students learn to put their project skills into practice in preparation for professional life. It is also expected that the students in this module learn to take on responsibility and independently organize topics and projects with external partners as well as find supervisors within the university for the project.

Teaching content*Course content*
Standards for scientific publications and presentations. Other topics
depending on the selected project.
A notice:
Two presentations are required in this module. An interim presentation within the module so that the project groups can inform each other. An external presentation of the final results so that interested students from all semesters can gain insight into the topics of this module.

literature*Literature*
Literature specific to the project work

Courses*Courses*		
Lecturer*Lecturer*	**Title of the course***Course Title*	**SWS***SPWP*

Authorized examiners according to MPO-A	Peer Project	

Module name *Module*(Freestyle zel)	**Robotics Systems**(ROSY-J24)
Module name (eng.)	Robotics Systems
Semester (frequency) *Semester (frequency)*	2 (every summer semester) (*every summer semester*)
ECTS points (duration) *ECTS (duration)*	5 (1 semester)
Type *Method of Examination*	Compulsory module*(compulsory modules)*
Languages) *Language(s)*	English
Student workload *Student Workload*	60 h contact time + 90 h self-study *60 h contact time + 90 h self-study*
Requirements (according to MPO) *Entry Requirements (MPO)*	
Recommended requirements *Recommended Requirements*	
Usability *Applicability*	MII
Type and duration of examination *Type/Duration of Assessment*	Written exam 1.5 hours or oral exam
Teaching and learning methods *Teaching Method*	Lecture, internship*(lecture, lab course)*
Module Responsible *Module Coordinator*	G. Kane

Qualification objectives *Aims and Objectives*

Students understand and can describe the mechatronics and SW structure of robots. They have know-how on robot applications around industrial processes. In these areas, they gain knowledge of both the hardware components of robots, their numerous sensors, actuators and physical configurations, as well as the algorithmic kinematics and dynamics and the software components required to drive them. Students learn about the periphery of a standard industrial robot cell and how they interact in the overall process environment. Knowledge of standard SW interfaces for integrating robots into an industrial cyber-physical system is gained by learning about the robot as a CPS component within a RAMI4.0 compliant automation architecture. Students are expected to gain insight into the emerging trends in robotics, human-machine interaction, lightweight robots, soft robotics and the expanding areas of robotics in an industrial country, including medical robotics, agricultural robots, search and rescue robots and more.

Teaching content *Course content*

Overview of different robot types including structural and behavioral specifications: workspace, energy sources, etc. Introduction to robot kinematics (forward and backward), robot dynamics. HW and SW interfaces to integrate the robot into an industrial flexible cell. Selection of different types of sensors, actuators and grippers and their application areas. Overview of current and emerging areas of robotics: industrial robotics, medical robotics, delivery robotics, agricultural robotics. Overview of traditional industrial robotic processes: welding, cutting, cleaning, palletizing, tendering, assembly/disassembly: what type of robot and energy source is recommended for each type of application? SW communication interfaces to connect a robot to an ICPS-based service cloud. Introduction to ROS, IROS, SKIROS (Robot Operating Systems). By combining seminars and practical projects, the content is adapted to the latest results of the I2AR Institute's research and innovation projects.

literature *Literature*
John J Craig: Introduction to Robotics, Mechanics and Control. Prentice Hall 2003. Heimann, B., Gerth, G. and Popp, K.: Mechatronics, 3rd edition, Hanser 2007. Roddeck, W.: Introduction to Mechatronics, Teubner, Stuttgart, 1997.
Vogel, J.: Electric Drives, Hüthig, Berlin, 1988.
Steven M. LaValle, Planning Algorithms, Cambridge University Press, 2006

Courses *Courses*		
Lecturer *Lecturer*	**Title of the course** *Course Title*	**SWS** *SPWP*
G. Kane	Introduction Robotic Systems	2
AW Colombo	Industrial Robotics Systems	2

Module name *Module*(Freestyle zel)	**Master's Thesis**(MTHS-J24)
Module name (eng.)	Master's Thesis
Semester (frequency) *Semester (frequency)*	3 (every winter semester) (*every winter semester*)
ECTS points (duration) *ECTS (duration)*	30 (1 semester)
Type *Method of Examination*	Compulsory module*(compulsory modules)*
Languages) *Language(s)*	English German
Student workload *Student Workload*	9 h contact time + 891 h self-study *9 h contact time + 891 h self-study*
Requirements (according to MPO) *Entry Requirements (MPO)*	See 6 'Admission to the Master's thesis' Master's Examination Regulations (MPO) Part B.
Recommended requirements *Recommended Requirements*	
Usability *Applicability*	MII
Type and duration of examination *Type/Duration of Assessment*	Master thesis with colloquium
Teaching and learning methods *Teaching Method*	Student work*(student work)*
Module Responsible *Module Coordinator*	Course spokesperson Industrial Informatics

Qualification objectives *Aims and Objectives*
In the Master's thesis, students demonstrate that they are able to work on new, complex tasks and problems from the scientific, application-oriented or professional fields of activity of this degree program and to independently manage processes in a scientific subject or in a strategy-oriented professional field of activity. The requirements structure is characterized by frequent and unpredictable changes. Students should have comprehensive, detailed and specialized knowledge of the latest findings in the subject areas of industrial informatics, as well as expanded knowledge in related areas. Students should have specialized technical or conceptual skills to solve strategic problems and weigh up alternatives even when information is incomplete, as well as develop and apply new ideas or processes and evaluate them taking into account different assessment criteria. Students should be able to lead groups responsibly within the framework of complex tasks and represent their work results, promote the professional development of others in a targeted manner and lead area-specific and cross-departmental discussions. Students should be able to define goals for new application- or research-oriented tasks, reflecting on the possible social, economic and cultural impacts, use appropriate means and independently acquire knowledge for this purpose.

Teaching content *Course content*
The master's thesis is a theoretical, empirical and/or experimental scientific final paper with a written report that is completed individually. The paper is then presented in a colloquium.

literature *Literature*
Literature topic-specific to the master thesis

Courses *Courses*		
Lecturer *Lecturer*	**Title of the course** *Course Title*	**SWS** *SPWP*

Authorized examiners according to MPO-A	Master's Thesis	

4.2 Elective modules

Module name *Module* (Freestyle zel)	**Human Factors and Augmented Reality** (HFAR-J24)
Module name (eng.)	Human Factors and Augmented Reality
Semester (frequency) *Semester (frequency)*	WPM (as required) (*as required*)
ECTS points (duration) *ECTS (duration)*	5 (1 semester)
Type *Method of Examination*	Elective module *(compulsory elective module)*
Languages) *Language(s)*	English
Student workload *Student Workload*	60 h contact time + 90 h self-study *60 h contact time + 90 h self-study*
Requirements (according to MPO) *Entry Requirements (MPO)*	
Recommended requirements *Recommended Requirements*	
Usability *Applicability*	MII
Type and duration of examination *Type/Duration of Assessment*	Oral exam
Teaching and learning methods *Teaching Method*	Lecture and seminar *(lectures and seminars)*
Module Responsible *Module Coordinator*	T. Pfeiffer

Qualification objectives *Aims and Objectives*
The students can evaluate and design modern user interfaces for industrial systems. To do this, they consider the basics of modern user interfaces and augmented reality technologies in the context of operating and working with industrial systems. This enables them to consider the user's perspective when developing technical solutions and to ensure ease of use.

In concrete terms, students can

- Understand the basics of human factors, usability and augmented reality,
- use modern user interfaces,
- analyze the usability of user interfaces,
- Create augmented reality applications based on frameworks.

Teaching content *Course content*
Theory - Basics of human factors - Basics of modern human-machine interfaces for worker training and worker management - Areas of application of human-machine interfaces - Criteria for the user-oriented design of human-machine interfaces - Methods for evaluating human-machine interfaces - Process models for the conception and implementation of human-machine interfaces

Practical part -Testing various modern user interfaces from industry - Conducting usability evaluations of user interfaces -Development of prototypes of augmented reality applications

The basic teaching content is taught in lecture form, special topics are worked on with the students in seminars and practical tasks are carried out in the laboratory.

literature *Literature*
Dörner, R.; Broll, W.; Grimm, P.; Jung, B.: Virtual and Augmented Reality (VR/AR): Foundations and Methods of Extended Realities (XR). Springer Verlag, 1st edition, January 13, 2022.

Courses *Courses*		
Lecturer *Lecturer*	**Title of the course** *Course Title*	**SWS** *SPWP*
T. Pfeiffer	Human Factors and Assistance Systems	2
T. Pfeiffer	Augmented Reality	2

Module name *Module*(Freestyle zel)	**Innovation Engineering**(IENG-J24)
Module name (eng.)	Innovation Engineering
Semester (frequency) *Semester (frequency)*	WPM (as required) (*as required*)
ECTS points (duration) *ECTS (duration)*	5 (1 semester)
Type *Method of Examination*	Elective module *(compulsory elective module)*
Languages) *Language(s)*	English
Student workload *Student Workload*	60 h contact time + 90 h self-study *60 h contact time + 90 h self-study*
Requirements (according to MPO) *Entry Requirements (MPO)*	
Recommended requirements *Recommended Requirements*	
Usability *Applicability*	MII
Type and duration of examination *Type/Duration of Assessment*	Written exam 1.5h or oral exam or term paper
Teaching and learning methods *Teaching Method*	Lecture, seminar, student work *(lecture, seminar, student work)*
Module Responsible *Module Coordinator*	J. Mäkiö

Qualification objectives *Aims and Objectives*

This course consists of three main topics: digital economy, open innovation and requirements engineering. The first topic deals with the digital economy and society including identifying, analyzing and describing the challenges of the digital age for institutions and individuals. Students are able to describe changes and challenges of digital technology and the economy and analyze their interdependencies. Students learn to develop a novel business model that is oriented towards the requirements of the digital age.

The second topic is Open Innovation. Students will understand this new paradigm based on the principles of integrated collaboration, jointly created shared value, a nurtured innovation ecosystem, unleashed exponential technologies and extraordinarily rapid adoption. In addition, students will learn collaborative learning and research to accelerate the innovation process towards tangible and especially service-oriented intangible products and solutions.

The third topic deals with requirements management of industrial cyber-physical systems. Students learn how requirements are captured, which aspects of both functional and non-functional requirements need to be considered particularly carefully and how these are identified, analyzed and described, how the requirements development process is organized and how ICPS requirements are documented.

Teaching content *Course content*
Due to the digitalization of society, the boundaries between countries and cultures are becoming increasingly less important. This change can be observed particularly at the organizational and individual level. As a result, organizations, companies, governments and individuals are facing new opportunities and challenges due to the digitalization of products and processes. The digitalization process is a challenging change for everyone involved. This change must be mastered in order to be successful. The first topic of this course deals with connections and dependencies between digital technology and organizational digitalization and their effects on the economy, society, organizations and individuals. Innovation in engineering and software development, creative problem solving and idea generation, idea evaluation techniques, writing workshop, main features of the Open Innovation Paradigm (OI2.0), innovation model based on extensive networking and co-creative collaboration between all actors of society, industrial patent processes linking innovation and patentability, the use of patent office databases, validation of 'patentability' and 'innovation aspects', new business models related to IoT and IoS paradigms, application of service level agreements to innovation processes, intellectual property rights (IPR) management and risk analysis, Technology Readiness Levels (TRLs) and innovation capabilities, understanding and managing the process of generating research and innovation actions Understanding requirements is key to successful ICPS engineering: building an ICPS system to fulfill its purpose depends on understanding the exact problem that needs to be solved. The purpose of this course is to learn challenges, principles, and practices for identifying, analyzing, and managing requirements from relevant sources, both at the beginning and during an ICPS development project. The course teaches challenges, principles, and concrete practices related to requirements management, including topics such as requirements analysis, elicitation, analysis, documentation, negotiation, verification and validation, requirements management, change management, and traceability.
literature *Literature* Brynjolfsson, E., McAfeeRace, A.: Against The Machine: How the Digital Revolution is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy, Digital Frontier Press, 2011 Kehal, H., Singh, V.: Digital Economy: Impacts, Influences, and Challenges, Idea Group Publishing, 2005 Peitz, M., Waldfoge, J.: The Oxford Handbook of the Digital Economy, Oxford University Press, 2012 Brynjolfsson, E., McAfeeRace, A.: Against The Machine: How the Digital Revolution is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy, Digital Frontier Press, 2011 Kehal, H., Singh, V.: Digital Economy: Impacts, Influences, and Challenges, Idea Group Publishing, 2005 Peitz, M., Waldfoge, J.: The Oxford Handbook of the Digital Economy, Oxford University Press, 2012 Petry, T.: Digital Leadership: Successful Leadership in Times of the Digital Economy, Haufe, 2016 Albach, H., Meffert, H., Pinkwart, A. Reichwald, R. (eds.): Management of permanent change. New York, Springer Gabler 2015. Missikoff, M., Canducci, M., Maiden N.,Enterprise Innovation: From Creativity to Engineering, WILEY, 2015. Intel Labs Europe, EU-OISPG: Open Innovation 2.0: A new paradigm EU HORIZON2020, Extract from Part 19 - Commission Decision C(2014)4995https://esto.nasa.gov/files/trl_definitions.pdf L. Martins, T. Gorschek: Requirements Engineering for Safety-Critical Systems, River Publishers, 2022 P. A. Laplante: Requirements Engineering for Software and Systems, Auerbach Publications, 2017

Courses *Courses*		
Lecturer *Lecturer*	**Title of the course** *Course Title*	**SWS** *SPWP*
J. Mäkiö	Digital Economy	2
AW Colombo	Innovation Management	2