TU Dortmund University

Department of Electrical Engineering and Information Technology

Module Handbook
for the Master’s Degree Program
Automation and Robotics

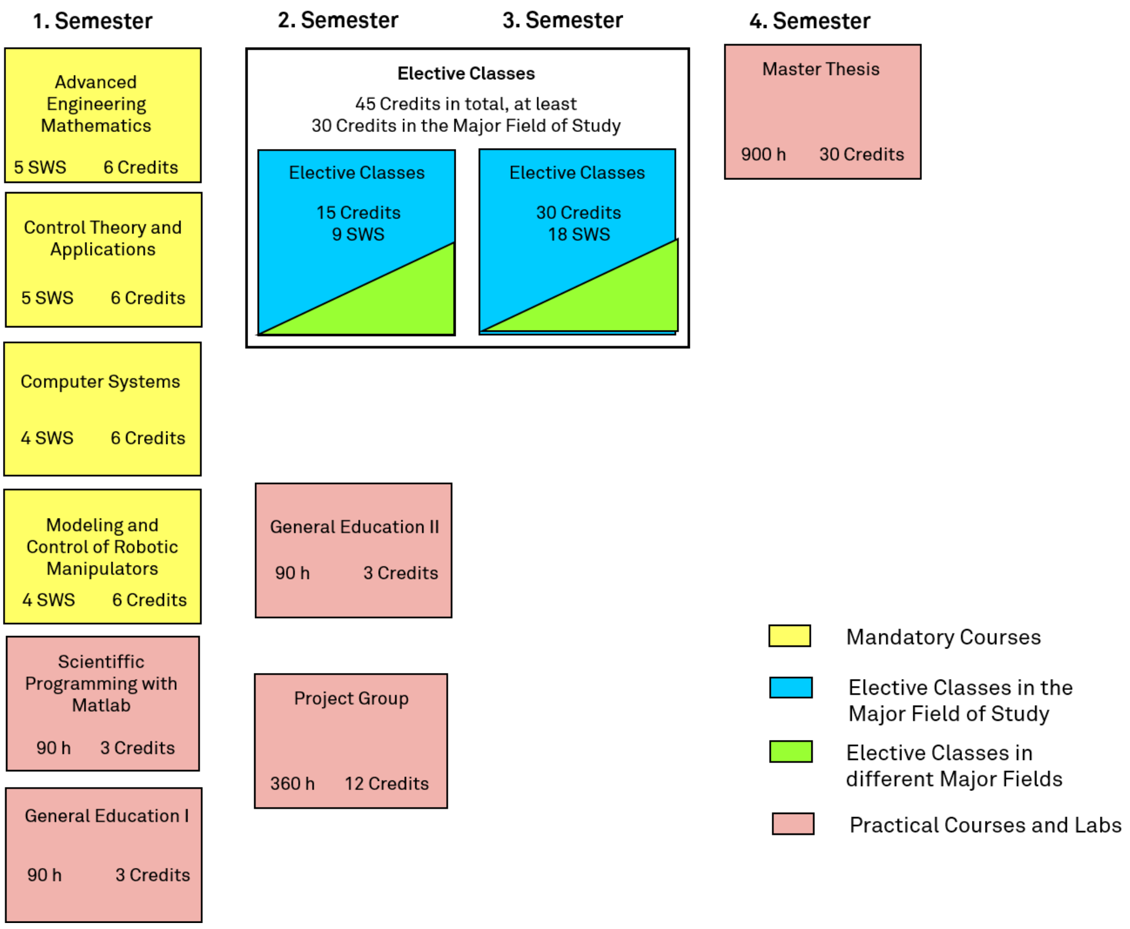
(Examination Regulations 2019)

Updated Version

Draft resolution for the Department Council on
22.July 2026

Inhaltsverzeichnis

Structure of the Study Program



The range of elective modules and Lab Courses may vary and is published in the current version of the module handbook. Modules may be discontinued or newly added. There is no entitlement to the offering or delivery of a specific elective module or Lab Course.

Mandatory Courses

Advanced Engineering Mathematics AR-101

Advanced Engineering Mathematics

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	1st (Semester)	6	60 h	120 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Advanced Engineering Mathematics (AEM)	Lecture	4	3
2	Advanced Engineering Mathematics (AEM)	Tutorial	2	2

2 **Course language**

English

3 **Teaching Content**

The subjects are chosen from

1. Linear Algebra: Vector spaces, matrices and equation systems, linear maps, Jordan-, LU-, QR-, and singular value decomposition, numerical aspects.
2. Differential Equation: Linear systems, differential equations with constant coefficients.
3. Laplace-Transform and Fourier Series
4. Differential Calculus with several variables: Derivatives, inverse and implicit functions, Taylor expansion and extreme values.
5. Stability of Differential Equations: Theorems of Ljapunov and Poincaré-Ljapunov.
6. Variational Calculus

Literatur

Bajpai, Avinash C. , Mathematics for engineers and scientists
Meyer, R.M., Essential mathematics for applied fields
Lancaster, P., Tismenetsky, M., The theory of matrices
Lang, S., Linear algebra
Slides

4 **Competencies**

The course gives an introduction to fundamental mathematical techniques used in almost every course. Attention is given to the underlying mathematical structure.

5 **Examinations**

Modulprüfung: The final exam will be a written (2 hours) exam.

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

8 **Module Type and Applicability**

Mandatory Course
Program: Automation & Robotics

9	**Module Supervisor** Dean of the Mathematics department/ Lecturers of the Mathematics department	**Faculty in charge**

Control Theory and Applications AR-102

Control Theory and Applications

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	1st (Semester)	6	60 h	120 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Control Theory and Applications (CTA)	Lecture	4	3
2	Control Theory and Applications (CTA)	Tutorial	2	2

2 **Course language**

English

3 **Teaching Content**

1. Modeling of dynamic systems: First principles models, state space representation, DAE systems, classes of systems, models, and signals, linearity and causality, steady states, operability, singular value decomposition, stability, linearization.
2. Linear state space theory: Autonomous behavior, eigenvalues, eigenvectors, Jordan form, controllability and pole assignment, LQ-optimal control, observability, observers, observer-based control, Kalman decomposition.
3. Laplace transform and transfer matrices: Introduction to the Laplace transform, transfer functions, poles, zeros, minimal realization, zeros of multivariable systems, frequency response, input-output stability.
4. Design of single-loop controllers: Internal stability, performance specification, classical SISO controller design, robust stability and performance, performance limitations
5. Discrete-time and sampled data systems: z-transform, z-transform of sampled data systems, stability, dead-beat control, w-transform

Literatur

Handouts
S. Skogestad, Postlethwaite: Multivariable Feedback Control, Wiley, 1996.
K. Zhou, J.Doyle: Essentials of Robust Control, Prentice Hall, 1998.

4 **Competencies**

This course provides the students with a solid background in control theory which is a prerequisite to solve automation problems in robotics as well as in production processes of all kinds.

5 **Examinations**

Modulprüfung: The final exam will be a written (2 hours) exam.

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

8 **Module Type and Applicability**

	Mandatory Course Program: Automation & Robotics
9	**Module Supervisor** **Faculty in charge** Prof. Dr. S. Lucia /Prof. Dr. S. Lucia

Modeling and Control of Robotic Manipulators AR-106

Modeling and Control of Robotic Manipulators

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	1st (Semester)	6	50 h	130 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Modeling and Control of Robotic Manipulators (MCRM)	Lecture	3	2
2	Modeling and Control of Robotic Manipulators (MCRM)	Tutorial	2	1
3	Modeling and Control of Robotic Manipulators (MCRM)	Lab	1	

2 **Course language**

English

3 **Teaching Content**

1. Spatial transformations
2. Forward and inverse kinematics
3. Differential kinematics and inverse kinematics algorithms
4. Dynamics
5. Motion control
6. Robotics System Toolbox and Robot Operating System (ROS)

Literatur

Siciliano et al., Foundations of Robotics, Springer

4 **Competencies**

Upon successful completion of the module, students possess advanced and specialized knowledge in the modeling, analysis, and control of robotic systems. They understand the mathematical and systems-theoretic foundations of spatial transformations, kinematic and dynamic models, as well as modern motion and control methods, and are able to formally describe and critically analyze these concepts.

Students are able to independently abstract complex problems in robotics, select appropriate modeling and control approaches, and methodically design, implement, and evaluate them. They can apply forward, inverse, and differential kinematics as well as dynamic models to systematically develop and analyze control strategies for robotic systems. In doing so, they make use of suitable tools and software environments such as the Robotics System Toolbox and the Robot Operating System (ROS).

Furthermore, students are capable of comparatively assessing different modeling and control approaches, evaluating their underlying assumptions, performance, and limitations, and making well-founded technical decisions. They can independently study scientific literature, classify current methods, and use them as a basis for further development, research, or application-oriented tasks.

In line with the qualifications framework at the master’s level, students additionally develop the ability to work independently, critically reflect on complex technical relationships, and clearly justify and communicate their results.

<table>
<tr><td></td><td colspan="2"></td></tr>
<tr><td>5</td><td colspan="2">Examinations
<i>Modulprüfung:</i> written exam (max. 180 minutes)</td></tr>
<tr><td>6</td><td colspan="2">Type of Examination
Module Finals</td></tr>
<tr><td>7</td><td colspan="2">Participation Requirements</td></tr>
<tr><td>8</td><td colspan="2">Module Type and Applicability
<i>Mandatory Course</i>
Program: Automation & Robotics)</td></tr>
<tr><td>9</td><td>Module Supervisor
apl. Prof. Dr. F. Hoffmann/ apl. Prof. Dr. F. Hoffmann</td><td>Faculty in charge
Fakultät für Elektrotechnik und Informationstechnik</td></tr>
</table>

Computer Systems offered for the last time in WiSe 26/27 AR-103

Computer Systems

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe (Block)	1 Semester	1st Semester	6	50 h	130 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
a)	Computer Systems (CS)	Lecture	4	3
b)	Computer Systems (CS)	Tutorial	2	1

2 **Course language**

English

3 **Teaching Content**

1. Microprocessors: Processor performance, instruction set, compilers, pipelining, and superscalar architectures
2. Storage Technology: SRAM, DRAM, ROM, magnetic recording, optical recording
3. Data Communication: Bus systems, Ethernet, TCP/IP
4. Memory Hierarchy: Caches, virtual memory, RAID systems

Literatur

General, Communication within Computer Systems: John L. Hennessy, David A. Patterson, Computer Architecture, a Quantitative Approach", 3rd Edition, Morgan Kaufmann, 2002
Semiconductor memory: Betty Prince, "High Performance Memories", Wiley, 1999
Optical Storage: Alan Marchant, Öptical Recording", Addison Wesley, 1999
Communication between Computer Systems: Andrew S. Tanenbaum, Computer Networks", Prentice Hall, 3rd edition 1996, ISBN 0133499456
Larry L. Peterson, Bruce S. Davie, Computer Networks, A Systems Approach", Morgan Kaufmann, 2nd ed. 1999

4 **Competencies**

By attending this course, students learn the architecture and the components of modern computer systems. This knowledge is directly required for advanced courses on distributed systems and communication systems. As computers are vital components of most robots and complex process automation systems, a basic understanding of computer systems is necessary for most practical work in this area, like project groups and lab courses.

5 **Examinations**

Studienleistung: All students are required to successfully complete 2 out of 4 special assignments in order to be admitted to the final exam.
Modulprüfung: The final exam is a written test (3 hours). The grade is solely determined by the final exam.

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

8	**Module Type and Applicability** *Mandatory Course* Program: Automation & Robotics	
9	**Module Supervisor** Prof. Dr. Selma Saidi / substitute lecturer in WiSe 2006/27: Dr. Ralf Burda	**Faculty in charge**

Scientific Programming with Matlab in Engineering AR-105

Scientific Programming with Matlab in Engineering

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	1st (Semester)	3	35 h	55 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Scientific Programming with Matlab in Engineering (SPM)	Lab	3	3

2 **Course language**

English

3 **Teaching Content**

1. Matlab Basics, Programming, Visualization
2. Symbolic Computing
3. Statistics
4. Numerical Optimisation
5. Control System Design
6. Simulink
7. Robotics

Literatur

Matlab documentation

4 **Competencies**

The course qualifies the students to solve scientific programming and engineering problems with Matlab. The students acquire deeper knowledge in the design and application of control systems and robotics.

5 **Examinations**

Course Work: Successful completion of 75% of programming assignments and xuccessful completion and presentaion of programming project.
The course grading is pass or fail.

6 **Type of Examination**

7 **Participation Requirements**

8 **Module Type and Applicability**

Mandatory Course
Program: Automation & Robotics

9

Module Supervisor	Faculty in charge
apl. Prof. Dr. F. Hoffmann/ apl. Prof. Dr. F. Hoffmann	Department of Electrical Engineering and Information Technology

Elective Courses Summer Term

Process Automation AR-205

Process Automation

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2nd (Semester)	5	25 h	65 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Process Control Lab	Lab	5	2

2 **Course language**

English

3 **Teaching Content**

A Process Control Lab consisting of four practical lab experiments. PPO1 which covers system identification and controller design; PPO2 which covers calorimetry and state estimation; PUR01 which is a level control experiment; and PA01 which is a process automation with a PLC

Literatur

Laboratory scripts

4 **Competencies**

Students are able to apply control theory basics to realistic example problems in a laboratory.

5 **Examinations**

Studienleistung: Satisfactory performance in a colloquium before each of the laboratory experiments is required to take part in each of the experiments..

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

The lab course builds upon the course Control Theory and Applications which is compulsory in the first semester.

8 **Module Type and Applicability**

Program: Automation & Robotics, Field of study: Process Automation

9

Module Supervisor	Faculty in charge
Prof. Dr. S. Lucia / Prof. Dr. S. Lucia	

Application of Robots AR-201

Application of Robots

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2nd (Semester)	5	40 h	110 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Application of Robots (AoR)	Lecture	3	2
2	Application of Robots (AoR)	Tutorial	2	1

2 **Course language**

English

3 **Teaching Content**

Industrial robots are a valuable tool for mastering current challenges in the manufacturing industry. They enable cost-effective and more sustainable production of increasingly individualized products in high-wage countries and help to overcome the shortage of skilled workers. To be able to do this, robot-based automation systems must be very well adapted to the task at hand. The aim of this course is to systematically look at the requirements of different production processes and translate them into high-performance solutions. Industrial robots are the core component of numerous automation systems for production and handling processes. This course covers production processes like primary shaping, forming, cutting, joining and assembly and examines their requirements on robot design, robot controllers, robot off-line programming, suitable effectors, and automation compatible workpiece design. As simulation based offline-programming is a prerequisite for the effective automation of a growing number of such production processes, simulation systems and offline-programming applications play an important part in this course. Sensor- and vision systems are also covered as essential components of many automation solutions, as well as programmable logic controllers.

Topics:

1. Robot based Production Processes
2. Sensors and measuring strategies to compensate inaccuracies of workpieces and automation components
3. Automation compatible design
4. Robot Effectors, Gripper Selection, Dimensioning of vacuum grippers
5. Robot Controllers, PLC
6. Application specific Offline-Programming and Simulation Systems

4 **Competencies**

After a successful completion of the module, students have acquired knowledge about how to design, program, use and operate a robot-based production cell or line as well as automated manufacturing facilities in general. This knowledge enables the students to understand and analyze a broad range of tasks around automation and robotics, to structure them and to find solutions in a systematic way.

5 **Examinations**

Modulprüfung: The examination is a written exam (duration: 60 minutes).

6	**Type of Examination** Module Finals
7	**Participation Requirements**
8	**Module Type and Applicability** Program: Automation & Robotics, Field of study: Robotics
9	**Module Supervisor** **Faculty in charge** PD Dr. J. Bickendorf/ PD Dr. J. Bickendorf

Dynamic Models AR-224

Dynamic Models

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2nd Semester	3	30 h	60 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
a)	Dynamic Models	Lecture	2	1
b)	Dynamic Models	Tutorial	1	1

2 **Course language**

English

3 **Teaching Content**

The lecture gives a systematic overview to dynamic process modeling and simulation. The basis is the setup of mass and energy balances, a discussion of momentum balances is deepening the understanding of such. Constitutive equations, such as equations of state and kinetic rate expressions, are applied. Model simplification and model reduction methods are briefly outlined. Suitable analytical and numerical solution approaches for dynamic and/or spatially distributed systems are presented and discussed. Especially in the context of continuously increasing computational power, the understanding of the capabilities and limits of applying numerical methods on chemical engineering
The course takes place in the first half of the semester.

4 **Competencies**

The student is able to generate suitable reaction engineering models based on general balance equations, including equations of state and kinetic approaches. In this module the student can employ analytical and numerical methodologies to solve the resulting equation systems. The students systematically plan the solution approaches and simplify the resulting models. They are able to solve known as well as new problems and evaluate the results.

5 **Examinations**

Modulprüfung: The final exam will be an oral (30 minutes) or written (2 hours) exam, depending on the number of participants (form will be announced in the second week of course).

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

Prerequisites: Basic knowledge of dynamic systems as e.g. provided by the course Control Theory and Applications.

8 **Module Type and Applicability**

Program: Automation & Robotics, Field of study: Process Automation

9

Module Supervisor	Faculty in charge
Prof. Dr. H. Freund / Prof. Dr. H. Freund	

Data-Based Dynamic Modeling AR-206

Data-Based Dynamic Modeling

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2nd (Semester)	3	30 h	60 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Data-Based Dynamic Modeling (DDM)	Lecture	2	1
2	Data-Based Dynamic Modeling (DDM)	Tutorial	1	1

2 **Course language**

English

3 **Teaching Content**

1. Identification of simple models from step responses.
2. Parameter identification: Basic idea, mathematical description of sampled systems, ARX, ARMAX and OE estimation.
3. Subspace Identification methods
4. Modeling using nonlinear black box models (perceptron neural nets, radial-basis-function nets), training, dynamic models, quality of neural net models.
5. Model errors: Sources of errors, limits of model accuracy, model accuracy and controller performance.

The course takes place in the second half of the semester.
Literatur
Slides
Handouts

4 **Competencies**

The students can identify the dominant dynamics of a process from step responses and can apply modern methods and algorithms to identify the parameters of linear process models from measured data. They know the structure of nonlinear black box models and can judge the quality and the limitations of data-based models.

5 **Examinations**

Modulprüfung: The final exam will be an oral (30 minutes) or written (2 hours) exam, depending on the number of participants (form will be announced in the second week of course).

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

Basic knowledge: Basic knowledge of dynamic systems as e.g. provided by the course Control Theory and Applications.

8 **Module Type and Applicability**

Program: Automation & Robotics, Field of study: Process Automation Robotics, Machine Learning

9	**Module Supervisor** Prof. Dr. S. Lucia / Prof. Dr. S. Lucia	**Faculty in charge**

Computer Vision AR-210

Computer Vision

Rota	Duration	Semester	CP	Attendence	Self Study
After Announcement	1 Semester	2nd / 3rd (Semester)	6	50 h	130 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Computer Vision (CV)	Lecture	2	2
2	Computer Vision (CV)	Tutorial	2	2

2 **Course language**

English

3 **Teaching Content**

For the majority of living beings vision is the most important perception mechanism for orienting themselves in the environment. Therefore, there exists a multitude of attempts to recreate this capability in artificial systems. In contrast to image processing techniques found in industrial applications the aim of such advanced systems for machine vision is to obtain a task-oriented interpretation of a complex scene with as few restrictions as possible concerning the context and the recording conditions.
In this lecture advanced techniques of machine vision are covered which to some extent are inspired by cognitive processes known from human visual perception. First, important aspects of imaging processes are introduced including the perception and representation of colors. Afterwards, methods for the computation of local feature representations (e.g. descriptors, depth, or motion) and for the extraction of image primitives (e.g. regions, contours and keypoints) are presented. Finally, the lecture focusses on appearance based object recognition techniques that lie at boundary between image segmentation and scene interpretation. Especially, deep neural networks will be covered that currently are the dominant methodology for the solution of machine perception tasks.
The accompanying tutorials will give students the opportunity to deepen their knowledge of the theoretical concepts presented in the lecture by working on relevant practical problems.

Literatur

Gonzalez, Rafael C.; Woods, Richard E.: Digital Image Processing, Prenctice Hall, 2nd Ed., 2002.
Forsyth, David A.; Ponce, Jean: Computer Vision - A Modern Approach, Prentice Hall, 2003.
Szeliski, Richard: Computer Vision, Springer, 2010

4 **Competencies**

In this module students will be made familiar with solutions for advanced problems in the field of machine vision. A fundamental understanding of the principles underlying visual perception systems will enable participants to apply such techniques for themselves in innvative application scenarios - as, e.g., robotics and man-machine interaction – and to assess their strengths and limitations.

5 **Examinations**

	Modulprüfung: oral examination (30–45 minutes) *Studienleistung:* as per announcement
6	**Type of Examination** Module Finals
7	**Participation Requirements** *Prerequisite Knowledge:* Basic knowledge of mathematics *Desirable knowledge:* Programming skills
8	**Module Type and Applicability** Program: Automation & Robotics, Field of study: Robotics, Machine Learning
9	**Module Supervisor** **Faculty in charge** Prof. Dr.-Ing. G. Fink/ Prof. Dr.-Ing. G. Fink

3D Computer Vision ETIT-233

3D Computer Vision

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2. Semester	5	35 h	115 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	3D Computer Vision Vorlesung (LSF-Nr. 08 0259)	V		2
2	3D Computer Vision Übung (LSF-Nr. 08 0260)	Ü		1

2 **Course language**

Englisch

3 **Teaching Content**

1. Introduction to projective geometry
2. Linear and nonlinear approaches to the calibration of camera systems
3. 3D reconstruction based on photogrammetric methods, especially bundle adjustment
4. Pattern classification methods for establishing point correspondences between images
5. Model-based 3D pose estimation
6. 3D reconstruction based on the point spread function (depth from focus/defocus)
7. 3D reconstruction of surfaces based on their physical reflectance properties (photoclinometry, shape from shading/polarisation)
8. Technical and scientific applications

Literatur

Horn: Robot Vision
Klette, Koschan, Schlüns: Computer Vision: Three-Dimensional Data from Images;
Hartley/Zisserman: Multiple Viewpoint Geometry

4 **Competencies**

Nach erfolgreichem Abschluss des Moduls beherrschen die Studierenden die wesentlichen Grundlagen der 3D-Bildverarbeitung, der Photogrammetrie sowie die hierfür benötigten linearen und nichtlinearen Optimierungsverfahren. Die Studierenden können Aufgabenstellungen für Systeme zur 3D-Szenerekonstruktion aus unterschiedlichen Anwendungsbereichen einordnen und selbständig mit eigenständig ausgewählter Methodik lösen.
Durch das Absolvieren des Moduls sollen die Studierenden darüber hinaus befähigt werden, die Herausforderungen heutiger und zukünftiger digitaler Gesellschaften zu erkennen und einzubeziehen und damit gesellschaftliches Engagement zu übernehmen. Dies umfasst im Bereich der 3D-Bildverarbeitung und der Photogrammetrie z.B. die Sensibilisierung für gesellschaftlich relevante Themen wie Alter und Technik oder Datensicherheit und digitale Teilhabe.

5 **Examinations**

<table>
<tr><td></td><td colspan="2"><i>Modulprüfung:</i> mündliche Prüfung (max. 40 Minuten) oder Klausur (max. 180 Minuten) *
*Die genauen Prüfungsmodalitäten werden spätestens zur 2. Veranstaltung bekannt gegeben.
Die Modulprüfung kann auf Wunsch der Kandidatin/ des Kandidaten jeweils in deutscher oder in englischer Sprache erfolgen.</td></tr>
<tr><td>6</td><td colspan="2">Type of Examination
Modulprüfung</td></tr>
<tr><td>7</td><td colspan="2">Participation Requirements
<i>Empfohlene Voraussetzungen:</i> Gute Kenntnisse in linearer Algebra sowie linearer und nichtlinearer Optimierung.</td></tr>
<tr><td>8</td><td colspan="2">Module Type and Applicability
<i>Wahlpflichtmodul</i> im Masterstudiengang „Elektrotechnik und Informationstechnik“, Studienschwerpunkte „Computer Engineering“ sowie „Robotik und Automotive“. <i>Wahlpflichtmodul</i> im Masterstudiengang Wirtschaftsingenieurwesen, Referenzmodulnummer: MB-306</td></tr>
<tr><td>9</td><td>Module Supervisor
Prof. Dr. rer. nat. Christian Wöhler</td><td>Faculty in charge
Department of Electrical Engineering and Information Technology</td></tr>
</table>

Aspects of Mathematical Modeling AR-214

Aspects of Mathematical Modeling

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe & SoSe	1 Semester	2nd/3rd (Semester)	5	40 h	110 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Aspects of Mathematical Modeling (AMM)	Lecture	3	2
2	Aspects of Mathematical Modeling (AMM)	Tutorial	2	1

2 **Course language**

English

3 **Teaching Content**

Different directions of mathematical modeling techniques are introduced that build on the course Advanced Engineering Mathematics and assume a solid background in mathematics. Among the subjects are the following:

1. Optimization: Theoretical and practical aspects of optimization problems, formulation, optimality conditions, linear programming, discrete optimization.
2. Applied partial differential equations: Prototypes, representation formulae, qualitative and quantitative behavior, conservation laws, elliptic, parabolic and hyperbolic equations, convection-diffusion-reaction systems.
3. Continuum mechanics: Inertia and momentum, equations of motion, external forces, conservation laws, deformations.
4. Modeling: Modeling with differential equations: Autonomous systems, linearization, phase plane analysis, non-dimensionalization, network dynamics, stability, bifurcations. Stochastic modeling: statistical inference, stochastic processes.

Literatur

References will be given in the courses.

4 **Competencies**

This course offers an introduction to different fundamental techniques of mathematical modeling and analysis that are useful for the dynamics and control of robotic devices. Tools that allow for the description and control of movement and the interaction with the environment are introduced. The ability to create and use models to estimate qualitatively and quantitatively the behavior of dynamic systems will be trained.

5 **Examinations**

Modulprüfung: The final exam will be an oral (20 minutes) or written (1.5 hours) exam, depending on the number of participants (form will be announced in the second week of the course).

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

Course: “Advanced Engineering Mathematics”

8	**Module Type and Applicability** Program: Automation & Robotics, Field of study: Robotics, Process Automation, Machine Learning	
9	**Module Supervisor** Dean of the Mathematics department / Lecturers of the Mathematics department	**Faculty in charge**

Cyber-Physical System Fundamentals AR-215

Cyber-Physical System Fundamentals

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	3rd (Semester)	6	105 h	75 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Cyber-Physical System Fundamentals (CPSF)	Lecture	4	4
2	Cyber-Physical System Fundamentals (CPSF)	Lab	2	

2 **Course language**

English

3 **Teaching Content**

The course is based on the presenter's book on the subject and includes the following topics:

1. Introduction: Definition of terms, scope of the course
2. Specification and modeling: models of computation, communication models, finite state machines, data flow, discrete event models, von-Neumann-models, expressiveness of models
3. CPS hardware: hardware-in-the-loop, sampling and A/D-conversion, processing, field-programmable gate arrays (FPGAs), communication hardware, D/A-conversion, sampling theorem, output
4. Standard software: embedded operating systems, real-time operating systems, priority inversion, middleware
5. Evaluation and validation: objective functions, Pareto-optimality, worst-case execution time, energy consumption, reliability, real-time calculus, verification
6. Mapping of applications to execution platforms: standard optimization techniques, real-time scheduling, rate monotonic scheduling, earliest deadline first scheduling, hardware/software partitioning, mapping of applications to heterogeneous multiprocessors
7. Selected optimizations.

Literatur

Peter Marwedel: Embedded System Design – Embedded Systems Foundations of Cyber-Physical Systems, and the Internet of Things, Springer, 2021
Technical documentation fort he used finite state machine design tool (StateMate or similar)

4 **Competencies**

Students successfully finishing the course should be able to

1. Understand how cyber-physical (CPS) hardware interacts with CPS software and use this knowledge to design CPS software,
2. Select models of computation and programming languages that are appropriate for a given design problem,
3. Select an appropriate scheduling technique for embedded systems, Apply hardware/ software design techniques in order to optimize the systems which they are supposed to design.

<table>
<tr><td></td><td colspan="2"></td></tr>
<tr><td>5</td><td colspan="2">Examinations
The students have to pass both the lab and the finals.
The final exam will be an oral (30 minutes) or written (2 hours) exam, depending on the number of participants (form will be announced in the second week of course).
The lab counts as a coursework but is not included in the module grade.</td></tr>
<tr><td>6</td><td colspan="2">Type of Examination
Module Finals</td></tr>
<tr><td>7</td><td colspan="2">Participation Requirements
Basic knowledge in programming as well as finite-state machines.</td></tr>
<tr><td>8</td><td colspan="2">Module Type and Applicability
Program: Automation & Robotics, Field of study: Robotics, Process Automation, Machine Learning</td></tr>
<tr><td>9</td><td>Module Supervisor
Prof. Dr. J. Chen/ Substitute instructor for winter semester 26/27: P. Ulbrich</td><td>Faculty in charge</td></tr>
</table>

Logistics of Chemical Production Processes AR-222

Logistics of Chemical Production Processes

Rota	Duration	Semester	CP	Attendence	Self Study
After Announcement	1 Semester	2nd (Semester)	3	30 h	60 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Logistics of Chemical Production Processes	Lecture	2	1
2	Logistics of Chemical Production Processes	Tutorial	1	1

2 **Course language**

English

3 **Teaching Content**

The students obtain an overview of supply chain management and planning and scheduling problems in the chemical industry and of techniques and tools for modeling, simulation and optimization. These include discrete event simulation, equation-based modeling, mixed-integer linear programming, heuristic optimization methods and modeling and optimization using timed automata.

Literatur

Handouts

Slides

4 **Competencies**

The students will be enabled to identify logistic problems, to select suitable tools and techniques for simulation and optimization and to apply them to real-world problems.

5 **Examinations**

Modulprüfung: The final exam will be an oral (20 minutes) or written (1.5 hours) exam, depending on the number of participants (form will be announced in the second week of the course).

Studienleistung: In addition, active participation and collaboration in 3 computer exercises is required.

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

8 **Module Type and Applicability**

Program: Automation & Robotics, Field of study: Process Automation

9

Module Supervisor	Faculty in charge
Prof. Dr. S. Lucia / Dr. Christian Sonntag	

Statistics for Researchers in Engineering Sciences AR-223

Statistics for Researchers in Engineering Sciences

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2nd (Semester)	5	40 h	110 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Statistics for Researchers in Engineering Sciences (STAT)	Lecture	3	2
2	Statistics for Researchers in Engineering Sciences (STAT)	Tutorial	2	1

2 **Course language**

English

3 **Teaching Content**

1. Empirical distributions and explanatory data analysis: frequency tables, bar charts, histograms, distribution characteristics
2. Probability theory: conditional probability, independence
3. Random variables and their distributions: discrete distributions (Uniform, Bernoulli, Binomial,Poisson), continuous distributions (Uniform, Normal), expectation and variance, sampling distribution theory, joint distributions, covariance and correlation
4. Estimation: properties of estimators, confidence intervals
5. Test of statistical hypotheses: Binomial test, Gaussian test, t-test, power, p-value
6. Regression: simple / multiple regression, tests concerning regression
7. Time series analysis: stochastic processes, stationarity, autocorrelation, filtering

Literatur
Slides

4 **Competencies**

This course gives an introduction to statistical concepts that are useful for research projects in various fields of application and areas of science. Furthermore the students should get a good grasp of the application of these concepts to engineering problems like prediction, optimal testing and estimation.

5 **Examinations**

Studienleistung: All students are requested to solve four take home problems.
Modulprüfung: The final exam will be an oral or a written exam, depending on the number of participants (form will be announced second week of course).

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

8 **Module Type and Applicability**

	Program: Automation & Robotics, Field of study: Robotics, Process Automation, Machine Learning	
9	**Module Supervisor** Prof. Dr. Bürkner/ Prof. Dr. Bürkner	**Faculty in charge**

Mobile Robots ETIT-269 (AR-225)

Mobile Robots

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2. Semester	5	50 h	100 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Mobile Roboter Vorlesung	V		2
2	Mobile Roboter Übung	Ü		2

2 **Course language**

English

3 **Teaching Content**

1. Robot Operating System (ROS2)
2. ROS Toolbox Matlab
3. Sensors, actuators and kinematics of mobile robots
4. Homing and trajectory following
5. Obstacle avoidance
6. Localisation
7. Path planning
8. Navigation
9. Online trajectory optimization
10. Mapping and SLAM

Literatur

selected papers on mobile robotics from journals and conferences

4 **Competencies**

After successfully completing the module, students possess advanced and specialized knowledge as well as practical experience in the field of mobile robotic systems. They understand the theoretical foundations, algorithmic concepts, and system-level relationships of mobile robotics and are able to critically analyze and apply them.
Students are capable of independently analyzing and abstracting complex problems in mobile robotics—particularly in the areas of obstacle avoidance, navigation, localization, path planning, and mapping—and solving them using self-selected methods and algorithms. They can design, implement, parameterize, and systematically evaluate appropriate approaches in ROS and MATLAB under realistic scenarios.
Furthermore, students are able to comparatively assess different approaches in mobile robotics, critically weigh their performance, limitations, and conditions of application, and justify their decisions on a sound technical basis. They can independently study scientific literature, critically contextualize current research results, and use them to address advanced development or research tasks.

	In line with the qualifications framework at the master’s level, students also develop the ability to recognize societal, ethical, and sustainability-related implications of the use of mobile robotic systems and to incorporate these aspects into their technical evaluations. This includes, in particular, issues related to human–machine interaction, sustainability, and the responsible deployment of autonomous systems.
5	**Examinations** *Modulprüfung:* • Successful completion of a practical programming exercise in ROS/Matlab/Python for mobile robot navigation • written exam
6	**Type of Examination** Modulprüfung
7	**Participation Requirements** Keine
8	**Module Type and Applicability** *Elective module* in the Master’s degree programs • „Elektrotechnik und Informationstechnik“, Studienschwerpunkt „Robotik und Automotive“ • Wirtschaftsingenieurwesen, Referenzmodul: MB-313 • Automation & Robotics, Field of study:Robotics, Machine Learning • Sustainable Energy Systems
9	**Module Supervisor** apl. Prof. Dr. rer. nat. Frank Hoffmann **Faculty in charge** Department of Electrical Engineering and Information Technology

Machine Learning in Robotics ETIT-277 (AR-310)

Machine Learning in Robotics

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2. Semester	5	35 h	115 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Machine Learning in Robotics Vorlesung	V		2
2	Machine Learning in Robotics Übung	Ü		1

2 **Course language**

English

3 **Teaching Content**

1. Fundamentals of Machine Learning
2. Regression
3. Gaussian Process Regression
4. Artificial Neural Networks
5. Recurrent Neural Networks & Transformers
6. Deep Learning
7. Reinforcement Learning

Literatur

Christopher M. Bishop, Hugh Bishop: Deep Learning: Foundations and Concepts, Springer, 2024
Richard Sutton, Andrew G. Barto: Reinforcement Learning: An Introduction, 2nd edition, MIT Press, 2018

4 **Competencies**

After successful completion of the module, students possess advanced knowledge of the theoretical foundations, methods, and current developments in machine learning. They are able to formally describe, analytically understand, and critically reflect on key model classes such as regression methods, Gaussian process models, neural networks, deep learning approaches (including recurrent architectures and transformers), and reinforcement learning techniques.
Students can abstract complex problem settings and independently select, combine, and implement suitable machine learning approaches. They are capable of designing application-specific models and learning procedures, developing training and optimization strategies, and systematically evaluating and interpreting their performance using appropriate metrics.

	Furthermore, students are able to comparatively analyze different learning methods and make well-founded decisions regarding their application. They can assess the strengths, weaknesses, and limitations of data-driven approaches. Students are also able to independently study scientific literature, critically contextualize current research results, and use them as a basis for advanced development, research, or knowledge-transfer tasks. In line with the qualifications framework at the master's level, students additionally develop the ability to recognize societal, ethical, and legal implications of the use of machine learning and to incorporate these aspects into their technical evaluations.	
5	**Examinations** *Modulprüfung:* Written exam *Studienleistung:* keine	
6	**Type of Examination** Modulprüfung	
7	**Participation Requirements** MA Automation and Robotics: The modules AR-310 (Machine Learning in Robotics) and AR-232 (Machine Learning Methods for Engineers) are mutually exclusive; simultaneous or subsequent enrollment in the other module is not permitted. Students specializing in Robotics are recommended to take AR-310, students specializing in Process Automation are referred to AR-232. Students specializing in Machine Learning may choose either module.	
8	**Module Type and Applicability** *Elective Module* in the Master's degree programs • „Elektrotechnik und Informationstechnik“, Profil: „Robotik und Automotive“ • Äutomation and Robotics”, Field of study: Robotics, Machine Learning • SSustainable Energy Systems”(Energy System Cataloque) • Wirtschaftsingenieurwesen, Referenzmodulnummer: MB-382	
9	**Module Supervisor** apl. Prof. Dr. rer. nat. Frank Hoffmann	**Faculty in charge** Department of Electrical Engineering and Information Technology

Smart Grids

ETIT-296
(SES-106)
(AR-314)

Smart Grids

Rota	**Duration**	**Semester**	**CP**	**Attendence**	**Self Study**
SoSe	1 Semester	2. Semester	6	55 h	125 h

1 **Module Structure**

No.	**Course / Element**	**Type**	**CP**	**SWS**
1	Smart Grids Lecture	V		3
2	Smart Grids Practical works	P		1

2 **Course language**

Englisch

3 **Teaching Content**

This course will handle the following aspects of the changing electrical energy network:

1. Energy transition towards sustainability
2. New distribution grid users (renewable energy sources, loads and energy storage)
3. Electro-mobility
4. Conventional distribution grids and their transformation for massive renewable integration
5. State estimation
6. Congestion management (Voltage CM and Thermal CM)
7. Protection and control functions
8. Time-series based planning of renewable dominated distribution grids
9. Grid automation and future trends

4 **Competencies**

Renewable energy resources are primarily integrated on the distribution grid level. Therefore, competencies of understanding the integration of renewable energy resources into the distribution grids are key for transforming the energy system towards sustainability. The students successfully finishing the course should be able to

- understand the challenges in today's and future sustainable electrical energy distribution grids
- comprehend the multiple areas of research done in the distribution grids
- develop new solution approaches for energy system transformation towards renewable energy integration based on their acquired knowledge through lectures and practical works

By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of smart grids, this includes, for example, raising awareness of socially relevant topics such as age and technology or data security and digital participation.

5 **Examinations**

	Modulprüfung: oral exam (max. 30 minutes) or written exam (max. 120 minutes)* *Studienleistung:* Active participation in practical works (laboratory tasks, presentations, etc.) is a prerequisite to participate in the examination. * The responsible lecturer will announce the mode of the examination two weeks after the start of the lecture at the very latest.	
6	**Type of Examination** Modulprüfung	
7	**Participation Requirements** *Notwendige Voraussetzungen:* Basic knowledge in Electrical Energy Engineering	
8	**Module Type and Applicability** *Elective* in the Master’s degree programs • „Elektrotechnik und Informationstechnik“, Studienschwerpunkte „Elektrische Energietechnik“ • „Wirtschaftsingenieurwesen“, Referenzmodul: MB-324 • Automation & Robotics, Field of study: Process Automation, Robotics, Machine Learning *mandatory module* in the Master’s degree program Sustainable Energy Systems.	
9	**Module Supervisor** Dr.-Ing. Ulf Häger	**Faculty in charge** Department of Electrical Engineering and Information Technology

Single-loop and multi-loop controller design AR-229

Single-loop and multi-loop controller design

Rota	Duration	Semester	CP	Attendence	Self Study
After Announcement	1 Semester	2nd (Semester)	3	40 h	50 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Single-loop and multi-loop controller design	Lecture	2	2
2	Single-loop and multi-loop controller design	Tutorial	1	1

2 **Course language**

English

3 **Teaching Content**

1. Frequency domain single loop controller design
    1.1. Specification of controller performance in the time domain and in the frequency domain
    1.2. Loop shaping: Classical PID and Lead-Lag controller design revisited
    1.3. Design using frequency response approximation (FASTER)
    1.4. Limits of controller performance
    1.5. Internal Model Control
2. Frequency domain multivariable controller design
    2.1. I/O-system description, poles, zeros of MIMO systems
    2.2. Stability criteria
    2.3. Decoupling, sequential loop closure, approximate decoupling, directionality
    2.4. Multivariable frequency response approximation
3. Control structure selection

Literatur

Multivariable Feedback Control - Analysis and Design by Sigurd Skogestad and Ian Postlethwaite, 2nd edition, Wiley, 2005
Modern Control Engineering by Katsuhiko Ogata, 4th edition, Prentice Hall

4 **Competencies**

The students can design multivariable controllers for chemical and biochemical processes based on input-output descriptions. They are aware of the limitations of controller performance in the scalar and in the multivariable case and of the influence of plant-model mismatch on stability and controller performance. They can apply modern tools to the selection of control structures.

5 **Examinations**

The final exam will be an oral (30 minutes) or written (2 hours) exam, depending on the number of participants (form will be announced in the second week of course). In Addition there will be an assignment. The successful completion of the assignment is a prerequisite for taking the module exam.

6	**Type of Examination** Module Finals	
7	**Participation Requirements**	
8	**Module Type and Applicability** Program: Automation & Robotics, Field of study: Process Automation	
9	**Module Supervisor** Prof. Dr.-Ing. Sebastian Engell and Prof. Dr. S. Lucia / Prof. Dr.-Ing. Sebastian Engell and Prof. Dr. S. Lucia	**Faculty in charge**

Remote Sensing ETIT-287

Remote Sensing

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2. Semester	5	35 h	115 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Remote Sensing Vorlesung	V		2
2	Remote Sensing Übung	Ü		1

2 **Course language**

Deutsch/ Englisch nach Bedarf

3 **Teaching Content**

1. Sensorsysteme zur Aufnahme von Luft- und Satellitenbildern
2. Eigenschaften von Luft- und Satellitenbildern in unterschiedlichen Spektralbereichen
3. Korrekturverfahren für atmosphärische und topographische Effekte
4. Verfahren zur Analyse von Bilddaten in Remote-Sensing-Anwendungen
5. Verfahren zur Analyse von Spektraldaten in Remote-Sensing-Anwendungen
6. Orthorektifizierung, Georeferenzierung und Koregistrierung von Luft- und Satellitenbildern
7. Klassifikationsverfahren für Multi- und Hyperspektralbilddaten
8. Praktische Anwendungsbeispiele aus der aktuellen Forschung

Literatur

Schowengerdt, R.A.: Remote Sensing: Models and Methods for Image Processing. 3rd Edition, Academic Press, 2007.

4 **Competencies**

Nach erfolgreichem Abschluss des Moduls beherrschen die Studierenden die wesentlichen Grundlagen des Remote Sensing sowie die hierfür benötigten Signal- und Bildverarbeitungsverfahren. Die Studierenden können Aufgabenstellungen für Systeme zum Remote Sensing aus unterschiedlichen Anwendungsbereichen einordnen und selbständig mit eigenständig ausgewählter Methodik lösen.
Durch das Absolvieren des Moduls sollen die Studierenden darüber hinaus befähigt werden, die Herausforderungen heutiger und zukünftiger digitaler Gesellschaften zu erkennen und einzubeziehen und damit gesellschaftliches Engagement zu übernehmen. Dies umfasst im Bereich des Remote Sensing z.B. die Sensibilisierung für gesellschaftlich relevante Themen wie Alter und Technik oder Datensicherheit und digitale Teilhabe.

5 **Examinations**

Modulprüfung: mündliche Prüfung (max. 40 Minuten) oder Klausur (max. 180 Minuten)
Studienleistung: keine

6 **Type of Examination**

Modulprüfung

7 **Participation Requirements**

	Empfohlene Kenntnisse: Ausreichende Kenntnisse in Grundlagen der Elektrotechnik, Signalverarbeitung, Bildverarbeitung	
8	**Module Type and Applicability** *Wahlpflichtmodul* im Masterstudiengang „Elektrotechnik und Informationstechnik“, Schwerpunkte „Computer Engineering“ und „Robotik und Automotive“. *Wahlpflichtmodul* im Masterstudiengang Wirtschaftsingenieurwesen, Referenzmodulnummer: MB-378	
9	**Module Supervisor** Prof. Dr. rer. nat. Christian Wöhler	**Faculty in charge** Fakultät für Elektrotechnik und Informationstechnik

Machine Learning Methods for Engineers AR-232

Machine Learning Methods for Engineers

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2nd (Semester)	5	50 h	100 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Machine Learning Methods for Engineers	Lecture	3	2
2	Machine Learning Methods for Engineers	Tutorial	2	2

2 **Course language**

English

3 **Teaching Content**

Description of the main challenges that arise when dealing with large data sets and presentations of different possibilities for data management, data cleaning and outlier detection. Basic definitions in artificial intelligence and machine learning: training, validation, backpropagation, loss functions, error metrics. Description of different machine learning-methods (linear and nonlinear regression, gaussian processes, clustering, neural networks, …) and their classification into different categories such as supervised vs. unsupervised, regression vs. classification. Usage of tools to efficiently implement machine learning-methods. Interpretation and analysis of the results and presentation of the potential of machine learning with examples of the chemical and biochemical engineering field.

Literatur

The slides of the course and any additional materials such as literature lists and website recommendations will be published in the virtual workrooms in Moodle provided for this purpose. Details will be announced at the beginning of the course.

4 **Competencies**

The students can analyze the quality of data sets and perform simple operations to clean and prepare the data for the application of different machine learning techniques. The students are able to design and apply several machine learning techniques using efficient software tools and they are able to transfer this knowledge to solve practical problems. The students can recognize reliable results from the application of the presented machine learning techniques and critically evaluate their limitations.

5 **Examinations**

Modulprüfung: Oral (max. 30 minutes) oder written (90 minutes) + Computer-based project and presentation of 10 minutes

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

	Basic knowledge of linear algebra. Basic programming knowledge. The modules AR-310 (Machine Learning in Robotics) and AR-232 (Machine Learning Methods for Engineers) are mutually exclusive; simultaneous or subsequent enrollment in the other module is not permitted. Students specializing in Robotics are recommended to take AR-310, students specializing in Process Automation are referred to AR-232. Students specializing in Machine Learning may choose either module.	
8	**Module Type and Applicability** Program: Automation & Robotics; Field of study: Process Automation, Machine Learning	
9	**Module Supervisor** Prof. Dr.-Ing. Sergio Lucia/ Prof. Dr.-Ing. Sergio Lucia	**Faculty in charge**

Mobile Radio Networks 1: Fundamentals and Design Aspects ETIT-407 (AR-234)

Mobile Radio Networks 1: Fundamentals and Design Aspects

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2nd semester	5	35 h	115 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Mobile Radio Networks 1: Fundamentals and Design Aspects: Lecture	V		2
2	Mobile Radio Networks 1: Fundamentals and Design Aspects: Lab Course	P		1

2 **Course language**

English

3 **Teaching Content**

1. Market aspects and historical development of mobile communications
2. System aspects (characteristics of propagation, subscriber mobility, resource demand and spectrum allocation, network planning, protocols)
3. TDMA- und CDMA-based cellular networks (2G GSM/GPRS/EDGE, 3G UMTS/HSPA)
4. System architecture of OFDMA-based cellular networks (4G LTE)

The discussion of theoretical content is complemented by practical demonstrations and by case studies on ongoing research and business aspects of mobile radio networks.

Literatur

Literature (respective latest version)
Walke, B.: Mobile Radio Networks, Wiley.
Rappaport, Theodore S.: Wireless communications: principles and practice. Prentice Hall.
Dahlmann, E.; Parkvall, S.; Sköld, J.: 4G: LTE/LTE-Advanced for Mobile Broadband, Academic Press.

4 **Competencies**

After successful completion of the module, students understand the system architectures, protocols, dimensioning and operation of mobile radio networks. Students are able to evaluate the possibilities and challenges of using wireless networks in different deployment environments and fields of application, and to make a technically sound selection. In this way, they acquire the competence to attend more advanced courses or to study more advanced topics for themselves.
By completing the module, students should also be able to recognize and incorporate the challenges of today’s and future digital societies and thus assume social responsibility. In the field of mobile radio networks, this includes, for example, raising awareness of socially relevant topics such as age and technology or data security and digital participation.

5 **Examinations**

	Modulprüfung: oral exam (max. 45 minutes) or written exam (max. 180 minutes)* *Studienleistung:* successful completion of lab tasks tasks required for registration to the exam. *The exact examination modalities will be announced by the 2nd lecture week at the latest.	
6	**Type of Examination** Module exam	
7	**Participation Requirements** None. *Recommended prerequisites:* Basic knowledge of digital communications and electromagnetic wave propagation	
8	**Module Type and Applicability** *Elective Course* in Master Degree Program • „Electrical Engineering and Information Technology“, profile „Computer Engineering“. • „Automation & Robotics”, recommended field of study „Cognitive Systems”, module reference number: AR-234. • „Wirtschaftsingenieurswesen“, module reference number: MB-392. • „Applied Computer Science” and „Computer Science”, both with application subject „Electrical Engineering”, module reference number: INF-MSc-AF-ET-230.	
9	**Module Supervisor** Prof. Dr.-Ing. Christian Wietfeld	**Faculty in charge** Faculty of Electrical Engineering and Information Technology

Mobile Radio Networks 2: Advanced Network Concepts ETIT-408 (AR-235)

Mobile Radio Networks 2: Advanced Network Concepts

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2nd semester	5	35 h	115 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Mobile Radio Networks 2: Advanced Network Concepts: Lecture	V		2
2	Mobile Radio Networks 2: Advanced Network Concepts: Lab Course	P		1

2 **Course language**

English

3 **Teaching Content**

1. Local radio networks (WLAN/Wi-Fi, WPAN, Mesh, DECT)
2. Wireless Internet of Things networks (Low Power Wide Area Networks, Cellular-IoT)
3. Advanced features of 4G and 5G networks (Carrier Aggregation, Device-to-Device, Network Slicing, Beamforming, Ultra Reliable and Low Latency Communications)
4. Satellite networks, Aerial Wireless Networks
5. Future mobile network concepts for 5G-Advanced and 6G (e.g. mmWave/THz spectrum, Reflective Intelligent Surfaces, Integration of Artificial Intelligence)

The discussion of theoretical content is complemented by practical demonstrations and by case studies on ongoing research and business aspects of mobile radio networks.

Literatur

Literature (respective latest version)

Liberg, Olof, et al.: Cellular Internet of Things: From Massive Deployments to Critical 5G Applications. Academic Press.

Dahlmann, E.; Parkvall, S.; Sköld, J.: 4G: LTE/LTE-Advanced for Mobile Broadband, Academic Press.

P. Marsch, A. Osseiran, J.F. Monserrat, 5G Mobile and Wireless Communications Technology, Cambridge University Press.

4 **Competencies**

Upon successful completion of the module, students understand advanced and upcoming mobile radio network concepts and terminology which enables them to characterize research-related challenges of integrating the considered features, assess the feasibility, and to develop design solutions according to design goals. Students further deepen their knowledge base on specific network designs for particular fields of application, and to make a technically sound selection.

By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of advanced mobile radio networks, this includes, for example, raising awareness of socially relevant topics such as age and technology or data security and digital participation.

5	**Examinations** *Modulprüfung:* oral exam (max. 45 minutes) or written exam (max. 180 minutes)* *Studienleistung:* successful completion of lab tasks for the registration to the exam. *The exact examination modalities will be announced by the 2nd lecture week at the latest.	
6	**Type of Examination** Module exam	
7	**Participation Requirements** None. *Recommended prerequisites:* Basic knowledge of mobile radio networks	
8	**Module Type and Applicability** *Elective Course* in Master Degree Programs • „Electrical Engineering and Information Technology“, Profile „Computer Engineering“. • „Automation & Robotics”, recommended field of study „Cognitive Systems”, ()module reference number: AR-235). • SSustainable Energy Systems” • „Wirtschaftsingenieurswesen“ (module reference number: MB-393) • „Applied Computer Science” and „Computer Science”, both with application subject „Electrical Engineering”, module reference number: INF-MSc-AF-ET-263.	
9	**Module Supervisor** Prof. Dr.-Ing. Christian Wietfeld	**Faculty in charge** Faculty of Electrical Engineering and Information Technology

Automotive Systems ETIT-291 (AR-237)

Automotive Systems

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2. Semester	5	35 h	115 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Automotive Systems Vorlesung	V		2
2	Automotive Systems Übung	Ü		1

2 **Course language**

Englisch

3 **Teaching Content**

1. Vehicle dynamics (tires, longitudinal and lateral dynamics)
2. Actuators in the mechatronic vehicle (steering, braking, and powertrain systems)
3. (Kinematic) vehicle models
4. Sensors measuring vehicle internal quantities (acceleration, yaw rate, steering angle, steering torque, wheel speed, sensor data processing)
5. Vehicle dynamics systems (braking and driving slip control systems)
6. Modern headlight systems and light engineering

Literatur

R. Rajamani: Vehicle Dynamics and Control (Springer)
U. Kiencke, L. Nielsen: Automotive Control Systems (Springer)

4 **Competencies**

The students acquire a profound knowledge of vehicle dynamics systems (dynamics, sensors measuring vehicle dynamics quantities, actuators, models, simulation, control, and optimization). They are able to understand and solve tasks on vehicle dynamics systems with appropriate methods.
By completing the module, students should also be able to recognize and incorporate the challenges of today’s and future digital societies and thus assume social responsibility. In the field of vehicle dynamics systems, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.

5 **Examinations**

Module finals: oral (max. 40 minutes) oder written exam (max. 180 minutes)

6 **Type of Examination**

Module finals

7 **Participation Requirements**

Recommended Prerequisites: Basic knowledge of mechatronics and mechanics.

8 **Module Type and Applicability**

<table>
<tr><td></td><td colspan="2"><i>Elective Module</i> in the Master’s degree progams
• „Elektrotechnik und Informationstechnik“, Studienschwerpunkt „Robotik und Automotive“.
• Automation and Robotics, field of study: Robotics, Machine Learning
• Sustainable Energy Systems, Energy Systems Cataloque
• Wirtschaftsingenieurwesen, Referenzmodulnummer: MB-379</td></tr>
<tr><td>9</td><td>Module Supervisor
Prof. Dr.-Ing. Prof. h.c. Dr. h.c. Torsten Bertram</td><td>Faculty in charge
Department of Electrical Engineering and Information Technology</td></tr>
</table>

Methods of Information Technology: Statistical Signal Processing and Machine Learning AR-238

Methods of Information Technology: Statistical Signal Processing and Machine Learning

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2nd (Semester)	10	70 h	230 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Methods of Information Technology	Lecture	6	4
2	Methods of Information Technology	Tutorial	4	2

2 **Course language**

English

3 **Teaching Content**

We go on a journey from methods of signal processing (deterministic, statistical) to methods of machine learning. On our way we will apply the respective methods in various applications. Starting with an overview of the methods used, we look at (1) methods for estimation and detection based on physics-based models. Here we particularly discuss the application to positioning using trilateration (GPS) and triangulation (using antenna arrays). The results are point estimates of the unknown parameters. Using statistical approaches (Bayesian statistics) we present the respective solutions, which not only yield the maximum likelihood estimate but also information on the reliability of the results. Next, we replace the physics-based models with machine learning models and look at (2) methods for regression and classification. Having acquired a solid understanding of the basic approaches using statistical signal processing and machine learning, we also discuss the differences and similarities of the methods (1) and (2) from the mathematical and application point of view. Then we will take a different road for solving machine learning problems by discussing (3) reinforcement learning, which is applied to problems where the environment(model) is unknown. Finally, based on our “lessons learned” we look at the use of large models (e.g. Large Language Models like ChatGPT) and how they work.

Methods: statistical signals, Fourier transform, correlation and convolution, binary sequences, linear and non-linear systems of equations, principal component analysis and subspace methods, Bayesian statistics, support vector machine, (deep) neural network, reinforcement learning.

Applications: GPS trilateration (time-of-arrival, time-difference-of-arrival), triangulation, cluster analysis, power systems, signal detection, transmission systems, PCB design, ChatGPT

Literatur

Statistical Signal Processing in Engineering, Wiley 2018.

G. Jame et. al.: An Introduction to Statistical Learning, Springer, 2nd Edition, 2021.

G. Strang: Linear Algebra and Learning from Data, Wellesley-Cambridge Press, 2019.

R.S. Sutton, A.G. Barto: Reinforcement Learning - An Introduction, 2nd Edition, The MIT Press, 2020

4 **Competencies**

	Students should be able to use different (physics-based and machine learning) models and the respective methods for estimation/regression and detection/classification. They should be able to apply this knowledge to various applications, thereby making the right choices concerning the mathematical tools used. Statistcal aspects should be present along the way in order to gain understanding of the input data and the obtained solutions. By completing the module, students should also be able to recognise and incorporate the challenges of current and future digital societies and thus take on social responsibility. In the area of physics-based and machine learning models, this includes, for example, raising awareness of socially relevant topics such as age and technology or data security and digital participation.
5	**Examinations** *Modulprüfung:* oral examination (max. 40 minutes) or written examination (max. 60 minutes) * *Studienleistung:* none *The exact examination modalities will be announced by the 2nd course at the latest
6	**Type of Examination** Module Finals
7	**Participation Requirements** None
8	**Module Type and Applicability** Program: Automation & Robotics, Field of study: Robotics, Machine Learning
9	**Module Supervisor** Prof. Dr.-Ing. Jürgen Götze / Prof. Dr.-Ing. Jürgen Götze **Faculty in charge**

Principles of Sustainability

ETIT-413
(SES-105)
(AR-239)

Principles of Sustainability

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2nd Semester	5	35 h	115 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Principles of Sustainability	V		2
2	Principles of Sustainability	Ü		1

2 **Course language**

English

3 **Teaching Content**

1. What is Sustainability?
2. Legal framework
3. Reporting und Monitoring
4. Our CO2 footprint
5. Circular Economy in the context of energy supply
6. Climate neutral energy supply and demand
7. Sustainable solutions for energy systems (2 lectures)
8. Social Responsibility
9. The Year 2040

Literatur
tbd

4 **Competencies**

After the successful completion, students have the necessary solid knowledge on principles of sustainability. They can put sustainable approaches and solutions into the context of the current legal framework and develop appropriate reporting and monitoring methods. The handling of the different levels of sustainability and their necessary interaction is conveyed based on energy systems. The students can derive the impact of new technology and processes on the path of sustainability.
By completing the module, students should also be able to recognize and incorporate the challenges of today’s and future digital societies and thus assume social responsibility. In the field of sustainability, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy.

5 **Examinations**

Modulprüfung: oral exam (max. 40 minutes) or written exam (max. 90 minutes)
Studienleistung: tbd

6 **Type of Examination**

Module Exam

7 **Participation Requirements**

	Recommended preconditions: Knowledge about principles of energy technology	
8	**Module Type and Applicability** *Elective Class* in the Master’s degree program • „Electrical engineering and Information Technology“, Major Fields „Computer Engineering“ and „Elektrische Energietechnik“ • Automation & Robotics, Field of study:Robotics, Machine Learning, Process Automation *Mandatory module* in the Master’s degree program Sustainable Energy Systems.	
9	**Module Supervisor** Hon.Prof. Dr.-Ing. Lars Jendernalik	**Faculty in charge** Faculty of Electrical Engineering and Information Technology

Secure Communications ETIT-294

Secure Communications

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2nd Semester	5	35 h	115 h

1 Module Structure

No.	Course / Element	Type	CP	SWS
1	Secure Communications (lecture)	V		2
2	Secure Communications (tutorial)	Ü		1

2 Course language

English

3 Teaching Content

1. History and Basics of Security
2. Symmetric Cryptography
3. Asymmetric Cryptography
4. Message Authentication Codes and Digital Signatures
5. Post-Quantum Cryptography
6. Secure Wireless Communications

Literature

Trappe: Introduction to Cryptography with Coding Theory
Stallings: Cryptography and Network Security: Principles and Practice
Bloch and Barros: Physical Layer Security: From Information Theory to Security Engineering

4 Competencies

This course equips students with the knowledge and skills to identify the challenges of secure and reliable communication systems, to understand, apply, and further develop solutions, and to interpret relevant standards. In addition to the technical aspects, the course enables students to recognize and integrate the broader challenges of current and future digital societies into their professional IT security practice, fostering social responsibility. Within the field of secure and reliable communication technology, this includes, for example, raising awareness of socially relevant issues such as ageing and technology, data security, and digital inclusion.

5 Examinations

Modulprüfung: oral exam (max. 30 minutes) or written exam (max. 90 minutes) *
* The exact examination modalities will be announced no later than in the second course session.

6 Type of Examination

Module Finals

7 Participation Requirements

None

8 Module Type and Applicability

	Elective module in the Master’s degree programs • “Elektrotechnik und Informationstechnik” (specialization “Computer Engineering”), • “Automation and Robotics” (Field of Study: RRoboticsänd Machine Learning) • “Sustainable Energy Systems” • ”Wirtschaftsingenieurwesen”(reference module number: MB-363)	
9	**Module Supervisor** Prof. Dr.-Ing. Onur Günlü	**Faculty in charge** Faculty of Electrical Engineering and Information Technology

Components and Systems for Electric Mobility ETIT-509

Components and Systems for Electric Mobility

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	3rd Semester	5	45 h	105 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Components and Systems for Electric Mobility (lecture)	V		2
2	Components and Systems for Electric Mobility (tutorial)	Ü		2

2 **Course language**

English

3 **Teaching Content**

1. Overview of electromobility and vehicle electronics
2. Energy transmission in electric vehicles
3. Power electronics (basics, DC/DC converters, inverters)
4. Drive technology for electric and hybrid vehicles
5. Battery technologies and battery management
6. Charging technology for electric vehicles
7. Basics of wired data transmission in vehicles
8. Special vehicle bus systems
9. Vehicle development process, testing and diagnostic aspects

Literatur

Slobodan Petrovic: Battery Technology Crash Course
Selected journal and conference papers regarding automotive systems

4 **Competencies**

After successfully completing the module, students will have in-depth knowledge of typical electronic components, energy and data networks for electric vehicles. They will be able to select and parameterize these networks appropriately for a specific vehicle. All important components of drive systems are known and can be integrated into any vehicle class. The in-depth knowledge of battery technologies also allows developments for energy or information technology.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility. In the field of mobile robots, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.

5 **Examinations**

Modulprüfung: oral exam (max. 40 minutes) or written exam (max. 180 minutes)

6 **Type of Examination**

Module Exam

7 **Participation Requirements**

<table>
<tr><td></td><td colspan="2">None</td></tr>
<tr><td>8</td><td colspan="2">Module Type and Applicability
<i>Elective Class</i> in the Master’s degree programs
• Sustainable Energy Systems
• Automation and Robotics
• Elektrotechnik und Informationstechnik
• Wirtschaftsingenieurswesen, Referenzmodul: MB-408</td></tr>
<tr><td>9</td><td>Module Supervisor
Prof. Dr.-Ing. Stephan Frei</td><td>Faculty in charge
Faculty of Electrical Engineering and Information Technology</td></tr>
</table>

Quantum Computing ETIT-500

Quantum Computing

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2. Semester	5	45 h	105 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Quantum Computing Vorlesung	V		2
2	Quantum Computing Übung	Ü		1
3	Quantum Computing Praktikum	P		1

2 **Course language**

Englisch

3 **Teaching Content**

1. Introduction into the mathematical and physical foundations of quantum mechanics (Dirac notation, unitary matrices, tensor product, wave equations, uncertainty principle, Schrödinger equation, superposition, entanglement, no-cloning theorem)
2. Quantum bits and quantum registers
3. Algorithms and quantum gates (Hadamard matrix, controlled-NOT, Toffoli gate, adder circuits, Deutsch algorithm, Deutsch-Jozsa algorithm, Grover iteration)
4. Quantum error correction (flip-bit and sign-flip, Shor code)
5. Quantum teleportation, Quantum cryptography, Quantum machine learning
6. Current research towards technical realization of Quantum computer (ion traps, laser cooling, optical and hyperfine structure qubits, cryogenic systems, cryo-CMOS, superconducting systems, BCS theory)

Literatur

Stefan Tappertzhofen, Jack Alexander-Webber – Quantum Technology, Elsevier, 1st Edition, 2025

Jack Hidary - Quantum Computing: An applied approach, Springer-Nature, 1st Edition, 2019

4 **Competencies**

Upon completion of the module, students will be familiar with the basics of modern quantum computers from an engineering perspective. They will gain knowledge about the mathematical and physical foundations of quantum computers and their associated algorithms, as well as current research on the technical realization of quantum computers. This theoretical knowledge will be expanded in the practical course through programming examples to develop practical skills regarding the functioning of quantum computers.

By completing the module, students will be able to recognize and incorporate the challenges of today's and future digital societies, thereby taking on social responsibility. This includes raising awareness of socially relevant topics in the field of modern quantum computers, such as aging and technology or circular economy and sustainability.

5 **Examinations**

<table>
<tr><td></td><td colspan="2"><i>Modulprüfung:</i> mündliche Prüfung (max. 40 Minuten) oder Klausur (max. 180 Minuten)
<i>Studienleistung:</i> regelmäßige aktive Teilnahme am Praktikum (Element 3)</td></tr>
<tr><td>6</td><td colspan="2">Type of Examination
Modulprüfung</td></tr>
<tr><td>7</td><td colspan="2">Participation Requirements
Keine</td></tr>
<tr><td>8</td><td colspan="2">Module Type and Applicability
<i>Elective Module</i> in the master’s degree programmes
• „Elektrotechnik und Informationstechnik“, Profile „Computer Engineering“ und „Nano- und Quantentechnolgie“
• „Automation and Robotics“
• Wirtschaftsingenieurswesen, Referenzmodul: MB-404</td></tr>
<tr><td>9</td><td>Module Supervisor
Prof. Dr.-Ing. Stefan Tappertzhofen</td><td>Faculty in charge
Fakultät für Elektrotechnik und Informationstechnik</td></tr>
</table>

Data Science for Engineers AR-107

Data Science for Engineers

Rota	Duration	Semester	CP	Attendence	Self Study
SoSe	1 Semester	2nd (Semester)	6	51 h	129 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Data Science for Engineers (DSE, Lecture)	L	3	2
2	Data Science for Engineers (DSE, Tutorial)	T	1.5	1
3	Data Science for Engineers (DSE, Programming Lab)	P	1.5	1

2 **Course language**

English

3 **Teaching Content**

1. Introduction to measurement error analysis and the law of error propagation
2. Statistical data analysis methods: linear and nonlinear correlations, principal component analysis, etc.
3. Methods of linear and nonlinear optimisation
4. Adaptation of linear and nonlinear, univariate and multivariate model functions to measured data
5. Classical and Bayesian methods for determination of the error intervals of estimated model parameters and their mutual dependencies
6. Relations between nonlinear model adaptation and supervised machine learning
7. Unsupervised learning (clustering”) methods and their application to measured data

Literatur

Press, W. H., et al. (2007). Numerical Recipes: The Art of Scientific Computing. 3rd edition, Cambridge University Press.
Bishop, C. M. (2006). Pattern Recognition and Machine Learning. Springer-Verlag.
Gelman, A., et al. (2013). Bayesian Data Analysis. CRC Press.

4 **Competencies**

In this module, the participants will acquire the competency of interpretating of measured data critically and of distinguishing significant from insignificant model parameter estimation. Furthermore, they will gain a deepended understanding of supervised machine learning methods in the context of nonlinear model adaptation. Furthermore, participants will learn to understand and apply unsupervised machine learning methods for the analysis and visualisation of high-dimensional measured data.

5 **Examinations**

Modulprüfung: written exam (2 hours)
Studienleistung: successful completion of the programming lab

6 **Type of Examination**

	Module Finals	
7	**Participation Requirements** -	
8	**Module Type and Applicability** *Mandatory Course* Automation & Robotics, Examination Regulation 2025 *Elective Course* Automation & Robotics, Examination Regulation 2019	
9	**Module Supervisor** Prof. Dr. rer.nat. Christian Wöhler	**Faculty in charge** Department of Electrical Engineering and Information Technology

Elective Courses Winter Term

Advanced Process Control AR-301

Advanced Process Control

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	3rd (Semester)	5	60 h	90 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Advanced Process Control (APC)	Lecture	3	2
2	Advanced Process Control (APC)	Tutorial	2	2

2 **Course language**

English

3 **Teaching Content**

1. Summary of the analysis of linear dynamic systems: Stability, controllability, observability observability. Stability of nonlinear systems using Lyapunov theory and summary of nonlinear control design methods.
2. State estimation for linear and nonlinear systems: Kalman Filter, Extended Kalman Filter, Particle Filter, Mov-ing Horizon Estimation.
3. Advanced model-predictive control: linear and nonlinear model predictive control, robust model predictive control, learning-based model predictive control.
4. Efficient implementation of model predictive control.

Literatur

Slides
Lecture Notes

4 **Competencies**

The course provides in-depth knowledge of state of the art techniques for advanced process control and prepares for further scientific work in this area and for industrial jobs in process control and operation departments or companies. The students understand the methods listed above and are able to choose the appropriate methods for the solution of practical problems, to synthesize a solution and to evaluate the results.

5 **Examinations**

Modulprüfung: The final exam will be an oral (max. 30 minutes) or written (2 hours) exam, depending on the number of participants (form will be announced second week of course).
Studienleistung: Active participation and collaboration in 75% of computer exercises is mandatory.
The students can acquire 15% additional bonus point doing a small controller design project.

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

Basic knowledge: Basic knowledge of dynamic systems and control, as e.g. provided by the course Control Theory and Applications.

8	**Module Type and Applicability** Program: Automation & Robotics, Field of study: Process Automation Robotics, Machine Learning	
9	**Module Supervisor** Prof. Dr. S. Lucia/ Prof. Dr. S. Lucia	**Faculty in charge**

Computational Intelligence - Not offered in winter semester 2026/27 AR-306

Computational Intelligence

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	3rd (Semester)	5	40 h	110 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Computational Intelligence (CI)	Lecture	3	2
2	Computational Intelligence (CI)	Tutorial	2	1

2 **Course language**

English

3 **Teaching Content**

Since the course covers three different aspects of computational intelligence, the contents can best be described following this division into three parts:

1. After a brief introduction with reference to the biological paradigm, the foundations for neural networks are laid with an introduction to threshold logic. Then, traditional single- and multi-layer perceptrons as well as modern deep learning architectures such as convolutional and recurrent neural networks are covered. Various training algorithms are discussed. The content is presented in a way that focuses on the practical and implementation aspects as well as theoretical considerations such as limitation and complexity issues.
2. Evolutionary Algorithms: Again stemming from a natural source of inspiration evolutionary algorithms are introduced as an example from the class of general randomized search heuristics. After a description of the main modules (initialization, selection, crossover, and mutation) comes a discussion of typical parameter settings for population sizes and crossover and mutation probability. Then theoretical aspects are considered, the focus is on the analysis of the mean convergence rates.
3. Fuzzy Logic: This final part starts with an introduction to fuzzy sets and fuzzy logic using fuzzy relations and the concept of fuzzy inference. Applications like fuzzy clustering and fuzzy controllers are discussed.

Literatur

A.E. Eiben and J.E. Smith: Introduction to Evolutionary Algorithms. Corrected 2nd printing. Springer 2007.
Raul Rojas: Neural Networks - A Systematic Introduction. Springer 1996. Available online.
Ian Goodfellow, Yoshua Bengio, and Aaron Courville: Deep Learning. MIT Press 2017.
G.J. Klir und B. Yuan: Fuzzy Sets and Fuzzy Logic. Prentice Hall 1995.
F. Höppner, F. Klawonn, R. Kruse und T. Runkler: Fuzzy Cluster Analysis. Wiley 1999.
Amit Konar: Computational Intelligence: Principles, Techniques and Applications. Springer 2005.

4 **Competencies**

	Computational Intelligence is used as an umbrella term for different approaches that deliver enhanced performance and applicability. It encompasses artificial neural nets, evolutionary algorithms, and fuzzy logic. This course gives a thorough introduction into all three aspects of computational intelligence from the perspective of computer science. It focuses on theoretical aspects as well as typical application scenarios. After attending the course students are expected to have a basic understanding of the working principles, application areas and limitations of the three approaches.
5	**Examinations** *Studienleistung:* Mandatory prerequisite for an admission to the module examination is the successful solution of 50 % of the homework presented and discussed in the tutorial. *Modulprüfung:* Final module exam is a written exam (90 minutes).
6	**Type of Examination** Module Finals
7	**Participation Requirements**
8	**Module Type and Applicability** Program: Automation & Robotics, Field of study: Robotics, Process Automation, Machine Learning
9	**Module Supervisor** **Faculty in charge** Prof. Dr. G. Rudolph/ Prof. Dr. G. Rudolph

Mathematical Simulation Techniques AR-308

Mathematical Simulation Techniques

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe & SoSe	1 Semester	2nd/ 3rd (Semester)	5	40 h	110 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Mathematical Simulation Techniques (MST)	Lecture	3	2
2	Mathematical Simulation Techniques (MST)	Tutorial	2	1

2 **Course language**

English

3 **Teaching Content**

Discretization and solution techniques for the numerical simulation of problems in continuum mechanics, as well as their efficient treatment on computer systems are introduced. The course Advanced Engineering Mathematics, a solid background in mathematics, and solid programming skills are assumed. Among the subjects are the following:

1. Practical finite elements: Variational formulation of partial differential equations, weak solutions, Ritz-Galerkin techniques, finite element approximation and analysis, numerical integration, boundary approximation, mesh generation, error control and reliability, solution of linear systems.
2. Computational aspects of fluid dynamics: Conservation laws, compressible and incompressible fluids, spatial discretization (FD, FV, FEM), stabilization techniques, explicit and implicit time stepping schemes, treatment of boundary conditions, projection- and operator-splitting -techniques.
3. High performance computing: Parallel computer architecture, performance-oriented programming, sparse numerical linear algebra, Krylov-subspace and multigrid solvers, preconditioning strategies, domain decomposition methods, shared and distributed memory parallelization with OpenMP and MPI, GPU Computing.
4. Approximation theory: Interpolation and approximation, polynomial spaces, splines and Bézier curves, existence and uniqueness, best-approximation properties, quasi-interpolation, quality assessment and error analysis.

Literatur

References will be given in the courses.

4 **Competencies**

This course provides students with fundamental mathematical simulation techniques that are essential to solve automation problems in robotics as well as in production and engineering processes of all kinds. The entire simulation pipeline is covered in theory and practice. Students are trained to solve real-life complex problems in “Numerics Labs”.

5 **Examinations**

	Modulprüfung: The final exam will be an oral (20 minutes) or written (1.5 hours) exam, depending on the number of participants (form will be announced in the second week of the course).
6	**Type of Examination** Module Finals
7	**Participation Requirements** *Course:* “Advanced Engineering Mathematics”, solid programming skills
8	**Module Type and Applicability** Program: Autom. & Robot., Field of study: Robotics, Process Automation, Machine Learning
9	**Module Supervisor** Dean of the Mathematics department/ Lecturers of the Mathematics department **Faculty in charge**

Batch Process Operation AR-311

Batch Process Operation

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	3rd (Semester)	5	40 h	110 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Batch Process Operation (BPO)	Lecture	3	2
2	Batch Process Operation (BPO)	Tutorial	2	1

2 **Course language**

English

3 **Teaching Content**

Many chemical and most biochemical production processes are performed as batch processes where finite quantities of material undergo a sequence of production steps in one or several pieces of equipment. Batch processes differ from continuous processes as they are transient (non-stationary) in nature and often different products are produced in the same equipment, leading to scheduling problems. The course extends the knowledge of the students in the field of operation and control of batch processes. It covers the current standards for batch automation as well as the monitoring, control and optimization of individual batch runs.

Literatur

Handouts
Slides

4 **Competencies**

After the course, the students understand the fundamental differences between batch and continuous operation. They know the standards for batch automation and can interact with automation engineers in this domain. They are able to apply state-of-the-art monitoring, control and optimization techniques in industrial batch processes.

5 **Examinations**

Modulprüfung: The final exam will be an oral (20 minutes) or written (1.5 hours) exam, depending on the number of participants (form will be announced in the second week of the course).
Studienleistung: In addition, there will be a graded homework.

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

Basic knowledge: Basic knowledge of mathematical modeling, dynamic systems, and control, as e.g. provided by the course Control Theory and Applications.

8 **Module Type and Applicability**

Program: Automation & Robotics, Field of study: Process Automation

9	**Module Supervisor** Prof. Dr. S. Lucia/ Prof. Dr. Stefan Krämer	**Faculty in charge**

Process Performance Optimization AR-312

Process Performance Optimization

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	3rd (Semester)	5	40 h	110 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Process Performance Optimization (PPO)	Lecture	3	2
2	Process Performance Optimization (PPO)	Tutorial	2	1

2 **Course language**

English

3 **Teaching Content**

The course gives an overview of state-of-the-art techniques and of their applications to optimize the performance of chemical and biochemical production processes. The following topics are dealt with:

1. Selection of controllers and control structures
2. Tuning of standard controllers
3. Optimization of the operating conditions by linear programming and nonlinear optimization
4. Model predictive control
5. Batch trajectory optimization
6. Model-based estimation of process variables for monitoring and control
7. Process performance monitoring

Literatur

Handouts, Slides

4 **Competencies**

The students acquire an in-depth knowledge of methods and technologies for the improvement of chemical and biochemical production processes by advanced control, model-based methods, data analysis and optimization and continuous improvement. The students acquire a comprehensive overview of the industrial practice in this area.

5 **Examinations**

Modulprüfung: The final exam will be an oral (30 minutes) or written (2 hours) exam, depending on the number of participants (form will be announced in the second week of the course).

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

Basic knowledge: Basic knowledge of dynamic systems and control is required, as e.g. provided by the course Control Theory and Applications.

8 **Module Type and Applicability**

Program: Automation & Robotics, Field of study: Process Automation

9	**Module Supervisor** **Faculty in charge** Prof. Dr. S. Lucia / Prof. Dr. S. Lucia

Real-Time Operating Systems Design and Implementation - Not offered in winter semester 2026/27 AR-315

Real-Time Operating Systems Design and Implementation

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	3rd (Semester)	6	50 h	130 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Real-Time Operating Systems Design and Implementation	Lecture	3	2
2	Real-Time Operating Systems Design and Implementation	Tutorial	3	2

2 **Course language**

English

3 **Teaching Content**

Real-time systems play a crucial role in many modern applications and systems, especially when data processing units need to be integrated into physical systems. This module provides basic and advanced knowledge about real-time systems themselves and their application. The events in this module cover the design and analysis to ensure compliance with real-world system conditions. This knowledge is deepened and practiced in the exercises. The module is particularly suitable for students who are interested in research around Cyber Physical Systems and Embedded Systems.

Literatur

Slides

4 **Competencies**

The students understand the basic concepts for the design and analysis in real-time systems, in particular worst-case analyzes. Students should be enabled to apply current procedures for verifying the schedulability of real-time systems and scheduling algorithms.

5 **Examinations**

Modulprüfung: The final exam will be an oral exam.

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

Required knowledge: Solid knowledge of embedded systems, basic knowledge of Operating Systems and C Programming

8 **Module Type and Applicability**

Program: Automation & Robotics, Field of study:Robotics, Machine Learning

9

Module Supervisor	Faculty in charge
Prof. Dr. J. Chen/ Prof. Dr. J. Chen	

Automated Driving ETIT-504 (AR-321)

Automated Driving

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	3. Semester	5	35 h	115 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Automated Driving Vorlesung	V		2
2	Automated Driving Übung	Ü		1

2 **Course language**

Englisch

3 **Teaching Content**

1. Exteroceptive sensors (camera, radar, lidar, ultrasonic, sensor fusion)
2. Conditional, highly, and fully automated driving
    - 2.1. Situation analysis and interaction-aware trajectory prediction
    - 2.2. Trajectory planning and coupled prediction and planning
    - 2.3. Control concepts to follow a planned trajectory
3. Machine learning in automated driving
4. Driver monitoring and hand-over models

Literatur

I. Goodfellow, Y. Bengio, A. Courville: Deep Learning (MIT Press)
D. Forsyth, J. Ponce (Ed.): Computer Vision: A Modern Approach (Prentice Hall)
selected papers on automated driving, robotics, and deep learning

4 **Competencies**

The students acquire a profound knowledge of automated driving systems. They are able to understand and solve tasks on perception, prediction, planning, control, and driver modelling with appropriate methods.
By completing the module, students should also be able to recognize and incorporate the challenges of today’s and future digital societies and thus assume social responsibility. In the field of automated driving systems, this includes, for example, raising awareness of socially relevant topics such as age and technology or circular economy and sustainability.

5 **Examinations**

Module finals: oral (max. 40 minutes) oder written exam (max. 180 minutes)
Coursework: none

6 **Type of Examination**

Module finals

7 **Participation Requirements**

Recommended Prerequisites: Basic knowledge of mechatronics and mechanics; lecture: Automotive Systems.

8 **Module Type and Applicability**

<table>
<tr><td></td><td colspan="2"><i>Wahlpflichtmodul</i> in den Masterstudiengängen
• „Elektrotechnik und Informationstechnik“, Profil „Robotik und Automotive“
• Äutomation and Robotics”, field of study: Robotics, Machine Learning
• SSustainable Energy Systems”
• ”WirtschaftsingenieurwesenRReferenzmodulnummer: MB-396
This course can only be taken as a SZusatzmodulïf the student is enrolled a master’s program.</td></tr>
<tr><td>9</td><td>Module Supervisor
Prof. Dr.-Ing. Prof. h.c. Dr. h.c. Torsten Bertram</td><td>Faculty in charge
Department of Electrical Engineering and Information Technology</td></tr>
</table>

Linear Matrix Inequalities for Systems and Control AR-322

Linear Matrix Inequalities for Systems and Control

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	1st or 3rd (Semester)	5	50 h	100 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Linear Matrix Inequalities for Systems and Control	Lecture	2,5	2
2	Linear Matrix Inequalities for Systems and Control	Tutorial	2,5	2

2 **Course language**

English

3 **Teaching Content**

Many challenges in control engineering can be efficiently handled and solved using linear matrix inequalities (LMIs). Examples include stability analysis, robust controller design, or constrained handling. For instance, Lyapunov inequalities ensuring stability can be easily formulated as LMIs. In general, LMIs provide a mathematical framework to express constraints on decision variables using linear combinations of symmetric matrices. If constrained to the set of positive (or negative) (semi-) definite matrices, a convex constraint on the decision variables results. Solving such LMIs then leads to a so-called semi-definite program (SDP), which is a convex optimization problem and can hence be efficiently solved using appropriate software.
Againts this background, the course covers the followings topics:

1. Introduction to LMIs and SDPs.
2. Lyapunov stability for linear systems via LMIs.
3. The bounded real lemma and its relation to the existence of a stabilizing controller and the feasibility of a certain LMI.
4. The design of robust H2 and H-infinity controllers.
5. Flexible pole placement using LMIs.
6. The design of general linear dynamic controllers and the separation principle.
7. The numerical solution of LMIs and SPDs using Matlab and Yalmip.

Literatur

Stephen Boyd, Laurent El Ghaoui, Eric Feron, and Venkataramanan Balakrishnan. Linear Matrix Inequalities in System and Control Theory. Society for Industrial and Applied Mathematics (SIAM), 1994.

4 **Competencies**

	Upon completion of the course, students will have the following competencies: 1. The ability to formulate, interpret and apply LMIs and SDPs. 2. The ability to implement stability analysis and controller design using LMIs. 3. Skills in the design of robust H2 and H-infinity controllers taking into account uncertainties and disturbances. 4. Mastering the numerical solution of LMIs and SDPs using appropriate software and algorithms.	
5	**Examinations** *Modulprüfung:* The format of the final examination, which is either oral (maximum duration of 45 minutes) or written (90 minutes), will be determined depending on the number of participants and announced in the second week of the course. Students also have the opportunity to earn an additional bonus by completing a small project * Examination prerequisites: tbd * The exact examination modalities will be announced at the latest for the 2nd event.	
6	**Type of Examination** Module Finals	
7	**Participation Requirements** *Recommended preconditions:* Applied convex optimization and Control Theory	
8	**Module Type and Applicability** Program: Automation & Robotics, Field of study:Robotics, Process Automation	
9	**Module Supervisor** Prof. Dr. Schulze-Darup/ Prof. Dr. Schulze-Darup	**Faculty in charge**

Spectroscopic methods AR-323

Spectroscopic methods

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	1st or 3rd (Semester))	5	35 h	115 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Spectroscopic methods	Lecture	3	2
2	Spectroscopic methods	Tutorial	2	1

2 **Course language**

English (German)

3 **Teaching Content**

1. light sources and detectors
2. selection rules
3. laser spectroscopy
4. non-dispersive infrared spectroscopy
5. fourier transform spectroscopy
6. Raman spectroscopy
7. fluorescence spectroscopy

Literatur
tbd

4 **Competencies**

After successfully completing the module, students will have in-depth knowledge of the use of electromagnetic radiation to analyze mixtures of substances. Students will then be able to understand and classify the underlying interaction mechanisms between light and matter. Students will be able to evaluate the possibilities and challenges of using spectroscopic methods in different environments and fields of application and make a technically sound selection.

5 **Examinations**

Modulprüfung: oral exam (max. 40 minutes) or written exam (max. 90 minutes) *
Examination prerequisites: tbd
* The exact examination modalities will be announced at the latest for the 2nd event.

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

Recommended preconditions: Fundamentals of electrical engineering and physics

8 **Module Type and Applicability**

Program: Automation & Robotics, Field of study:Robotics, Machine Learning, Process Automation

9	**Module Supervisor** Prof. Stefan Palzer, PhD / Prof. Stefan Palzer, PhD	**Faculty in charge**

Advanced Imaging Systems ETIT-511

Advanced Imaging Systems

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	3rd Semester	5	45 h	105 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Advanced Imaging Systems (lecture)	V		2
2	Advanced Imaging Systems (tutorial)	Ü		1

2 **Course language**

English

3 **Teaching Content**

1. Engineering Optics and Signal Processing: Electromagnetic Waves, Geometric Optics, Wave Optics, Fourier Optics, Diffraction, Lenses, Aberations, Optical System Analysis, Quantum Detectors, Image processing Fundamentals
2. Imaging Systems for Space Science: e.g. Spectrometers, Space Telescopes, Instruments for Planetary Exploration, Instruments for Earth Observation and Environmental Monitoring, Radio Telescopes
3. Medical Imaging Systems: e.g. Computer Tomography, Magnetic Resonance Tomography
4. Imaging Systems for Autonomous systems and manufacturing: e.g. Radar and Lidar for autonomous driving, Photolithography Systems, non-destructive testing

Literatur

Demtröder, W. (2019). Electrodynamics and Optics (1st ed.), Cham: Springer
Born, M., & Wolf, E. (2019). Principles of optics: Electromagnetic theory of propagation, interference and diffraction of light (60th anniversary ed.). Cambridge University Press.
Schroeder, D. J. (2000). Astronomical Optics (2nd ed.). San Diego; Tokyo: Academic Press.
Maier, A., Steidl, S., Christlein, V., & Hornegger, J. (Eds.). (2018). Medical Imaging Systems: An Introductory Guide (Lecture Notes in Computer Science, Vol. 11111). Cham: Springer
Recent publications in the field

4 **Competencies**

This course enables students to develop a solid foundation in the principles and methods used for analyzing and designing optical systems and related data processing algorithms across a range of applications. In addition, they gain practical, hands-on experience in applying specialized software tools to the usage, analysis and design of optical systems in various real-world contexts.

5 **Examinations**

Modulprüfung: The final exam will be an oral (max. 40 min) or written (max. 180 min) exam, depending on the number of participants (form will be announced in the second week of the course).

6 **Type of Examination**

Module Finals

7	**Participation Requirements** *Recommended prerequisites:* Programming skills (MATLAB/Python) and basic knowledge of the Fourier transform.	
8	**Module Type and Applicability** *Compulsory elective module* (Wahlpflichtmodul) in the Master’s degree program „Elektrotechnik und Informationstechnik“, specializations „Nano- und Quantentechnologie“ or „Computer Engineering“.	
9	**Module Supervisor** Prof. Dr. rer. nat. Christian Wöhler Lecturer: Dr. Kay Wohlfarth	**Faculty in charge** Faculty of Electrical Engineering and Information Technology

Smart Grid System Engineering: Safety, Security and Resilience ETIT-508

Smart Grid System Engineering: Safety, Security and Resilience

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	3. Semester	5	35 h	115 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Smart Grid System Engineering: Safety, Security and Resilience Lecture	V		2
2	Smart Grid System Engineering: Safety, Security and Resilience Practical Works	P		1

2 **Course language**

Englisch

3 **Teaching Content**

The course focuses on the interdisciplinary principles and practical methods of system engineering for smart grids, with emphasis on system safety, functional safety, cybersecurity, and resilience. It introduces key concepts such as lifecycle models, SGAM, risk analysis techniques, and relevant safety standards (e.g., IEC 61508, ISO 26262).
A special focus is placed on the role of Digital Twins and Artificial Intelligence in the design and operation of secure and resilient smart grid systems. Through case studies and applied exercises, students gain theoretical and practical skills to develop safe and future-ready energy infrastructures.

Literatur

Leveson, Nancy G. An introduction to system safety engineering. MIT Press, 2023.
Hollnagel, Erik, David D. Woods, and Nancy Leveson. Resilience engineering: Concepts and precepts. Ashgate Publishing, Ltd., 2006.
Gräßler, Iris, and Christian Oleff. Systems engineering. Verstehen und industriell umsetzen. Berlin Heidelberg (2022).

4 **Competencies**

The aim of the lecture is to provide a solid foundation in system safety, functional safety, systems engineering, and resilience in the context of smart grids and critical energy infrastructures.
Students will learn to apply systems engineering principles, conduct hazard and risk analyses, and work with standards such as IEC 61508 and ISO 26262. Through case studies and hands-on exercises, they develop practical skills in designing and validating safe, reliable, and resilient energy systems.
The course also prepares students to engage with emerging technologies such as Digital Twins and Artificial Intelligence, and to critically reflect on their societal and ethical implications in future energy system design.

5 **Examinations**

	Partial achievements: 1. written exam (max. 120 minutes) 2. Team project project in which a practical example is developed and documented using the methods and practices introduced in the lecture and the accompanying practical work. Both partial achievements are graded and contribute equally to the finale grade for the module. *Studienleistungen/course Assessment:* Active participation in practical sessions (e.g., laboratory tasks) is required to be admitted to the written exam.	
6	**Type of Examination** Partial Achievement	
7	**Participation Requirements** *Mandatory:* Should have Successfully completed either SG or PSOS.	
8	**Module Type and Applicability** *Elective Class* in the Master's degree programs • „Elektrotechnik und Informationstechnik“ • “Sustainable Energy Systems”, Energy Systems Energy Systems Cataloque • “Automation and Robotics”	
9	**Module Supervisor** Apl. Prof. Dr.-Ing. Ulf Häger Dozenten: Dipl.-Ing. Dr.techn. Andreas Strasser, Dipl.-Ing. Thomas Krug	**Faculty in charge** Fakultät für Elektrotechnik und Informationstechnik

Natural Language Processing AR-324

Natural Language Processing

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	3rd (Semester)	9	70 h	200 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Lecture	Lecture	6	4
2	Tutorial	Tutorial	3	2

2 **Course language**

English

3 **Teaching Content**

1. Fundamentals of text data handling (e.g., encoding) and visualizations
2. Text data as features and preprocessing: tokenization, stopwords, stemming, lemmatization, n-grams, Regex, tf-idf, Zipfs law, filtering
3. Part-of-speech (POS) tagging and named entity recognition (NER)
4. Sentiment analysis
5. (Static) embeddings (e.g., word2vec, fastText, GLoVE)
6. (Probabilistic) topic models (e.g., pLSA, LDA, CTM, STM)
7. Neural and transformer-based topic models (e.g., BERTopic)
8. Transformer-based (pretrained) language models (e.g., BERT, (Chat)GPT)
9. (Advanced) training methods: fine-tuning, parameter-efficient fine-tuning (PEFT) & low-rank adaptation (LoRA), few-shot learning, near-domain training, transfer learning, ...
10. Evaluation of NLP sytems

Literatur

Most of the important NLP papers are published in the ACL Anthology: https://aclanthology.org/
Book from Marten Grootendorst and Jay Alammar: https://www.llm-book.com/
Online resource for illustrations and explanations of transformers:
Jay Alammar: https://jalammar.github.io/
Marten Grootendorst: https://newsletter.maartengrootendorst.com/
Online class (StanfordNLP): https://web.stanford.edu/class/cs224n/
Further reading (less relevancy):
Machine Learning for Text, doi:10.1007/978-3-319-73531-3 (some parts outdated)
Text Mining with R: https://www.tidytextmining.com/
R packages to start: https://www.tidytextmining.com/preface.html
Python libraries to start: NLTK, Gensim, spaCy, CoreNLP, TextBlob, Scikit-learn, torch, transformers, Adapters

4 **Competencies**

	Students will acquire in-depth theoretical and methodological knowledge of key natural language processing (NLP) techniques, ranging from classical statistical approaches to transformer-based language models. They will be able to independently prepare and analyze textual data and select, adapt, and critically evaluate appropriate modeling techniques depending on the context. They can implement, adapt, evaluate, and assess methods such as tokenization, tf-idf, vector space models for word/document embeddings, topic models, and transformer-based, pre-trained language models (e.g., BERT) in terms of their assumptions, performance, and limitations. In addition, they are able to use fine-tuning strategies (e.g., PEFT, LoRA, transfer learning, few-shot learning) in a targeted manner. Students can apply NLP models to specific questions, interpret results scientifically, and justify methodological decisions in a comprehensible manner.
5	**Examinations** *Modulprüfung:* Written exam (120 Minutes = 60 minutes theory + 60 minutes programming)
6	**Type of Examination** Module Finals
7	**Participation Requirements** Basic knowledge of Python (alternatively R). Basic knowledge of machine learning fundamentals and evaluation of models (e.g., cross-validation).
8	**Module Type and Applicability** Program: Automation & Robotics, Field of study: Machine Learning
9	**Module Supervisor** **Faculty in charge** Dr. J. Rieger/ Dr. J. Rieger

Medical Robotics ETIT-414

Medical Robotics

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	2. Semester	5	40 h	110 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Medical Robotics	L		2
2	Medical Robotics	Ü		2

2 **Course language**

English

3 **Teaching Content**

1. Challenges of medical robotics
2. Surgical robotics: challenges, applications, and research
3. Assistive robotics: challenges, applications, and research
4. Micro/Nano robotics: challenges, applications, and research
5. Safety, sensors and control for medical applications

Literature

Taylor, Russell H., et al. MMedical Robots and Systems.SSpringer Handbook of Robotics, edited by Bruno Siciliano and Oussama Khatib, 2nd ed., Springer, 2016, pp. 1657–1684.
Bleuler, H., Van der Loos, H. F. M., Carmine, M., & Salcudean, S. E. (2016). Rehabilitation and Health Care Robotics. In B. Siciliano & O. Khatib (Eds.), Springer Handbook of Robotics (2nd ed., pp. 1685–1714). Springer. doi.org
Nelson, B. J., Dong, L., & Arai, F. (2016). Micro-/Nanorobots. In B. Siciliano & O. Khatib (Eds.), Springer Handbook of Robotics (2nd ed., pp. 671–706). Springer. doi.org

4 **Competencies**

After the successful completion of the course students will understand the challenges of medical robotics regarding their construction, control, and implementation. They will be able to understand which requirements the different stakeholders have and know approaches to deal with them. Apart from that they will learn basics regarding sensor fusion, medical imaging, tracking, and biomechanics.

5 **Examinations**

Module examination: oral examination (30 minutes) or written examination (max. 60 minutes).*
*The exact examination modalities will be announced no later than in the second course session.

6 **Type of Examination**

Module examination

7 **Participation Requirements**

The number of participants is not limited

8 **Module Type and Applicability**

	Elective Course in the Master’s Programmes Automation and Robotics, Field of study: Robotics; Electrical Engineering and Information Technology, Field of study: Robotics and Automotive	
9	**Module Supervisor** Prof. Dr. rer. nat. Sabine Thürauf	**Faculty in charge** Faculty of Electrical Engineering and Information Technology

MODELLBILDUNG UND SIMULATION – Modern Coding Systems and Applications ETIT-304

Modeling and simulation – Modern Coding Systems and Applications

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	1. Semester	8	70 h	170 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Modern Coding Systems and Applications Lecture	V		4
2	Modern Coding Systems and Applications Tutorial	Ü		2

2 **Course language**

Englisch

3 **Teaching Content**

1. Basic models for modern coding systems
2. Principles of digital coding: encoding/decoding concepts, performance metrics, and simulation-based evaluation
3. Modern codes: Polar codes, LDPC codes, iterative decoding
4. Analog coding for over-the-air function computation
5. Machine learning-based coding methods: autoencoder-based communication systems, neural decoders, and data-driven performance optimization
6. Coding for modern storage and distributed systems: DNA storage, coded distributed computing, and network coding concepts
7. Coding for trustworthy and efficient networked applications: federated learning, privacy-aware distributed learning, and selected blockchain/network-coding applications
8. Modelling, simulation, and validation of coding systems: abstraction levels, performance-complexity trade-offs, benchmark scenarios, and interpretation of simulation results
9. Selected recent research papers on modern coding applications, including student presentations and moderated technical discussions

Literatur

Richardson and Urbanke: Modern Coding Theory
MacKay: Information Theory, Inference, and Learning Algorithms
Selected recent articles from journals and conferences on modern coding systems and applications

4 **Competencies**

	This course equips students with the knowledge and skills to model, simulate, and evaluate modern coding systems for data storage, distributed computation, communication, networked learning, and cyber-physical infrastructures. Students learn to identify suitable source, channel, storage, computation, learning, and network models, to understand and apply digital, analog, and learning-based coding methods, and to assess their performance using simulation-based and analytical tools. After successful completion of the module, students are able to compare modern coding approaches with respect to reliability, efficiency, latency, complexity, scalability, and implementation constraints. They can interpret recent research papers and transfer the presented methods to emerging application areas such as wireless communication systems, DNA storage, over-the-air computation, federated learning, network coding, trustworthy distributed systems, smart grids, distributed energy infrastructures, autonomous robotic systems, and industrial automation networks. In addition to the technical aspects, the course enables students to recognize and integrate the broader challenges of current and future digital societies into their professional practice, fostering social responsibility. Within the field of modern coding systems and their applications, this includes, for example, raising awareness of socially relevant issues such as data security, privacy, digital inclusion, sustainable communication and storage infrastructures, reliable information processing in networked systems, and resource-efficient digitalization of energy, automation, and robotic systems.
5	**Examinations** *Modulprüfung:* oral examination (max. 40 minutes) or written examination (max. 180 minutes).* *Studienleistung:* Successful completion of coursework includes the preparation and presentation of a selected recent research article as well as active participation in a moderated technical discussion, for example in the role of session chair. Successful completion of the coursework is a prerequisite for admission to the module examination. *The exact examination modalities will be announced no later than in the second course session.
6	**Type of Examination** Module examination
7	**Participation Requirements** None
8	**Module Type and Applicability** *Basismodul* in the Master's degree program "Electrical Engineering and Information Technology" for all Studienschwerpunkte/profiles. *Wahlpflichtmodul* (compulsory elective module) in the Master's degree program "Automation and Robotics", recommended for the profiles "Machine Learning" and "Robotics". *Elective module* for the Master's degree programs "Nachhaltige Energiesysteme" and "Sustainable Energy Systems", subject to the credit-point compatibility of the respective study regulations. For this Master's degree program, the Coursework imposed above will not be applied/considered, so that they can consider this course as a 5-credit points course.

9	**Module Supervisor** Prof. Dr.-Ing. Onur Günlü	**Faculty in charge** Fakultät für Elektrotechnik und Informationstechnik

General Education, Project Group, and Master Thesis

General Education I AR-371

General Education I

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe	1 Semester	1st Semester	3	45 h	45 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Language Class (German as foreign language)	Seminar	3	4
2	Foreign Language Class (Native speakers in German)	Seminar	3	4

2 **Course language**

English/ German

3 **Teaching Content**

Students attend a language course offered by the university language center.
Two participation options exist depending on the student's native language:

1. **German as a Foreign Language**
   Students whose native language is not German must take a German language course.
   General Education I typically corresponds to level A1.1 according to the Common European Framework of Reference for Languages (CEFR).
2. **Other Foreign Languages**
   Students whose native language is German may take a language course in any language other than German or English.

Typical course contents include basic communication skills such as:
- introducing oneself and others
- asking for and providing simple information
- describing professions and fields of study
- making appointments and communicating simple requests
- asking for and explaining directions
- writing short messages or invitations
- basic vocabulary related to everyday life

Students who already possess prior knowledge of a language may enroll in a course at a higher CEFR level, subject to placement by the language center.

4 **Competencies**

Upon successful completion of the module, students acquire basic communicative competence in the selected foreign language at an introductory level (approximately A1.1 according to the Common European Framework of Reference for Languages – CEFR).

	Students are able to: • understand and use familiar everyday expressions and basic phrases • introduce themselves and others and ask and answer simple questions about personal details • communicate in a simple way if the other person speaks slowly and clearly • understand and use basic vocabulary related to everyday life and university contexts Students also develop intercultural awareness and improve their ability to communicate in an international academic environment.
5	**Examinations** *Modulprüfung:* 3 Credits will be rewarded for either taking a class acknowledged for 1 or 2 or 3. Each class has to be passed by a final examination. Modalities of examinations are subject to the responsible lecturer. Passing the examination and assignment of credits shall be marked on a course–passing certificate.
6	**Type of Examination** Module Finals
7	**Participation Requirements** Students whose native language is not German must take a course in German as a Foreign Language. Students whose native language is German must select a foreign language other than German and English. Students with prior knowledge of a language may enroll in a course at a higher level according to the placement procedures of the language center.
8	**Module Type and Applicability** Program: Automation & Robotics
9	**Module Supervisor** Dean of the faculty of Electrical Engineering and Information Technology **Faculty in charge**

General Education II **AR-372**

General Education II

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe & SoSe	1 Semester	2nd / 3rd Semester	3	45 h	45 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Language Class (German as foreign language)	S	3	4
2	Foreign Language Class (Native speakers in German)	S	3	4

2 **Course language**

English/ German

3 **Teaching Content**

Students attend a language course offered by the university language center.
Two participation options exist depending on the student’s native language:

1. **German as a Foreign Language**
   Students whose native language is not German must take a German language course.
   General Education II typically corresponds to level A1.2 according to the Common European Framework of Reference for Languages (CEFR).
2. **Other Foreign Languages**
   Students whose native language is German may take a language course in any language other than German or English.

Typical course contents include basic communication skills such as:

- introducing oneself and others
- asking for and providing simple information
- describing professions and fields of study
- making appointments and communicating simple requests
- asking for and explaining directions
- writing short messages or invitations
- basic vocabulary related to everyday life

Students who already possess prior knowledge of a language may enroll in a course at a higher CEFR level, subject to placement by the language center.

4 **Competencies**

Upon successful completion of the module, students deepen their communicative competence in the selected foreign language and typically reach level A1.2 according to the Common European Framework of Reference for Languages (CEFR).

<table>
<tr><td></td><td colspan="2">Students are able to:
- understand and use frequently used everyday expressions and simple sentences
- communicate in routine situations requiring a simple and direct exchange of information
- describe basic aspects of their personal background, studies, and everyday environment
- participate in simple conversations related to everyday and academic contexts
Students further develop intercultural awareness and their ability to communicate in an international academic environment.</td></tr>
<tr><td>5</td><td colspan="2">Examinations
<i>Modulprüfung:</i> 3 Credits will be rewarded for either taking a class acknowledged for 1 or 2 or 3. Each class has to be passed by a final examination. Modalities of examinations are subject to the responsible lecturer. Passing the examination and assignment of credits shall be marked on a course–passing certificate.</td></tr>
<tr><td>6</td><td colspan="2">Type of Examination
Module Finals</td></tr>
<tr><td>7</td><td colspan="2">Participation Requirements
Students whose native language is not German must take a course in German as a Foreign Language.
Students whose native language is German must select a foreign language other than German and English.
General Education II normally builds upon the competencies acquired in General Education I. Students with sufficient prior language proficiency may enroll directly in a higher-level course according to the placement procedures of the language center.</td></tr>
<tr><td>8</td><td colspan="2">Module Type and Applicability
Program: Automation & Robotics</td></tr>
<tr><td>9</td><td>Module Supervisor
Dean of the department of Electrical Engineering and Information Technology</td><td>Faculty in charge</td></tr>
</table>

Project Group AR-380

Project Group

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe & SoSe	1 Semester	2nd / 3rd Semester	12	120 h	240 h

1 Module Structure

No.	Course / Element	Type	CP	SWS
a)	Project Group	Project	12	4

2 Course language

English/ German

3 Teaching Content

1. Organizing an academic task into work packages
2. Assigning the work packages to work teams
3. Processing the work packages within those work teams
4. Coordination of the work teams
5. Combining the findings of the individual work packages to a final result
6. Reviewing the results

4 Competencies

By attending the Project Group, students learn to split various tasks into small work packages which then can be handled with little overlapping. The students are able to process different task requirements for example by considering deadlines and economically reasonable use of resources. They have the ability to present the results in front of an expert audience.

5 Examinations

Modulprüfung: The scientific subject of the Project Group's work has to pertain to the research field of Automation and Robotics.
The individual achievement of each student has to be reviewed and to be graded.

6 Type of Examination

Module Finals

7 Participation Requirements

8 Module Type and Applicability

Project Group
Program: Automation & Robotics

9

Module Supervisor	Faculty in charge
Dean of the department of Electrical Engineering and Information Technology	

Master Thesis AR-400

Master Thesis

Rota	Duration	Semester	CP	Attendence	Self Study
WiSe & SoSe	1 Semester	4th Semester	30	– h	900 h

1 **Module Structure**

No.	Course / Element	Type	CP	SWS
1	Master Thesis	Master Thesis	30	–

2 **Course language**

English

3 **Teaching Content**

1. Becoming acquainted with an academic task by using specifications
2. Analyzing scientific literature, standards and methods
3. Developing solution approaches
4. Verification and evaluation of the solution approaches
5. Selection and implementation of the most suitable approach
6. Scientific description of the methods and solutions in written form

The contents and results of the Master's thesis must be processed and presented to an expert audience. The presentation must take place no later than 6 weeks after submission of the thesis.
The scientific subject of the Master Thesis has to correspond to the field of study.

4 **Competencies**

The student is able to work independently on a narrowly defined technical-scientific problem from his or her subject area using scientific methods. He or she is able to evaluate rel-evant preliminary work from the specialist literature, develop new approaches to solutions, evaluate these and finally implement a solution. Furthermore, he or she is able to present the results in writing in a structured way so that the relevant aspects of the solution are understood. The student is also able to present the results to a specialist audience and discuss them at the end.
By completing the module, students should also be able to recognize and incorporate the challenges of today's and future digital societies and thus assume social responsibility.

5 **Examinations**

Module finals: A final talk of the student is the module exam.

6 **Type of Examination**

Module Finals

7 **Participation Requirements**

Required prerequisites: The Master Thesis cannot be started before receiving 80 credit points within the curriculum of the Master Program.
The subject of the Master Thesis has to be assigned to the student's major field of study.

8 **Module Type and Applicability**

	Module in the Master’s degree program Automation & Robotics.	
9	**Module Supervisor** Dean of the Department of Electrical Engineering and Information Technology	**Faculty in charge** Faculty of Electrical Engineering and Information Technology

Versionsinformationen

Versionsinformationen

V 1.0: Vom Fakultätsrat der Fakultät für Elektrotechnik und Informationstechnik am 30.01.2019 beschlossene Version des Modulhandbuchs

Änderungen der Version vom 20.09.2019 gegenüber der Basisversion vom 30.01.2019:

- Wegfall des Moduls AR-224
- Wegfall des Moduls AR-313 „Multivariable Control“
- Aufnahme des Moduls AR-315: „Real-Time Operating Systems Design and Implementation”
- Aufnahme des Moduls AR-316: „Online Problems”
- Aufnahme des Moduls AR-317: „Human-Centered Robotics“

Änderungen vom 15.04.2020 gegenüber der Version vom 20.09.2019:

- Neuaufnahme des Moduls AR-226 „Robot und Interface Mechanisms“
- Neuaufnahme des Moduls AR-227 „Hardware Software Codesign“
- Neuaufnahme des Moduls AR-228 „Distributed and Networked Control”
- Neuaufnahme des Moduls AR-229 „Single-Loop and Multi-Loop Controller Design
- Neuaufnahme des Moduls AR-318 „Nonlinear Model Predictive Control – Theory and Applications“

Änderungen vom 14.07.2021 gegenüber der Version vom 15.04.2020:

- Wegfall der Module AR-207 „Process Optimization“, AR-226 „Robot and interface mechanisms“ und AR-317 „Human-Centered Robotics”
- Neuaufnahme des Moduls AR-230 „Practical Distributed Optimization in julia“
- Neuaufnahme des Moduls AR-231 „Remote Sensing“
- Neuaufnahme des Moduls AR-232 „Machine Learning Methods for Engineers“
- Neuaufnahme des Moduls AR-319 “Mobile and Pervasive Computing”
- Frau Prof. Dr. Selma Saidi übernimmt das Modul AR-103 „Computer Systems“
- Aktualisierung der Modulverantwortlichkeit in den Modulen AR-102, AR-205, AR-206, AR-220, AR-221, AR-222, AR-229, AR-301, AR-311, AR-312
- Überarbeitung Modul AR-201 „Application of Robots“: Erhöhung LP von 3 auf 5
- Überarbeitung Modul AR-301 „Advanced Process Control“: Erhöhung LP von 3 auf 6
- Überarbeitung Modul AR-205 „Process Automation“: Verringerung der LP von 8 auf 4
- Überarbeitung Modul AR-220 „Logic Control“: Verringerung der LP von 6 auf 3, Ergänzung des Schwerpunkts „Process Automation”

Änderungen vom 19.10.2022 gegenüber der Version vom 14.07.2021:

- Neuaufnahme des Moduls: AR-233 „Optimal Power Flow Problems“
- Neuaufnahme des Moduls: AR-234 „Mobile Radio Networks 1“
- Neuaufnahme des Moduls: AR-235 „Mobile Radio Networks 2“
- Neuaufnahme des Moduls: AR-236 „Embedded Autonomy“
- Neuaufnahme des Moduls: AR-320 „Machine Learning and optimal Control”
- Aktualisierung des Moduls AR-227: „Hardware Software Codesign“, Erhöhung von. 5 auf 10 CP
- Aktualisierung des Moduls AR-301: „Advanced Process Ciontrol“, Senkung von 6 auf 5 CP
- Aktualisierung des Moduls AR-310: neuer Titel „Machine Learning in Robotics“
- Wegfall des Moduls AR-303: „Mobile Communication Networks”

Änderungen vom 03.05.2023 gegenüber der Version vom 19.10.2022:

- Aktualisierung des Moduls AR-210

- Neuaufnahme der Module AR-237 und AR-321
- Wegfall der Module AR-220 und AR-221

Änderungen vom 30.04.2025 gegenüber der Version vom 03.05.2023:

- Wegfall des Moduls AR-202 Scheduling Problems and Solutions
- Wegfall des Moduls AR-230 Practical Distributed Optimization in julia
- Wegfall des Moduls AR-236 Embedded Autonomy
- Wegfall des Moduls AR-302 Networked Mobile Robot Systems
- Wegfall des Moduls AR-316 Online Problems
- Wegfall des Moduls AR-318 Nonlinear Model Predictive Control – Theory and Applications
- Wegfall des Moduls AR-320 Machine Learning and optimal Control
- Neuaufnahme der Module AR-238 Methods of Information Technology: Statistical Signal Processing and Machine Learning
- Neuaufnahme der Module AR-239 Principles of Sustainability
- Neuaufnahme der Module AR-322 Linear Matrix Inequalities for Systems and Control
- Neuaufnahme der Module AR-323 Spectroscopic methods
- Sprachliche Korrekturen und Anpassungen.

Änderungen vom 13.07.2026 seit dem 30.04.2025

- Neu aufgenommen bzw. wieder aufgenommen wurden folgende Module:
  - ETIT-508 „Smart Grid System Engineering: Safety, Security and Resilience“
  - ETIT-509 „Components and Systems for Electric Mobility“
  - ETIT-511 „Advanced Imaging Systems“
  - ETIT-294 „Secure Communications“
  - AR-324 „Natural Language Processing“
  - ETIT-500 „Quantum Computing“
  - ETIT-304 „Modeling and Simulation – Modern Coding Systems and Applications“
  - ETIT-414 „Medical Robotics“
  - AR-224 „Dynamic Models“
  - AR-107 ”Data Science for Engineers”

- Weggefallen bzw. nicht mehr angeboten werden folgende Module:
  - AR-227 Hardware Software Codesign
  - AR-228 Distributesd and networked control
  - ETIT-233 Optimal Power Flow Problems
  - AR-319 Mobile and pervasive Computing

- Inhaltlich, kompetenzbezogen oder allgemein aktualisiert bzw. überarbeitet wurden folgende Module:
  - AR-201 „Application of Robots“
  - AR-102 „Control Theory and Application“
  - AR-206 „Data-Based Dynamic Modeling“
  - AR-312 „Process Performance Optimization“
  - AR-225 / ETIT-269 „Mobile Robots“
  - AR-310 / ETIT-277 „Machine Learning in Robotics“
  - AR-106 / ETIT-244 „Modeling and Control of Robotic Manipulators“
  - AR-371 „General Education I“
  - AR-372 „General Education II“
  - AR-400 „Master Thesis“

  - AR-229 „Single-Loop and Multi-Loop Controller Design“
  - AR-314 „Smart Grids“
  - AR-237 „Automotive Systems“
  - AR-205 Process Automation

- Prüfungen bzw. Prüfungsanforderungen wurden bei folgenden Modulen geändert, aktualisiert oder präzisiert:
  - AR-225 / ETIT-269 „Mobile Robots“
  - AR-206 „Data-Based Dynamic Modeling“
  - AR-215 „Cyber-Physical System Fundamentals“
  - AR-229 „Single-Loop and Multi-Loop Controller Design“
  - AR-105 „Scientific Programming with Matlab in Engineering“
  - AR-314 „Smart Grids“
  - AR-237 „Automotive Systems“
  - AR-234 / ETIT-407 „Mobile Radio Networks 1“
  - AR-235 / ETIT-408 „Mobile Radio Networks 2“

- Aktualisiert wurden die Modulverantwortlichkeiten folgender Module:
  - AR-102 „Control Theory and Application“
  - AR-206 „Data-Based Dynamic Modeling“
  - AR-312 „Process Performance Optimization“
  - AR-322 „Linear Matrix Inequalities for Systems and Control“