Module Guide
Master Robotics

Faculty Applied Natural Sciences and Industrial Engineering
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MRO-01 Robot Dynamics

Module code	MRO-01
Module coordination	Dr. Roman Zashchitin
Course number and name	MRO1101 Robot Dynamics
Lecturer	Dr. Roman Zashchitin
Semester	1
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

Robot Dynamics is an advanced course that delves into the mathematical and mechanical foundations governing the movement and control of robotic systems. This course provides students with a comprehensive understanding of the principles, equations, and methodologies used in modeling and controlling the dynamic behavior of robots. It covers both theoretical aspects and practical applications, with a focus on rigid body dynamics and motion control. The Robot Dynamics course is designed to provide students with a deep understanding of the principles and concepts related to the dynamics of robotic systems. This advanced-level course covers both theoretical foundations and practical applications in the field of robot dynamics. Students will explore the mathematical modeling of robot motion, the analysis of forces and torques, and the control of robotic movement. The course focuses on rigid body dynamics, which are fundamental for various applications, including industrial automation, aerospace, medical robotics, and autonomous systems.

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

Professional competence:

- Develop a strong comprehension of the core principles and theoretical foundations governing the dynamics of robotic systems.
- Apply mathematical modeling techniques to accurately describe the dynamic behavior of robot manipulators, taking into account factors such as mass distribution, inertia, and external forces. o Formulate dynamic equations of motion for robotic systems using advanced methods, including Lagrange's equations, to understand how forces and torques affect robot movement.
- Ensure the safety and reliability of robotic systems.

Methodological competence:

- Students will be able to translate real-world robot dynamics into mathematical equations and analyze them methodically.
- Competence in interpreting data and drawing meaningful conclusions from experimental results is developed.
- Design various control strategies, such as PID control, robust control, and feedback linearization. These competences are vital for effectively governing robot motion and improving control performance.

Personal competence:

- Personal competences such as adaptability and flexibility will be nurtured as students learn to adjust to changing circumstances and technological advancements in the field of robotics.
- Students will cultivate a personal problem-solving mindset, which is important for addressing challenges in complex robotic systems.

Social competence:

- Collaboratively solving complex problems related to robot dynamics is a social competence that involves brainstorming, sharing ideas, and building consensus on solutions.

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and transfer possibility for the application of robot dynamics in dynamic action and applications, specifically in AI based control. Interfaces to mechatronics, electrical engineering and computer engineering.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field.

Learning Content

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

- Kinematics o Rigid body dynamics.
- Robot dynamics modelling
- Control of Robot Dynamics
- Trajectory planning and path generation
- Dynamics simulation and Software tools
- Force control o Vision servoing
- Grasping and manipulation
- Wheeled mobile robots
- Redundant Robots and Singularities
- Dynamics in Non-Cartesian Coordinates
- Advanced control strategies (e.g. Model Predictive Control)

Teaching Methods

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

Recommended Literature

[1]. "Robot Modeling and Control" by Mark W. Spong, Seth Hutchinson, and M. Vidyasagar.

[2]. "Modern Robotics: Mechanics, Planning, and Control" by Kevin M. Lynch and Frank C. Park.

[3]. Robotics, Planning and control, by Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, Giuseppe Oriolo.

[4]. Springer Handbook of Robotics, by Bruno Siciliano and Oussama Khatib (Editors).

[5]. "Introduction to Robotics: Mechanics and Control" by John J. Craig.

MRO-02 Advanced Methods in Control Engineering

Module code	MRO-02
Module coordination	Prof. Dr. Dmitrii Dobriborsci
Course number and name	MRO1102 Advanced Methods in Control Engineering
Lecturer	Prof. Dr. Dmitrii Dobriborsci
Semester	1
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

Advanced control engineering is a specialized field within the broader discipline of control engineering that focuses on the development and application of sophisticated control techniques for complex systems. In advanced control engineering, engineers and researchers work on designing control systems that go beyond basic proportional-integral-derivative (PID) control. These systems are capable of handling intricate, nonlinear, time-varying, and uncertain processes, often involving high-performance, precision, and safety requirements. An Advanced Methods in Control Engineering course delves into modern techniques and tools used in the design and analysis of control systems. It focuses on advanced control theories, algorithms, and methodologies that enable engineers to tackle complex control problems and achieve superior performance. This course provides a structured path through advanced control engineering concepts and practical applications. The course includes a combination of theoretical lectures, hands-on exercises and case studies to ensure that students gain a strong foundation in advanced control theory and its real-world applications.

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

Professional competences:

- Deep understanding of advanced control methods, enabling them to design complex control systems for a wide range of applications.
- Applying optimization techniques to control systems, resulting in improved performance and efficiency.
- Proficiency in controlling nonlinear systems, which are common in real-world applications, leading to more versatile control strategies.
- The capability to develop adaptive control systems that can self-adjust to changing system conditions and parameters.
- Design control systems that are robust to uncertainties and external disturbances, enhancing system reliability.

Methodological competence:

- ability to create accurate mathematical models of dynamic systems, which is crucial for control system design.
- skill to conduct both simulations and real-world experiments to validate control system designs.
- Improved analytical and problem-solving skills for addressing complex control challenges.
- The ability to conduct literature reviews to stay updated with the latest research and emerging trends in control engineering.
- Competence in using advanced control software and simulation tools to model, analyze, and optimize control systems.

Personal competence:

- manage complex control system projects, from inception to implementation, including time management and resource allocation.
- Improved ability to communicate complex control concepts and designs effectively with both technical and non-technical stakeholders.
- Encouragement to think creatively and innovatively when designing control systems for various applications.

Social competence:

- Proficiency in building professional networks with peers, mentors, and industry professionals to stay informed about current trends and to explore career opportunities.

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and transfer possibility for the application of advanced control engineering methods in various application scenarios. It creates interfaces to courses of study such as mechatronics, computer science, robotics, automation.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field.

Learning Content

"Advanced Methods in Control Engineering" course covers advanced control theory, techniques, and applications. This type of course is typically offered at the postgraduate level and assumes a foundational understanding of control engineering concepts. Topics in this course are:

- Introduction to Advanced Control.
- State-Space Representation.
- Optimal Control.
- Robust Control.
- Nonlinear Control.
- Adaptive Control.

Furthermore, this course covers system identification in the control applications (e.g. under disturbances):

- least square method.
- Kalman filtering.
- disturbance estimation and cancellation.

Also, this course considers discrete time control.

- Transitioning from continuous-time to discrete-time control.
- Discrete-time state-space representation.
- Discretization of continuous-time controllers.

This course concludes with NN (neural network)-based control methods:

- Neural Network-Based Control Concepts..
- Recurrent Neural Networks in Control
- Reinforcement learning.

Teaching Methods

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

- i-Learn (online learning platform).

Recommended Literature

[1]. "Nonlinear Systems" by Hassan K. Khalil

[2]. "Model Predictive Control: Theory and Design" by James B. Rawlings and David Q. 9 Mayne

[3]. "Optimal Control Theory: An Introduction" by Donald E. Kirk

[4]. "Neural Network Control of Nonlinear Discrete-Time Systems" by K. S. Narendra and Anudeepthi V. Kadali

MRO-03 Statistics and Machine Learning for Computer Vision

Module code	MRO-03
Module coordination	Prof. Dr. Tobias Schaffer
Course number and name	MRO1103 Statistics and Machine Learning for Computer Vision
Lecturer	Prof. Dr. Tobias Schaffer
Semester	1
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

The "Statistics and Machine Learning" course is designed to teach students the principles, techniques, and statistical evaluation methods of modern machine learning, with a particular focus on applications in computer vision. Students learn how mathematical foundations, statistical reasoning, and machine learning algorithms interact when analyzing visual data and developing predictive models. The course emphasizes both, a general theoretical understanding of machine learning as well as the ability to apply these methods to image-based problems. Upon completion of this course, the students have achieved the following learning objectives:

Professional competence:

- Perform supervised learning for regression and classification, including model formulation, loss functions, and evaluation metrics.
- Explain and implement core machine learning algorithms such as gradient descent, backpropagation, regularization techniques, and neural network architectures.
- Understand and analyze computer-vision-related deep learning models, especially convolutional neural networks, vision transformers, multimodal models, and graph neural networks.
- Apply concepts of latent-variable modeling, autoencoders, and generative methods (GANs, diffusion models) to image-based learning problems.

Methodological competence:

- Formulate machine-learning problems mathematically, including clear definitions of loss functions and optimization objectives.
- Analyze and compare algorithms based on their statistical, mathematical, and computational properties.
- Select suitable models or architectures for computer-vision tasks based on formal criteria.
- Apply dimensionality-reduction principles and feature extraction concepts relevant to visual data.
- Understand the structure and training dynamics of deep neural networks, including gradient-based optimization and regularization strategies.
- Critically evaluate results obtained from models and reason about possible sources of error, overfitting, or bias.

Personal competence:

- Develop the ability to reason analytically and critically about statistical statements, learning algorithms, and model behavior.
- Strengthen their capability to work independently with mathematical and machine-learning concepts using lecture material and exercise sheets.
- Learn to reflect on limitations, assumptions, and ethical considerations in machine learning, especially in the context of image data and automated decision-making.
- Build confidence in engaging with new developments in machine learning and deep learning beyond the course content.

Social competence:

- Communicate technical concepts, derivations, and results from data or model evaluations clearly and precisely.
- Discuss solution strategies or theoretical questions collaboratively with peers, especially while working on exercise sheets.
- Present findings and reasoning coherently to both technically trained and interdisciplinary audiences.

Applicability in this and other Programs

The course provides machine learning and deep learning theory with the related statistical background and is also applicable for various AI-related master degree programs.

Entrance Requirements

Bachelor degree in mechatronics, computer-science or a closely related field.

Learning Content

The course provides a solid theoretical foundation in statistics and machine learning, combined with practical applications. Students learn fundamental and advanced concepts relevant to computer vision, including mathematical and statistical preliminaries, regression and classification, neural networks, convolutional models, transformers, latent-variable models, generative methods, and selected advanced topics such as multimodal architectures. Emphasis is placed on understanding core algorithms, deriving and applying methods analytically, and solving calculation tasks. The course aims to equip students with both conceptual understanding and practical reasoning skills for modern machine learning methods used in computer vision.

Topics in this course are:

- Mathematical and Statistical Foundations
- Regression and Classification
- Neural Networks
- Gradient Descent and Backpropagation
- Regularization
- Convolutional Networks
- Recurrent Neural Networks
- Transformers
- Vision-Language Models and Multimodal Transformers
- Latent Variables and Autoencoders
- Generative Adversarial Networks and Diffusion Models

Teaching Methods

- Seminar-like teaching with weekly exercise sheets
- i-Learn (online learning platform)

Recommended Literature

[1]. Bishop, Christopher M.: Deep Learning: Foundations and Concepts, Springer, 2024.

[2]. Goodfellow, Ian, Bengio, Yoshua, Courville, Aaron: Deep Learning, MIT Press, 2016.

[3]. Aggarwal, Charu C.: Neural Networks and Deep Learning: A Textbook, 2nd Edition, Springer, 2024.

[4]. Kubat, Miroslav: An Introduction to Machine Learning, 3rd Edition, Springer, 2021.

MRO-04 Technical Project Management

Module code	MRO-04
Module coordination	Dr. Jürgen Holz
Course number and name	MRO1104 Technical Project Management
Lecturer	Dr. Jürgen Holz
Semester	1
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	Portfolio (With planned room)
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

The Technical Project Management course is designed to equip students with the essential knowledge and skills needed to successfully plan, execute, and manage technical projects in various domains. This course integrates project management principles with a focus on technical aspects, providing students with the tools to effectively lead and execute projects that involve technology, engineering, or scientific components. Students will learn to balance technical requirements, project scope, timelines, and resource management to deliver successful outcomes. After completion of this module, the student has achieved the following learning objectives:

Professional competence:

- Competence in planning, executing, and overseeing complex technical projects from initiation to closure, including resource allocation and risk management.
- An understanding of the technical aspects of projects, allowing students to make informed decisions and effectively communicate with technical experts.
- Competence in ensuring that project deliverables meet defined quality standards and that quality control measures are effectively implemented. o Ability to handle changes in project scope and requirements effectively, making adjustments while minimizing disruptions to project progress.
- Understanding of agile methodologies and their application in technical projects, promoting adaptability and flexibility

Methodological competence:

- Competence in defining project objectives, scope, and requirements, creating project plans, and managing the project schedule and budget.
- Ability to identify, assess, and mitigate project risks, as well as develop contingency plans to minimize the impact of unexpected events.
- Competence in identifying and analyzing stakeholders, understanding their needs, and effectively communicating with project teams and stakeholders.
- Ability to evaluate and select vendors, manage contracts, and ensure vendor performance aligns with project goals.
- Proficiency in maintaining comprehensive project documentation, providing transparent reporting to stakeholders, and conducting project closure activities.

Personal competence:

- Development of critical thinking skills for assessing project challenges, making informed decisions, and solving complex technical problems.
- The ability to adapt to evolving project requirements, methodologies, and changing project conditions.
- Understanding and applying ethical principles in project management, particularly concerning data privacy, diversity, and inclusion.
- Improved time management skills to meet project deadlines and manage competing priorities effectively.

Social competence:

- Building relationships with industry peers and experts, creating opportunities for professional growth and knowledge exchange.
- The skill to assess project outcomes, identify areas for improvement, and implement continuous improvement strategies in future projects.

Applicability in this and other Programs

The module provides the necessary theoretical background and transfer possibility for the technical project management and team cooperation. Interfaces to any technically related programmes.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field.

Learning Content

This extended Technical Project Management course offers students an opportunity to thoroughly understand and apply project management principles within a technical context. It places a strong emphasis on hands-on learning, real-world case studies, and practical application, ensuring that students are well-prepared to lead and manage complex technical projects effectively. In addition, the following topics are also covered in this module:

- Project Initiation and Stakeholder Analysis.
- Project Planning and Work Breakdown Structure (WBS).
- Resource Allocation and Scheduling.
- Risk Management in Technical Projects.
- Technical Requirements and Scope Management.
- Agile Project Management in Technical Projects.
- Quality Management in Technical Projects.
- Project Documentation, Reporting, and Closure.

Teaching Methods

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

Recommended Literature

[1]. "A Guide to the Project Management Body of Knowledge (PMBOK Guide)" by Project Management Institute (PMI)

[2]. "Project Management for Engineering and Construction" by Garold D. Oberlender

[3]. "Agile Project Management with Scrum" by Ken Schwaber

[4]. "Effective Project Management: Traditional, Agile, Extreme" by Robert K. Wysocki

[5]. Project Management: A Systems Approach to Planning, Scheduling, and Controlling"
by Harold Kerzner

MRO-05 Embedded Systems

Module code	MRO-05
Module coordination	Dr. Hamidreza Heidari
Course number and name	MRO1105 Embedded Systems
Lecturer	Dr. Hamidreza Heidari
Semester	1
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

An Embedded Systems course focuses on the integration of control theory with embedded systems, which are computer systems designed to perform dedicated functions within a larger mechanical or electrical system. This course emphasizes the design, implementation, and analysis of control systems that are embedded within real-world applications. Upon completion of this module, depending on a more theoretical or more practical focus, students will be able to design embedded robotic solutions including, microcontroller programming, learn common embedded systems peripherals like GPIO (General Purpose Input/Output) pins, digital and analog sensors, and actuators. This course emphasizes real-time implementation of algorithms, which is crucial for robotic systems as they act in the dynamic environments.

Professional competence:

- Developing a high level of expertise in embedded systems, microcontroller programming, and related technologies.
- Proficiency in designing and architecting embedded systems to meet specific requirements and constraints.
- Competence in programming embedded systems using C/C++ and understanding the intricacies of low-level code.
- Proficient at integrating software and hardware components for embedded systems.
- Understanding and applying real-time concepts in embedded system design, ensuring timely responses to events.

Methodological competence:

- Developing the ability to identify and troubleshoot issues in embedded systems and propose effective solutions.
- Competency in working with Real-Time Operating Systems (RTOS) for multitasking and resource management.
- Methodical approach to testing and debugging embedded systems to ensure reliability and correctness. o Skill in documenting the design, development, and testing processes effectively.
- Competence in planning and organizing embedded system projects, including resource allocation and time management.

Personal competence:

- Demonstrating flexibility in learning and adapting to new technologies and hardware platforms.
- Maintaining a high level of motivation and curiosity to explore and understand embedded systems concepts.
- Managing challenges and setbacks effectively, maintaining composure in complex problem-solving scenarios.

Social competence:

- Effectively conveying technical information and ideas to peers and team members.
- Working collaboratively with team members, respecting diverse perspectives, and achieving shared project goals.
- Skill in addressing and resolving conflicts within project teams, fostering a positive working environment.

Applicability in this and other Programs

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

Entrance Requirements

Bachelor degree in mechatronics or a closely related field.

Learning Content

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

Topics:

- Introduction to Embedded Systems
- Microcontrollers and Microprocessors
- Embedded C Programming
- Embedded System Peripherals
- Real-Time Operating Systems (RTOS)
- Embedded System Development Tools
- Embedded System Design

Teaching Methods

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

Recommended Literature

[1]. "Embedded Systems: Introduction to ARM Cortex-M Microcontrollers" by Jonathan Valvano

[2]. "Embedded Systems: Real-Time Operating Systems for ARM Cortex-M Microcontrollers" by Jonathan Valvano

[3]. "Programming Embedded Systems in C and C++" by Michael Barr

[4]. "Real-Time Systems Design and Analysis" by Phillip A. Laplante

MRO-06 Cross-Cultural Development for Engineers

Module code	MRO-06
Module coordination	Stefanie Dierlmeier
Course number and name	MRO1106 Cross-Cultural Development for Engineers
Lecturers	Stefanie Dierlmeier Melanie Wittmann
Semester	1
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	Portfolio (With planned room)
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

This module is to prepare engineering students for navigating the dynamics of a collaborative working environment and settling down in the target employment region Germany. This course takes into account intercultural and soft skills at professional level to integrate well into multi-cultural work settings.

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

Professional competence:

- Students will be trained to deal with cultural norms and regulations adequately.
- Concepting, implementing and reflecting upon the culture-specific project presentations allows students to actively apply their cultural knowledge gained onto their native countries and thus strengthen their critical thinking skills by putting different cultural aspects in contrast to one another.
- They will be coached how to conduct presentations to lay the groundwork for later presentations frequently expected to deliver as engineers.

Methodological competence:

- The cohort is expected to acquire an understanding of the target matrix and methodology related to intercultural communication.
- They are sensibilized on dealing professionally with stereotypes and prejudices by reflecting on their own culture and the target culture Germany in depth.
- Students learn to develop strategies to analyze cultures, e.g. main target culture Germany, by applying the theoretical knowledge obtained onto various practical work-environment simulations in class.
- They will be enabled to identify common personality types, including their own, within the working world based on the four-colour personality theory by Thomas Erikson and guided to develop their own handling strategies.

Personal competence:

- Students will be encouraged to develop a cosmopolitan mindset towards intercultural situations.
- The cohort will strengthen their awareness of problems common to arise within intercultural contexts and learn to develop coping strategies to overcome emerging communication barriers.

Social competence:

- Students intensify and refine their individual observation and reflection skills against an intercultural backdrop.
- Multi-cultural teamwork skills as well as communication are fostered through the collaboration on role plays and simulation exercises.

Applicability in this and other Programs

Theoretical and practical approaches taught in this course can be transferred onto the German language classes and Career Service seminars, for instance.

Entrance Requirements

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

Learning Content

The module shall impart knowledge and practical approaches to overcome communication challenges frequently arising in multi-cultural work settings. A core part of this module is to establish a practical relation from students native source culture to the German target culture to prepare them for the requirements and challenges they are likely to handle if their future career is pursued within Germany. Furthermore, essential soft skills for engineers, such as dealing with various personality types at the workplace, problem-solving skills or organizational skills, are paramount to this course. Following this module, students have recognized their individual actions continuously being affected by culture-specific values and norms. Furthermore, theoretic and practical expertise in the field of intercultural communication is to be provided. The latter is particularly enhanced by the student cohort deriving from different nationalities throughout the globe.

Pillar I: Global collaboration

Engineers often work in international teams or with global clients, which renders global collaboration skills decisive in todays interconnected world. Sample topics include:

- cultural competencies (understanding cultural differences, effective communication techniques, verbal and non-verbal clues, body language, cultural sensitivity)
- communication skills (clear and concise writing for emails, reports etc., language skills, team dynamics)
- global ethics & compliance
- fostering innovation & creativity

Pillar II: Personal development

Personal and interpersonal skills complement the technical knowledge of students and are thus essential for effective communication, collaboration, problem-solving, and adaptability in a global context. Sample topics include:

- organisational skills (e.g. time management, planning, planning, prioritisation)
- problem-solving skills (e.g. brainstorming, innovation, critical thinking, researching, summarising knowledge)
- conducting a presentation
- interpersonal skills (e.g. active listening, social perceptiveness, handling feedback, recognising and dealing with different personality types at the workplace, based on the scientific four-colour-personality theory)
- ethical and professional conduct
- emotional intelligence (self-awareness and regulation, motivation and resilience)

Pillar III: Cultural studies of target country Germany

For international students planning to study in Germany, understanding certain cultural, social, and practical aspects of the country is crucial for a smooth transition and enriching experience. Sample topics include:

- social/cultural norms and values
- education system
- language and dialects, identifying resources for learning German
- political culture, e.g. federalism
- work regulations for students
- healthcare system
- accommodation
- workplace culture & hierarchical structures

Pillar IV: Career growth in Germany

Career guidance and German language input related to the working world is to help students navigate their professional paths effectively and ensures they can leverage their education and skills to achieve long-term success. Sample topics include:

- requirements of the German job market
- professional etiquette
- networking
- online presence
- conduct at job fairs
- how to apply
- mock job interviews

Teaching Methods

- This module encompasses seminars, simulations, case studies and role play to promote students individual scope of action pursued in intercultural settings.
- Intercultural presentations developed by students are integral to solidify their cultural reflection skills by putting their native culture in comparison to the knowledge on German cultural studies taught within the course.
- iLearn (online learning platform)

MRO-07 Advanced Methods in Robotics

Module code	MRO-07
Module coordination	Christy Paul
Course number and name	MRO-IR2101 Advanced Methods in Robotics
Lecturer	Christy Paul
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	Portfolio (With planned room)
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

An "Advanced Methods in Robotics" course typically delves into more advanced concepts and techniques in the field of robotics, assuming a foundation in robotics fundamentals. The course covers a wide range of advanced topics in robotics, focusing on practical applications and emerging trends. It's designed to provide students with a deep understanding of advanced methods and the ability to apply them to real-world robotics problems.

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

Professional competence:

- Gain a deep understanding of advanced robotics principles, technologies, and methodologies.
- Develop skills in using advanced sensors and perception techniques, such as Lidar, depth cameras, and Visual SLAM, to enhance robotic perception.
- Master advanced motion planning and control algorithms, including reinforcement learning and real-time reactive control.
- Aquire proficiency in using machine learning for robotics applications, from supervised and unsupervised learning to reinforcement learning and transfer learning.
- Develop the ability to implement Simultaneous Localization and Mapping (SLAM) techniques for robot localization and environment mapping.

Methodological competence:

- Enhance problem-solving skills, particularly in addressing complex challenges in robotics and applying appropriate methodologies.
- Gain experience in experimental design, data collection, and analysis for robotics research and development.
- Acquire project management skills for planning, executing, and delivering robotics projects

Personal competence:

- Strengthen self-motivation for continuous learning, experimentation, and exploration of advanced robotics concepts.
- Improve adaptability in keeping pace with rapidly evolving robotics technologies and methodologies.

Social competence:

- Enhance the ability to work effectively in multidisciplinary teams on complex robotics projects.
- Build leadership skills and the capacity to mentor and guide peers in advanced robotics concepts and projects .

Applicability in this and other Programs

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

Entrance Requirements

Bachelor degree in mechatronics or a closely related field.

Learning Content

The "Advanced methods in robotics" course is designed to provide students with an in-depth exploration of advanced concepts, methodologies, and technologies in the field of robotics. Building upon fundamental robotics knowledge, this course delves into cutting-edge advancements, including advanced sensors, perception, planning and control, machine learning for robotics, human-robot interaction, and practical applications in various domains. Through a combination of theoretical learning, hands- on projects, and research opportunities, students will develop the skills and expertise required to tackle complex robotics challenges and contribute to the advancement of the field. This results in several relevant subject areas, such as:

- Advanced Sensors and Perception
- Localization
- Mapping
- Simultaneous Localization and Mapping
- Path Planning and Navigation
- Machine Learning for Robotics
- Autonomous self-driving vehicles
- Swarm robotics
- Soft robotics
- Human-Robot Interaction

Teaching Methods

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

Recommended Literature

[1]. "Probabilistic Robotics" by Sebastian Thrun, Wolfram Burgard, and Dieter Fox

[2]. "Reinforcement Learning: An Introduction" by Richard S. Sutton and Andrew G. Barto

[3]. "Introduction to Autonomous Robots" by Nikolaus Correll, Bradley Hayes, et al.

[4]. "Handbook on Soft Robotics" by Thrishantha Nanayakkara.

[5]. "Human-Robot Interaction: An Introduction" by Kerstin Dautenhahn, et al.

[6]. "SLAM: Simultaneous Localization and Mapping for Robots" by Giorgio Grisetti, et al.

[7]. "Robotics: Science and Systems" (Proceedings of the annual RSS conference)

MRO-08 Image Processing and Computer Vision

Module code	MRO-08
Module coordination	Prof. Dr. Tobias Schaffer
Course number and name	MRO-IR2102 Image Processing and Computer Vision
Lecturer	Prof. Dr. Tobias Schaffer
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	Portfolio (With planned room)
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

The "Image Processing and Computer Vision" course provides a compact introduction to classical and modern methods of image processing and machine vision. Topics include digital image fundamentals, spatial and frequency filtering, edge detection, camera models, calibration, stereo vision, feature detection and matching, motion analysis, and optical flow. Building on this, modern deep-learning models for classification, detection, segmentation, generative modeling (Autoencoders, VAEs, GANs), adversarial robustness, Visual SLAM, and 2D/3D pose estimation are introduced. Students gain theoretical foundations and practical skills for analyzing visual data and constructing computer-vision pipelines.

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

Professional competence:

- Develop a deep understanding of image processing techniques, including filtering, enhancement, and segmentation.
- Gain skills in computer vision, covering object optical flow, and 3D reconstruction.
- Acquire knowledge of deep learning models, especially convolutional neural networks (CNNs), for image classification, object detection, and semantic segmentation.
- Understand fundamental Visual-SLAM concepts and apply feature-based components.
- Explore emerging trends in computer vision, enabling students to stay current with the latest advancements and contribute to the field.

Methodological competence:

- Develop skills in designing experiments and evaluating the performance of image processing and computer vision algorithms.
- Formulate and solve computer-vision problems using mathematical and algorithmic tools.
- Enhance problem-solving skills, particularly in diagnosing and addressing issues in image analysis and computer vision.
- Assess model quality using established metrics (IoU, Dice, reprojection error, Hausdorff, etc.).

Personal competence:

- Analytical and independent problem-solving skills for visual data tasks.
- Awareness of limitations, robustness, and vulnerability in machine vision.
- Improve adaptability to keep up with rapidly evolving technologies and methodologies in image processing and computer vision.

Social competence:

- Enhance the ability to work effectively in multidisciplinary teams on complex computer vision projects.
- Communicate vision-analysis results clearly and collaborate effectively in technical discussions.

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and transfer possibility for the application of computer vision systems in different systems and applications with applicability to robotics, mechatronics, computer engineering or related fields.

Entrance Requirements

Bachelor degree in mechatronics, computer-science or a closely related field.

Learning Content

The course covers the essential theoretical and practical foundations of image processing and machine vision. Students learn how images are formed, processed, and transformed, and how visual information can be extracted, interpreted, and used for decision-making. The content spans classical signal-processing methods, geometric computer vision, and modern deep-learning-based approaches. Emphasis is placed on understanding algorithms, applying them to real visual data, and evaluating their performance in practical scenarios.

Topics:

- Fundamentals of Image Processing
- Mathematical Foundations for Computer Vision
- Camera Models and 3D Geometry
- Feature Detection and Matching
- Motion Analysis and Optical Flow
- Deep Learning for Computer Vision
- Object Detection and Segmentation
- Generative Models
- Adversarial Robustness
- Visual SLAM (Simultaneous Localization and Mapping)
- Pose Estimation and Motion Capture

Teaching Methods

- Seminar-like teaching with practical exercises
- i-Learn (online learning platform).

Recommended Literature

[1]. Gao, Xiang; Zhang, Tao (2021). "Introduction to Visual SLAM From Theory to Practice", Springer.

[2]. Burger, Wilhelm; Burge, Mark J. (2022). "An Algorithmic Introduction to Computer Vision", 3rd Edition, Springer.

[3]. Fergus, Paul; Chalmers, Carl (2022). "Applied Deep Learning: Tools, Techniques, and Implementation", Springer.

[4]. Bishop, Christopher M.: Deep Learning: Foundations and Concepts, Springer, 2024.

MRO-09 Robot Modeling and Simulation

Module code	MRO-09
Module coordination	Christy Paul
Course number and name	MRO-IR2103 Robot Modeling and Simulation
Lecturer	Christy Paul
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	Portfolio (With planned room)
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

The "Robot Modeling and Simulation" course focuses on advanced software aspects of robot modeling and simulation. This course explores advanced software tools, libraries, and platforms used for modeling and simulating robotic systems, with a particular focus on software aspects. Students will delve into topics such as dynamics, sensor simulation, control algorithms, high-level simulation environments, multibody dynamics, soft robots, parallel and redundant manipulators, hybrid systems, advanced sensor simulation, and virtual reality (VR) applications in robotics simulation. The course includes research or project work that emphasizes advanced software applications in robot simulation.

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

Professional competence:

- Develop an advanced level of proficiency in using software tools, libraries, and platforms for robot modeling and simulation .
- Gain expertise in modeling multibody dynamics and constraint-based modeling, enabling accurate simulation of complex robotic systems.
- Specialized knowledge and skills in simulating soft robots and deformable bodies, which are increasingly important in robotics applications.
- Master the simulation of complex robot manipulators, including parallel and redundant systems, and apply advanced control algorithms.
- Develop the ability to model and simulate hybrid systems and engage in co-simulation of diverse subsystems within robotics applications.

Methodological competence:

- Develop advanced skills in designing and analyzing complex robotic simulations, including performance evaluation and optimization.
- Learn advanced methods for experimentation and testing in simulated environments, with a focus on real-time control and performance assessment.
- Enhance problem-solving skills, particularly when addressing challenges related to multibody dynamics, soft robotics, and parallel manipulators.

Personal competence :

- Cultivate advanced critical thinking and creative problem-solving skills when faced with complex issues in robot modeling and simulation.
- Develop the ability to adapt to rapidly evolving software and technology, staying current with the latest advancements in robotics simulation.
- Strengthen self-motivation and initiative, especially when undertaking advanced research or project work in a specialized area.

Social competence:

- Collaboration skills when working with multidisciplinary teams on complex robotics projects, leveraging advanced software applications .
- Improve advanced communication skills to convey complex technical ideas to both technical and non-technical stakeholders .
- Build leadership skills and the capacity to mentor and guide peers in advanced software applications within the context of robotics simulation .

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and transfer possibility for the application of tools and instrumentation for robot modeling and simulation. Interfaces to mechatronics, electrical engineering and computer engineering.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field.

Learning Content

By the end of the course, students will have developed a comprehensive skill set that includes advanced software proficiency, in-depth knowledge of advanced topics in robotics simulation, and the ability to engage in cutting-edge research or advanced projects in the field. These competences prepare them for roles in software development, research, and innovation within the domain of robot modeling and simulation.

Topics:

- Advanced Robot Kinematics with Software
- Trajectory and Motion Planning
- High-Level Simulation Platforms and Software
- Virtual Reality (VR) and Robotics Simulation
- Advanced Sensor Simulation
- Software-based optimization for motion planning and control
- Advanced Robot Manipulation and Grasping Software

Teaching Methods

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

Recommended Literature

[1]. "Parallel Robots" by J. M. Herve

[2]. "Modeling and Control of Robot Manipulators" by Lorenzo Sciavicco and Bruno Siciliano

[3]. "Hybrid Systems: Computation and Control" by Rajeev Alur and George J. Pappas

[4]. "Virtual Reality and Augmented Reality: Myths and Realities" by Philippe Fuchs, Guillaume Moreau, and Pascal Guitton

[5]. "Robot Modeling and Control" by Mark W. Spong, Seth Hutchinson, and M. Vidyasagar

[6]. "Modern Robotics: Mechanics, Planning, and Control" by Kevin M. Lynch and Frank C. Park

[7]. "Introduction to Robotics: Mechanics and Control" by John J. Craig

MRO-10 Industrial Robotics and Automation

Module code	MRO-10
Module coordination	Dr. Hamidreza Heidari
Course number and name	MRO-IR2104 Industrial Robotics and Automation
Lecturer	Dr. Hamidreza Heidari
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

The "Industrial Robotics and Automation" course provides an in-depth exploration of the principles, technologies, and applications of industrial automation and robotics systems. Students will learn about the design, programming, and operation of industrial robots, as well as the integration of automation solutions in manufacturing and industrial processes.Upon completion of this module, the student has achieved the following learning objectives:

- Develop a strong understanding of industrial robotics and automation systems.
- Gain proficiency in the operation and programming of industrial robots.
- Learn about automation technologies, including PLCs and SCADA systems.

- Apply knowledge to the design and optimization of automated manufacturing processes.

Professional competence:

- Develop a deep understanding of industrial robotics and automation systems, including their design, operation, and applications in manufacturing.
- Gain practical skills in programming and controlling industrial robots, covering topics such as kinematics, dynamics, and vision systems.
- Acquire proficiency in Programmable Logic Controllers (PLCs) and Supervisory Control and Data Acquisition (SCADA) systems, including programming and integration.
- Learn to design and implement automation solutions for industrial processes, considering factors like safety, efficiency, and cost-effectiveness.

Methodological competence:

- Develop the ability to analyze and solve complex problems in industrial automation and robotics, both theoretically and practically.
- Gain practical experience in programming, configuring, and operating industrial robots and automation systems through labs and projects.
- Learn to design experiments and analyze data to optimize automation solutions and manufacturing processes.

Personal competence:

- Foster critical thinking skills to evaluate and improve automation and robotics solutions in a constantly evolving industry.
- Develop adaptability to keep pace with rapidly changing automation technologies and methodologies.
- Cultivate self-motivation for continuous learning and problem-solving in the field of industrial robotics and automation.

Social competence:

- Collaboration skills when working with multidisciplinary teams on complex robotics projects, leveraging advanced software applications .
- Improve advanced communication skills to convey complex technical ideas to both technical and non-technical stakeholders .
- Build leadership skills and the capacity to mentor and guide peers in advanced software applications within the context of robotics simulation .

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and transfer possibility for the application of automation technologies, including PLCs and SCADA systems. Interfaces to mechatronics, electrical engineering and computer engineering.

Entrance Requirements

Bachelors degree in mechatronics or a closely related field.

Learning Content

This "Industrial Robotics and Automation" course aims to equip students with the knowledge and skills required for careers in industrial automation, manufacturing, and robotics. It covers fundamental principles, hands-on experience, and emerging trends in the field, making it a valuable course for those looking to enter the industrial automation industry **.**

Topics:

- Industrial Robot Fundamentals
- Industrial Automation Technologies
- Automation Sensors and Actuators
- Automation System Integration
- Industrial Robotics in Practice
- Industry 4.0 and smart manufacturing .

Teaching Methods

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

Recommended Literature

[1]. "Industrial Automation and Robotics: An Introduction" by A. K. Gupta

[2]. "Industrial Robotics: Technology, Programming, and Applications" by Mikell P. Groover and Mitchell Weiss

[3]. "Introduction to Autonomous Robots" by Nikolaus Correll, Bradley Hayes, et al. [4]. "Robot Modeling and Control" by Mark W. Spong, Seth Hutchinson, and M. Vidyasagar

[5]. "PLC Programming Using RSLogix 5000: Basic Concepts of Ladder Logic Programming!" by Gary Dunning.

MRO-11 Case Study ROS Robot Programming

Module code	MRO-11
Module coordination	Ruben Contreras
Course number and name	MRO-IR2105 Case Study ROS Robot Programming
Lecturer	Ruben Contreras
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	Portfolio
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

On the basis of a real-world robotics application example, this case study provides a comprehensive exploration of the Robot Operating System (ROS) and its practical application in programming and controlling robots. Students will be introduced to the fundamentals of ROS, develop programming skills for modern robotic systems, and engage in project-based, hands-on work that culminates in the design and implementation of a complete robotic solution. The course encompasses key aspects of robotics, including perception, AI-driven decision-making, motion planning and control, navigation, and manipulation.

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

Professional competence:

- Develop expertise in using the Robot Operating System (ROS) to program, control, and navigate robots effectively in real-world scenarios.
- Acquire the skills to design, implement, maintain, and optimize modular ROS-based software architectures for robotic systems.
- Learn to integrate hardware (sensors, cameras, actuators) and software components into a functional robotic system.
- Gain competence in developing motion planning algorithms for robots, enabling them to navigate and interact with their environment.
- Master techniques for sensor data processing, object recognition, and environment mapping.

Methodological competence:

- Develop the ability to analyze open-ended robotics problems and derive suitable system architectures and solutions.
- Apply scientific methodologies for robot experimentation, data collection, and analysis.
- Learn to model and simulate robots and their environments to test algorithms and strategies.
- Develop the practice of systematic documentation, including software design, experiments, and project results, in an effective manner.

Personal competence:

- Application of software development concepts based on the ROS framework for research and implementation of robot motion control algorithms in complex dynamic environments.
- The students learn different concepts that can be applied to deploy robotics-related applications.

Social competence:

- Develop effective communication skills to collaborate with peers and convey technical concepts to non-technical stakeholders.
- Foster teamwork and cooperation within diverse project teams, valuing diverse perspectives and contributions
- Build the capacity to resolve conflicts and disagreements constructively within the team or among project stakeholders.

Applicability in this and other Programs

The skills and competences acquired in the ROS Robot Programming module are applicable to a wide range of masters degree programs and fields, including Robotics, Artificial Intelligence, Industrial Engineering, Automation, and Mechatronics, as well as research-oriented and industrial development contexts.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field.

Learning Content

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

The topics of the case studies can vary each semester.

Teaching Methods

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

Remarks

The case studies are examined as a so-called "portfolio exercise" and therefore do not follow a classic written examination format. The assessment is based on the continuous development and final implementation of a functional robotics project, including software artifacts, documentation, and system performance.

The theoretical knowledge acquired during the course is directly applied in practice, enabling students to analyze complex problems, design system architectures, and implement and evaluate solutions on real robotic platforms. This approach intensifies the transfer of knowledge into practice and supports the targeted deepening of technical, methodological, and collaborative competences.

Recommended Literature

[1]. "Programming Robots with ROS: A Practical Introduction to the Robot Operating System" by Morgan Quigley, Brian Gerkey, and William D. Smart

[2]. "Mastering ROS for Robotics Programming" by Lentin Joseph

[3]. "ROS-Industrial: An Open-Source Robot Operating System Consortium for Manufacturing Robotics" by R. Owens and B. J. Panzera

[4]. "ROS Robotics Projects" by Lentin Joseph

MRO-12 Intelligent Multi-Agent Systems

Module code	MRO-12
Module coordination	Prof. Dr. Sebastian Grundstein
Course number and name	MRO-IR2106 Intelligent Multi-Agent Systems
Lecturer	Prof. Dr. Sebastian Grundstein
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	Portfolio
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

The "Intelligent Multi-Agent Systems" course provides an in-depth exploration of the principles, algorithms, and applications of multi-agent systems. Multi-agent systems involve multiple agents or entities that interact to achieve a common goal. These systems have applications in various domains, including robotics, distributed computing, autonomous vehicles, and more. Students will learn about the design of intelligent agents, negotiation, cooperation, coordination, and decision-making in multi-agent environments. The course will cover both theoretical foundations and practical applications, enabling students to design and implement intelligent multi- agent systems.

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

Professional competence:

- Develop a deep understanding of multi-agent systems, their principles, and their applications.
- Gain skills in designing intelligent agents capable of autonomous decision-making and communication.
- Learn to design and implement communication and negotiation protocols for effective agent interactions.
- Understand the principles of cooperation and coordination among multiple agents, including task allocation and planning.
- Explore advanced topics such as coalition formation, game theory, swarm intelligence, and collective behavior in multi-agent systems.

Methodological competence:

- Develop skills in designing experiments and simulations to evaluate the performance of multi-agent systems.
- Acquire project management skills for developing multi-agent systems, including requirements analysis, design, and testing.
- Enhance problem-solving skills, particularly in diagnosing and addressing issues in multi-agent systems.
- Understand the importance of simulation and testing in the development and validation of multi-agent systems.

Personal competence:

- Foster critical thinking and analytical skills to evaluate and improve multi-agent systems.
- Cultivate innovation and creativity in designing intelligent multi-agent solutions and addressing complex challenges.
- Improve adaptability to keep pace with evolving technologies and methodologies in multi-agent systems.

Social competence:

- Improve the ability to communicate complex technical ideas to both technical and non-technical stakeholders.
- Build leadership skills and the capacity to mentor and guide peers in advanced robotics concepts and projects.
- Gain insights into the challenges and opportunities presented by global collaboration in the development and application of intelligent multi-agent systems .

Applicability in this and other Programs

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

Entrance Requirements

Bachelor degree in mechatronics or a closely related field.

Learning Content

This "Intelligent Multi-Agent Systems" course equips students with a solid foundation in multi-agent systems theory and practical development. By the end of the course, students will have the knowledge and skills to design, implement, and analyze intelligent multi-agent systems for various applications, making them valuable contributors in the fields of robotics, distributed computing, and more.

Topics:

- Overview of multi-agent systems.
- Historical perspective and milestones in multi-agent systems .
- Intelligent Agents.
- Agent architectures and design principles .
- Autonomous agents, communication, and collaboration .
- Communication and Coordination.
- Autonomous agents, communication, and collaboration .
- Coordination mechanisms: centralized, decentralized, and distributed .
- Negotiation protocols and strategies .
- Cooperation and Collaboration.
- Multi-agent planning and task allocation .
- Multi-agent learning and knowledge sharing .
- Swarm intelligence and collective behavior .
- Simulation and testing of multi-agent systems .

Teaching Methods

- Seminar-like teaching with joint exercises as well as presentations to deepen the knowledge achieved through application
- i-Learn (online learning platform)
- Practical Exercise in Anylogic to develop and simulate an intelligent Multi-Agent-System in a domain of choice

Recommended Literature

[1]. "Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations" by Yoav Shoham and Kevin Leyton-Brown

[2]. "Introduction to Multiagent Systems" by Michael Wooldridge

[3]. "Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence" by Gerhard Weiss

[4]. "Swarm Intelligence" by Russell C. Eberhart and Yuhui Shi

[5]. "Reinforcement Learning: An Introduction" by Richard S. Sutton and Andrew G. Barto

[6]. "Agent-Based and Individual-Based Modeling: A Practical Introduction" by Steven L. Railsback and Volker Grimm

MRO-13 Soft Robotics

Module code	MRO-13
Module coordination	Christy Paul
Course number and name	MRO-AR2101 Soft Robotics
Lecturer	Christy Paul
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	Portfolio (With planned room)
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

Soft Robotics is an emerging subfield of robotics with great potential for interfacing with delicate objects and living systems. Soft actuators are made of soft and compliant materials such as polymer/metal composites, elastomers, and hydrogels. These soft machines operate based on pneumatic, electrical, chemical, and optical actuation mechanisms. This course will focus on modeling, control, and manufacturing of electroactive polymer actuators and soft pneumatics actuators and their application in soft robotic systems.

Professional competence:

- Learn and understand the fundamental principles of soft robotics, including materials, actuation, sensing, and control strategies

- Gain hands-on experience in designing and developing soft robotic systems with bioinspired and multidisciplinary approaches
- Apply modeling, simulation, and experimental techniques to analyze system performance and reliability
- Evaluate and apply industry standards, regulatory frameworks, and emerging trends to guide innovations in soft robotics for professional practice
- Understand the societal, ethical, and sustainable implications of professional engineering practice

Methodological competence:

- Apply systematic research methodologies to design experiments, collect data, and analyze results in soft robotics projects
- Evaluate and select appropriate modeling, simulation, and fabrication techniques for solving complex problems in soft robotic systems
- Implement systematic problem-solving approaches to develop actuation, sensing, and control solutions

Personal competence:

- Apply critical thinking to analyze and evaluate the mechanical properties of soft materials, identifying and solving complex design challenges in robotic applications
- Adapt and integrate novel fabrication methods into soft robotic systems, demonstrating flexibility and innovation in rapidly evolving research contexts
- Demonstrate selfmotivation and autonomy in pursuing independent projects, reflecting on learning progress, and setting research goals that contribute to both personal growth and the field of robotics

Social competence:

- Develop effective communication skills to convey complex ideas to peers, multidisciplinary teams, and non-technical stakeholders
- Enhance collaboration on projects and design challenges, demonstrate leadership, and make fair, inclusive, and socially responsible decisions
- Gain awareness of the societal, ethical, and environmental impact of technology, promoting responsible and sustainable innovation

Applicability in this and other Programs

This module provides students with the theoretical foundation and transfer possibility of soft robotics concepts to diverse systems and applications. It also explores interfaces with mechatronics, electrical engineering, and computer engineering, enabling students to adapt and apply their skills across multidisciplinary projects and real-world scenarios.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field

Learning Content

This course introduces students to the emerging field of soft robotics, a rapidly evolving area at the intersection of materials, biology, and intelligent systems. It aims to equip students with practical skills, problem-solving abilities, and hands-on experience, enabling them to understand and engage with cutting-edge technologies. By the end of the course, students will be prepared to apply their knowledge in innovative ways and tackle future challenges in this dynamic field.

Selected topics:

- Science of Soft Robots
- Actuation mechanisms in Soft Robotics
- Sensing and Perception
- Bioinspiration
- Materials and Fabrication
- Modeling and Simulation
- Control strategies for Soft Robotics

Teaching Methods

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

Recommended Literature

[1] "The Science of Soft Robots: Design, Materials and Information Processing" by Koichi Suzumori, Kenjiro Fukuda, Ryuma Niiyama, and Kohei Nakajima.

[2] "Handbook on Soft Robotics" by Thrishantha Nanayakkara.

[3] "Advances in Chemical Engineering: Soft Robotics" by Luca Magagnin.

[4] "Soft Robotics for Medical and Healthcare Applications" by Shaik Himam Saheb, Tharakeshwar Appala, and Mohammad S. Khan.

MRO-14 Sensor Fusion and Perception for Assistive Robotics

Module code	MRO-14
Module coordination	Christy Paul
Course number and name	MRO-AR2102 Sensor Fusion and Perception for Assistive Robotics
Lecturer	Christy Paul
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	Portfolio (With planned room)
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

This course provides an in-depth understanding of sensor fusion and perception techniques tailored for assistive robotic applications. Students will explore how multiple sensor inputs can be integrated to enable robots to perceive and interpret complex, dynamic environments. Emphasis will be placed on practical applications, including navigation in human-centric spaces, obstacle avoidance, and understanding human activities and intentions.

Professional competence:

- Understand the principles of sensor types, architectures, and system representations in assistive robotics
- Gain hands-on experience in probabilistic fusion techniques and multi-sensor integration for reliable perception
- Master data association, object recognition, and calibration methods to ensure accurate and robust system performance
- Acquire the ability to implement safety, redundancy, and fault-tolerant strategies in sensor fusion systems
- Develop skills to manage sensor resources and optimize sensor management strategies in complex robotic applications
- Apply interdisciplinary knowledge from mechatronics, electrical, and computer engineering to design and deploy assistive robotic systems effectively

Methodological competence:

- Evaluate systematic sensor fusion and perception techniques to design and analyze assistive robotic systems
- Develop structured approaches for modeling, simulation, and integration of multi-sensor data
- Acquire project management skills to plan, structure, and execute robotics projects, ensuring systematic progress and reliable outcomes

Personal competence:

- Apply critical thinking and analytical skills to interpret sensor data and solve perception challenges in assistive robotics
- Gain hands-on experience in experimental design, sensor data collection, and systematic analysis
- Develop self-directed learning and adaptability to explore new sensors, algorithms, and robotic applications independently

Social competence:

- Develop the ability to communicate complex sensor fusion and perception concepts clearly to peers, multidisciplinary teams, and non-technical stakeholders
- Demonstrate effective teamwork by collaborating on projects, respecting diverse perspectives, and resolving conflicts constructively
- Foster empathy and human-centered perspective by aligning technical solutions with the needs of vulnerable populations

Applicability in this and other Programs

This module provides students with the theoretical foundation and practical insights necessary to apply sensor fusion techniques in assistive robotics. It highlights the transferability of these concepts to related fields, with clear interfaces to mechatronics, electrical engineering, and computer engineering

Entrance Requirements

Bachelor degree in mechatronics or a closely related field.

Learning Content

This module offers a rigorous exploration of the sensing and perception frameworks that form the foundation of assistive robotic systems. By engaging with topics such as sensor types, system representations, probabilistic fusion methods, data association, and multi-sensor calibration, students develop a thorough understanding of how heterogeneous sensor data can be integrated to support reliable and intelligent robot behavior. The content emphasizes both theoretical principles and practical implementation, enabling learners to interpret uncertainty, manage dynamic environments, and address real-world challenges in human-centered spaces.

- Sensor Types and Perceptions in Assistive Robots
- Sensor Architectures and System Representations
- Probabilistic Fusion Techniques
- Data Association and Object Recognition
- Multi-Sensor Calibration and Synchronization
- Safety, Redundancy & Fault Tolerance in Sensor Fusion
- Sensor Management

Teaching Methods

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

Recommended Literature

[1] "Probabilistic Robotics" by Sebastian Thrun, Wolfram Burgard, and Dieter Fox.

[2] Springer Handbook of Robotics by Bruno Siciliano and Oussama Khatib.

[3] Introduction to Autonomous Mobile Robots by Roland Siegwart, Illah R. Nourbakhsh, and Davide Scaramuzza.

[4] Multi-Sensor Data Fusion: An Introduction by H.B. Mitchell.

[5] Sensor and Data Fusion by Dr. Ir. Nada Milisavljevi#.

[6] Intelligent Assistive Robots: Recent Advances in Assistive Robotics for Everyday Activities by Amer Mohammed, Juan C. Moreno, Kyoungchul Kong, and Yacine Amirat.

MRO-15 Biomechanics

Module code	MRO-15
Module coordination	Prof. Dr. Tim Weber
Course number and name	MRO-AR2103 Biomechanics
Lecturer	Prof. Dr. Tim Weber
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

This course explores the fundamental principles of biomechanics and their application in the design of assistive robotic systems. Students will learn how to analyze human movement and physical interactions to create robots that complement and enhance human capabilities, especially for individuals with mobility impairments or other physical disabilities. Emphasis will be placed on understanding human musculoskeletal mechanics, joint kinematics, and ergonomic considerations in human-robot interaction.

Professional competence:

- understanding the building blocks of human movement (Kinemtatics)
- understanding classical mechanics and its application (Kinetics) in Biomechanics

- understanding the use and application of optimization in Biomechanics (overdetermined systems)
- understanding materials special to the human body (cartilage, bone, skin)

Methodological competence:

- application of classical mechanics in a biomechanical setting
- application of measurements of human movement
- application of solution for (simple) open and closed kinematic chains and the respective hand calculations
- overview of biosignals concerning biomechanics (e.g. EMG)

Personal competence:

- The module Biomechanics teaches students how to transfer classical mechanics to biomechanics
- The students learn how to measure different aspect of biomechanics (kinematic, kinetic) and translate that into insights
- The students learn about special aspect of biomechanical sructures (Wolff's Law for Bone growht, cartilage)

Social competence:

- Students are able to view the problems from the field of mechanics from the meta level and to use their competences acquired in the module appropriately and situation-based in individual and group discussions.

Applicability in this and other Programs

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Entrance Requirements

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

Learning Content

1.Musculoskeletal system and joint mechanics

2.Kinematics&dynamics of human movement

3.Biomechanical Modeling and Simulation

4.Ergonomics and safety in assistive robotics design

Teaching Methods

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

i-Learn (online learning platform)

Recommended Literature

Nikravesh, P. E. (1987). Computer aided analysis of mechanical systems. Prentice Hall.

Nikravesh, P. E. (2018). Planar multibody dynamics: Formulation, programming with MATLAB (R), and applications, second edition (2nd ed.). CRC Press.

Leger, D. L. (1999). Fundamentals of biomechanics: Equilibrium, motion and deformation (M. Nordin, Ed.; 2nd ed.). Springer.

Holzmann, G., Meyer, H., & Schumpich, G. (2000). Technische Mechanik: Teil 1: Statik (9th ed.). Vieweg & Teubner.

MRO-16 Rehabilitation Robotics

Module code	MRO-16
Module coordination	Dr. Hamidreza Heidari
Course number and name	MRO-AR2104 Rehabilitation Robotics
Lecturer	Dr. Hamidreza Heidari
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

This course explores the principles, technologies, and applications of robotics in rehabilitation. Students will learn how to design and implement robotic systems that assist individuals recovering from injury, surgery, or neurological conditions. The course covers topics such as exoskeletons, robotic prosthetics, and therapy devices, with a strong emphasis on human-centered design, adaptability, and effectiveness in aiding recovery. Students will gain hands-on experience in developing rehabilitation robotics solutions and evaluating their impact on patient outcomes.

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

- Develop a solid understanding of rehabilitation robotics architectures, including end-effector devices, exoskeletons, and therapy robots.
- Understand the clinical context, use-cases, and basic rehabilitation protocols in which robotic systems are deployed.
- Apply modeling and control techniques to humanrobot interaction in rehabilitation scenarios.
- Evaluate safety, usability, and effectiveness of rehabilitation robotic systems based on technical and therapy-related criteria.

Professional competence:

- Develop a deep understanding of the principles and application domains of rehabilitation robots, including upper- and lower-limb systems, gait trainers, and robot-assisted therapy devices.
- Gain competence in modeling kinematics and dynamics of humanrobot interaction in rehabilitation systems and interpreting the resulting physical quantities.
- Acquire skills in designing and analyzing control strategies for rehabilitation robots (e.g. assist-as-needed control, impedance/admittance control, trajectory-based and bio-signal-driven assistance).
- Understand requirements related to safety, ergonomics, and usability in clinical and home-based rehabilitation environments.
- Gain familiarity with relevant standards, validation procedures, and performance measures used to assess rehabilitation technology.

Methodological competence:

- Develop the ability to translate rehabilitation goals and clinical requirements into engineering specifications for robotic systems.
- Gain experience in using simulation and modeling tools to design and virtually test rehabilitation robotic devices and control algorithms.
- Apply signal processing and estimation methods to sensor data (e.g. motion capture, IMUs, force/torque sensors, EMG) in rehabilitation scenarios.
- Plan and conduct small-scale experimental studies or human-in-the-loop simulations, including data collection, analysis, and interpretation.
- Critically review scientific literature on rehabilitation robotics and compare alternative technical approaches and solutions.

Personal competence:

- Strengthen critical thinking when assessing benefits, risks, and limitations of robotic technologies in rehabilitation and healthcare.
- Develop adaptability and a willingness to continuously update knowledge in a rapidly evolving field at the intersection of robotics, biomechanics, and medicine.
- Enhance self-directed learning skills through independent literature research and project work.

- Build awareness of ethical responsibility when designing systems that directly interact with vulnerable user groups.

Social competence:

- Learn to collaborate effectively in interdisciplinary teams involving engineers, clinicians, therapists, and other stakeholders.
- Improve communication skills to explain technical concepts of rehabilitation robotics to non-technical stakeholders such as medical staff and patients.
- Develop the ability to document and present project outcomes in a structured and understandable way (reports, posters, short presentations).
- Gain sensitivity to ethical, legal, and social implications of deploying rehabilitation robots, including user autonomy, privacy, inclusiveness, and acceptance.

Applicability in this and other Programs

The module provides the necessary theoretical knowledge and transfer possibility for the application of robotic systems in rehabilitation and clinical environments. It builds interfaces to biomechanics, sensor fusion, humanrobot interaction, assistive robotics, and advanced control. The module is relevant for degree programmes in robotics, mechatronics, biomedical engineering, and other engineering programmes dealing with medical and assistive technologies.

Entrance Requirements

Bachelor degree in mechatronics or a closely related field.
Basic knowledge in control engineering, robotics, and programming is recommended.

Learning Content

On the basis of selected rehabilitation scenarios, students will explore and work on the topic by combining theoretical foundations, literature research, and simulation-based design tasks.

Topics:

1. Types of rehabilitation robots and their applications (end-effector devices, exoskeletons, gait trainers, robotic prostheses)
2. Design and application of robotic systems for rehabilitation therapy (clinical goals, user requirements, safety and ergonomics)
3. Sensing and control systems in rehabilitation robotics (force/torque sensing, motion capture, EMG, impedance and assist-as-needed control)
4. Adaptive and intelligent rehabilitation robotics (personalization, progress adaptation, AI-based decision support)

5 Service robots in healthcare institutions (logistics, patient support, telepresence and monitoring)
6 Ethics and challenges in rehabilitation robotics (acceptance, regulations, data protection, human factors)

Teaching Methods

- Seminar-like teaching with joint exercises and discussions to deepen the knowledge achieved through application.
- Literature research and critical reading of current rehabilitation robotics publications.
- Simulation-based exercises for modeling and control of rehabilitation robots.
- Case-study work in small groups on selected rehabilitation applications.
- i-Learn (online learning platform) for providing materials, quizzes, and assignment submission.

Recommended Literature

[1] Riener, Robert. *Rehabilitation Robotics.*
[2] Reinkensmeyer, D. J.; Dietz, V. (eds.). *Neurorehabilitation Technology.* Springer.
[3] Siciliano, Bruno; Khatib, Oussama (eds.). *Springer Handbook of Robotics* chapters on medical and rehabilitation robotics.
[4] Rosen, Jacob (ed.). *Wearable Robotics: Systems and Applications.* Elsevier.
[5] Selected recent articles from *IEEE Transactions on Neural Systems and Rehabilitation Engineering* , *Journal of NeuroEngineering and Rehabilitation* , and related medical robotics journals.

MRO-17 Case Study Assistive Robotics for Improvement of Life Quality

Module code	MRO-17
Module coordination	Dr. Hamidreza Heidari
Course number and name	MRO-AR2105 Case Study Assistive Robotics for Improvement of Life Quality
Lecturer	Dr. Hamidreza Heidari
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	Portfolio
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

The case study "Assistive Robotics for Improvement of Life Quality" deals with real-world applications related to the design, modeling, and simulation of assistive robotic solutions. Students are given the opportunity to independently and creatively address topics such as rehabilitation robotics, exoskeletons, social-assistive robots, or healthcare-oriented robotic platforms.

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

Professional competence:

- Students obtain in-depth knowledge of assistive robotic technologies such as rehabilitation robots, wearable exoskeletons, prosthetics, telepresence systems, and assistive home devices.
- They are able to evaluate the functional capabilities, safety constraints, and human-factor requirements of assistive systems.
- Students can design or simulate assistive robotic concepts and assess performance through metrics relevant to human well-being, ergonomics, and safety.

Methodological competence:

- Students can perform structured literature research and critically review state-of-the-art research in assistive robotics.
- They can independently select and apply suitable technical methods such as compliant control, sensor fusion, motion planning, or machine learning-based adaptation.
- Students are able to document and evaluate their chosen methodology and interpret results in a scientifically sound manner.

Personal competence:

- Students learn how to independently approach complex interdisciplinary problems, combining robotics, biomechanics, healthcare, and user requirements.
- They develop analytical thinking, creativity, and responsibility when designing solutions for sensitive user populations such as elderly or disabled individuals.
- Students reflect on ethical, ergonomic, and safety considerations when designing assistive robotic technologies.

Social competence:

- Students can collaborate within teams, distribute responsibilities, and integrate user perspectives into design decisions.
- They are able to articulate technical concepts clearly and present results in a structured and application-oriented way to both technical and non-technical stakeholders.
- Students acquire the ability to evaluate solutions collaboratively, discuss trade-offs, and provide constructive feedback.

Applicability in this and other Programs

The module provides the necessary theoretical and practical competencies to understand and design assistive robotic systems aimed at enhancing human quality of life.
It creates interfaces to degree programmes such as robotics, mechatronics, medical technology, biomedical engineering, humanrobot interaction, and rehabilitation engineering.

Entrance Requirements

Bachelor degree in mechatronics, robotics, biomedical engineering, industrial engineering or a closely related field.

Learning Content

Students independently explore assistive robotics topics through case-based scenarios, simulation, or conceptual implementation.

Examples of case-study topics include:

1. Wearable exoskeleton for muscle weakness support Design of lower-limb or upper-limb exoskeleton support and ergonomic evaluation.
2. Home assistance for daily living Robotic platforms for household tasks, cleaning, or personal assistance.
3. Rehabilitation and physical therapy support Assistive devices enabling motor recovery, range-of-motion training, or tele-rehabilitation.
4. Mobility support for elderly or disabled users Navigation aids, robotic wheelchairs, or autonomous walker devices.
5. Sensory augmentation for visually or hearing-impaired individuals Wearables or devices for tactile, auditory, or visual enhancement.

The topics of the case studies can vary each semester.

Teaching Methods

- Literature research
- Simulation or prototyping tasks
- Application of evaluation methods
- Guided work on seminar topics in small groups
- Presentations and discussion rounds

Remarks

The case studies are examined as a **portfolio exercise** and are therefore not a classic examination.

Students apply theoretical knowledge to practical scenarios, analyze problems independently, and evaluate solution strategies.

This leads to a targeted deepening of their technical, methodological, and ethical competences.

Recommended Literature

- Siciliano, Bruno; Khatib, Oussama. Springer Handbook of Robotics.
- Riener, Robert. Rehabilitation Robotics.
- Bartneck, Christoph. HumanRobot Interaction: An Introduction.
- Rosen, Jacob. Wearable Robotics: Systems and Applications.
- IEEE Transactions on Robotics, ICRA , IROS , HRI , and relevant medical robotics journals.

Additional topic-specific literature will be provided depending on the selected case study.

MRO-18 Human-Robot Interaction

Module code	MRO-18
Module coordination	Prof. Dr. Volha Kukso
Course number and name	MRO-AR2106 Human-Robot Interaction
Lecturer	Prof. Dr. Volha Kukso
Semester	2
Duration of the module	1 semester
Module frequency	each semester
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	4
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	written ex. 90 min.
Duration of Examination	90 min.
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

This course examines the principles, techniques, and challenges of human-robot interaction (HRI) within the context of assistive robotics. Students will explore how robots can be designed to effectively interact with and assist people in daily tasks, particularly individuals with disabilities or special needs. Topics will include user-centered design, social and ethical aspects, communication interfaces, and real-time adaptive interactions. The course combines theoretical knowledge with hands-on experience, allowing students to prototype and evaluate interaction designs.

Professional competence

Students understand fundamental concepts and challenges of human-robot interaction in assistive contexts, can recognise basic user needs, and are able to relate them to simple interaction requirements, communication modalities, and principles of adaptive behaviour.

Methodological competence

They can apply basic user-centered approaches, plan and conduct small HRI design or evaluation tasks, and represent and assess interaction processes and results using simple analytical or modelling tools.

Personal competence

Students reflect on their own design decisions, take responsibility when considering the needs of vulnerable user groups, and handle uncertainty within iterative interaction design processes.

Social competence

They can discuss HRI concepts and challenges clearly and constructively and provide or respond to structured feedback on interaction designs or evaluation approaches.

Applicability in this and other Programs

This module is particularly relevant for students specialising in assistive robotics, rehabilitation robotics, human-machine interaction, and user-centered system design.

Entrance Requirements

Basic knowledge of robotics and perception systems from the first-semester modules of the Master Robotics programme is recommended.

Learning Content

1.User-centered design in assistive robotics
2.Communication modalities in HRI
3.Real-time adaptive interactions
4.Evaluation and Testing of HRI Systems

Teaching Methods

Lectures

Remarks

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Recommended Literature

Siciliano, B., & Khatib, O. (2008, 2016). *Springer handbook of robotics* (1st., 2nd ed.). Springer.

Bartneck, C., Belpaeme, T., Eyssel, F., Kanda, T., Keijsers, M., & Sabanovic, S. (2024).
Humanrobot interaction: An introduction (2nd ed.). Cambridge University Press.

Tian, L., Wu, T. L. Y., Robinson, N. L., Carreno-Medrano, P., Chan, W. P., Sakr, M., Abdi, E., Croft, E. A., & Kuli#, D. (2024).
Experimental methodology for humanrobot interaction: Guidelines and case studies for human-centred and ethical robotics research (1st ed.). CRC Press.

Shiomi, M., & Sumioka, H. (Eds.). (2024).
Social touch in humanrobot interaction: Symbiotic touch interaction between human and robot (1st ed.). CRC Press.
https://doi.org/10.1201/9781003384274

MRO-19 Subject-Related Elective Course (FWP)

Module code	MRO-19
Module coordination	Prof. Dr. Dmitrii Dobriborsci
Course number and name	Embedded Linux Tele-Experiments with Mobile Robots Entrepreneurial Thinking
Lecturers	Gerhard Diel Andreas Geiling Prof. Dr. Josef Schmid Virtuelles Angebot vhb
Semester	3
Duration of the module	1 semester
Module frequency	annually
Course type	compulsory course
Level	postgraduate
Semester periods per week (SWS)	12
ECTS	5
Workload	Time of attendance: 60 hours self-study: 90 hours Total: 150 hours
Type of Examination	Examination form of the chosen module
Weighting of the grade	5 out of 90 ECTS
Language of Instruction	English

Module Objective

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

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

- Tele Experiments with Mobile-Robots

The offer is reviewed every semester and updated if necessary.

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

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

Professional competence:

The competences result from the chosen FWP subject.

Methodological competence:

The competences result from the chosen FWP subject.

Personal competence:

The competences result from the chosen FWP subject.

Social competence:

The competences result from the chosen FWP subject.

Applicability in this and other Programs

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

Entrance Requirements

Bachelor`s degree in mechatronics or a closely related field

Learning Content

The contents result from the respective FWP subject.

Teaching Methods

The didactic methods result from the respective FWP subject.

Remarks

The FWP range of subjects includes courses with different ECTS values. Students are advised to take courses with at least 5 ECTS values.

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

Recommended Literature

The literature result from the respective FWP subject.

Embedded Linux

Objectives

After successfully completing the module, students will have acquired the following technical, methodological, and personal skills:

- Technical skills: Students will be familiar with working with embedded Linux systems. In addition to file system structure and distribution creation, this also includes software management and driver development.
- Methodological skills: Students are able to integrate programs into a Linux environment and implement smaller embedded tasks on the software side.
- Personal skills (social skills and self-competence): Students are able to assess given problems in terms of feasibility, implementation effort and tool selection.

Entrance Requirements

Basic knowledge of programming with C/C++

Learning Content

1. Introduction to Linux
2. Shell basics
3. Bash script programming
4. Boot sequence of an embedded Linux system
5. Distribution creation
6. C++ under Linux
7. Software packages and management
8. Linux kernel modules

Type of Examination

written ex. 90 min.

Methods

seminar-style course with exercises

Recommended Literature

E-Books:

- http://openbook.rheinwerk-verlag.de/linux
- http://openbook.rheinwerk-verlag.de/linux_unix_programmierung
- http://openbook.rheinwerk-verlag.de/shell_programmierung
- http://openbook.rheinwerk-verlag.de/unix_guru/

Tele-Experiments with Mobile Robots

Objectives

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

Learning Content

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

Contents:

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

3) Path planning of a car-like mobile robot
4) Modelling of the forward and inverse kinematics of differential drive robot
5) Sensor data acquisition and processing

Type of Examination

written student research project

Methods

Virtual internship

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

Forms of interaction with fellow learners:
e-mail

Entrepreneurial Thinking

Objectives

The objective of this module is to prepare engineering students for entrepreneurial thinking and action in technology-driven environments. Students gain a holistic understanding of entrepreneurship, combining mindset, leadership, creativity, business fundamentals, and practical application.

The module enables students to develop, evaluate, and present entrepreneurial ideas from ideation to pitch, while strengthening self-leadership, resilience, teamwork, and communication skills. Particular emphasis is placed on practical relevance, interdisciplinary collaboration, and the development of sustainable business concepts applicable to real-world contexts.

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

Professional competence:

- Understand the role and responsibilities of entrepreneurs in technology-driven and innovation-oriented environments
- Explain fundamental concepts of entrepreneurship, business models, and market validation
- Develop structured entrepreneurial ideas and assess their feasibility
- Apply leadership principles within entrepreneurial teams

- Communicate entrepreneurial concepts clearly and convincingly to different stakeholders

Methodological competence:

- Apply creative ideation methods (e.g. Design Thinking) to identify and structure problem-solution approaches
- Use entrepreneurial frameworks such as Lean Canvas or Business Model Canvas
- Conduct basic market and competitor analyses
- Structure and prepare professional pitches and concept presentations
- Reflect systematically on entrepreneurial processes and learning progress

Personal competence:

- Demonstrate self-leadership and personal responsibility in uncertain and dynamic situations
- Develop resilience and perseverance when facing challenges and setbacks
- Reflect on their own strengths, values, and behavioral patterns
- Manage stress and maintain focus during complex project phases
- Act proactively and independently within entrepreneurial contexts

Social competence:

- Work effectively in interdisciplinary and multicultural teams
- Communicate constructively and respectfully within group processes
- Handle conflicts and feedback situations in a professional manner
- Take responsibility within team structures and contribute to shared goals
- Present ideas confidently in front of an audience and respond to questions

Entrance Requirements

Bachelors degree in engineering, computer science, or a closely related field.

Learning Content

The module covers the following topics:

Entrepreneurial Mindset and Self-Leadership

- Role of the entrepreneur
- Self-leadership, resilience, and personal responsibility
- Motivation, perseverance, and dealing with uncertainty

Ideation and Creativity

- Opportunity recognition
- Problem-solution fit
- Creative methods and ideation techniques

Team, Leadership, and Communication

- Team dynamics and collaboration
- Leadership in entrepreneurial contexts
- Communication, feedback, and conflict management

Business Models and Market Understanding

- Business model development
- Customer discovery and validation
- Market analysis and go-to-market strategies

Technology, Innovation, and Business Environment

- Innovation processes in startups and established organizations
- Technology-driven entrepreneurship

Finance, Funding, and Legal Basics

- Basic financial understanding (cash flow, break-even)
- Funding options and public support programs
- Legal aspects of starting a business in Germany

Pitching and Presentation

- Storytelling and pitch structure
- Presentation skills and stage presence
- Handling questions and feedback

Type of Examination

Portfolio

Methods

The module is taught in a seminar-style format combining:

- Interactive lectures
- Practical exercises and workshops
- Group work and project-based learning
- Case studies and real-world examples
- Presentations and pitch sessions
- Guided reflection and feedback
- iLearn (online learning platform)

Recommended Literature

- Osterwalder, A., & Pigneur, Y. Business Model Generation
- Ries, E. The Lean Startup
- Blank, S. The Startup Owners Manual
- Brown, T. Change by Design MRO
- Aulet, B. Disciplined Entrepreneurship

- Fitzpatrick, R. The Mom Test
- Faltin, G. Kopf schlägt Kapital
- Covey, S.R. The 7 Habits of Highly Effective People

MRO-20 Master Module

Module code	MRO-20
Module coordination	Prof. Dr. Dmitrii Dobriborsci
Course number and name	MRO3102 Master Thesis MRO3103 Master Colloquium
Semester	3
Duration of the module	1 semester
Module frequency	annually
Course type	required course
Level	postgraduate
Semester periods per week (SWS)	2
ECTS	5
Workload	Time of attendance: 30 hours self-study: 720 hours Total: 750 hours
Type of Examination	colloquium, master thesis
Weighting of the grade	25 out of 90 ECTS
Language of Instruction	English

Module Objective

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

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

The Master's module consists of the Master's thesis (20 ECTS) and the Master's colloquium (5 ECTS). Both parts must be successfully completed. Additionally, participation in the seminar series "Career Start into German Technology Companies" is mandatory in order to obtain the 5 ECTS. The seminars/workshops are offered as block events during the first two semesters of study. The events cover a variety of topics that are of great importance for the preparation of the Masters thesis. In addition to scientific working methods, students are also introduced to application processes and the general conditions of the German labor market and its entry after graduation. After submitting the Masters thesis, the colloquium will take place. The Master's thesis is presented in a presentation of about 15 minutes and then defended (presentation and defense overall 45 minutes). The colloquium is assessed with 5 ECTS.

Professional competence

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

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

Methodological c ompetence

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

Personal competence

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

Social competence

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

Applicability in this and other Programs

The Master's programme " **Intelligent Robotics** " enables students to work scientifically. The Master's degree entitles the holder to a subsequent doctorate.

Entrance Requirements

The registration for the master thesis requires that at least 40 ECTS credits have been achieved (cf. study and examination regulations (SPO).

Learning Content

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

The master thesis includes:

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

By writing a master thesis, students should demonstrate their ability to apply the knowledge and skills acquired during their studies to an independent scientific thesis. The master thesis is followed by a colloquium as an oral examination. The students present their master thesis and defend it.

Teaching Methods

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

Seminars, workshops, colloquium

Remarks

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

Recommended Literature

Literature selected by the student for the specific subject area. Support for scientific work:

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

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

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

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