Module manual for
Robotic Systems
Engineering
MSRoboSys

SPO Version 2021
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RWTH AACHEN UNIVERSITY

Module manual for Robotic Systems Engineering (Master (1-Subject))

Module manual for
Robotic Systems
Engineering
MSRoboSys

RWTH AACHEN UNIVERSITY

Examination Regulation Field

Module offer

Examination offer

Teaching offer

CONTENT
Module manual for Robotic Systems Engineering MSRoboSys

Examination Regulation Title & Version:
Robotic Systems Engineering (SPO Version / 2021)

Title	Robotic Systems Engineering
Short title	MSRoboSys
Version	2021
Study/Qualification Objectives	The master's degree program in Robotic System Engineering qualifies graduates to use computer-aided design software for the design and generation of complex technical solutions for robotics applications and automation technologies. They thus acquire in-depth knowledge of robotics technology. Graduates who have obtained this master's degree have the following qualifications: • They have experienced robots as a typical example of a mechatronic system, which only comes together to form an optimal solution through the sensible combination of mechanics, drives, sensors, and information processing. • In addition to conception and development, the graduates' field of activity also includes the organization of workflows and the monitoring of manufacturing processes. • They are qualified to work scientifically and have acquired in-depth theoretical and analytical knowledge of engineering and methods. • Graduates possess communication skills and understand how to perceive the highly complex technical applications of robot technologies as a holistic task under aspects of constantly increasing mechanization and to place them in a corresponding context for solution-oriented, sustainable developments. • Furthermore, graduates are able to update their knowledge constantly and independently. They can use this creatively to gain new insights and solve problems and demonstrate a critical awareness of the tasks at the interface between engineering science and social issues (increasing digitization of the working and living environment). They have the knowledge and skills to recognize new developments and technologies at an early stage and to assess and evaluate their significance for the respective field of activity accordingly.
Qualification Profile	
Additionnal information	

+ Robotic Systems (4018563)

Module titel	Robotic Systems (Compulsory subject)
Identifier	4018563
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2018
Valid until	-
Module level	Bachelor/Master
Content	1st Lecture Introduction to Industrial Robots (History of Robotics, Definition of Robotics, World Robotic Market, Requirements and application scenario, Essential construction elements of an industry robot, Category of robotics, Robotic Companies and StartUps, Future smart and intelligent Robots) 2nd Lecture Introduction to Advanced Robots (Advanced, Space, Food, Medical, Home Cleaning Robots, Mobile Manipulators, Intelligent Vehicles, World Robotic market: Service Robotics) 3rd Lecture General Robot Structures (Joints and Motion, Degree of Freedom, Workspaces, Different Classifications) 4th Lecture Structural Synthesis (Selection of robotic structures / quantitative optimization) 5th Lecture Robot End-effector Technology (Types and function of different End-effector technologies) 6th Lecture Gripper Technology (Characteristics of Objects, The Grasp, Gripper Mechanisms, Merit Indices, Design) 7th Lecture Components of Robotic Systems (Gears) 8th Lecture Components of Robotic Systems (Actuators) 9th Lecture Components of Robotic Systems (Sensors and Vision Systems) 10th Lecture Components of Robotic Systems (Control and Safety Architecture) 11th Lecture Properties and Benchmarking (Performance evaluation) 12th Lecture Mobile Manipulators (Types of Wheels, Kinematic Constrains, Robot Configuration Variables, Characterization of robot mobility, Wheeled Robot Structures) 13th Lecture Control and Path Planning (Artificial Intelligence)
Learning Objectives/ Learning Outcomes	Knowledge and understanding: The students have a profound comprehension of the fundamentals of robotic systems as well as the components used to build and run a robotic system. Thus, they are capable of comprehending, describing and analyzing robotic systems and components. Skills and competencies: The students got a brief overview about existing and future robotic systems. The students are capable of running through the development and implementation process of a mechatronic robotic gripper. They have the ability to analyse the kinematic structure of robots as well as grippers. Furthermore, they have the knowledge and the ability to launch and use general robotic components (stepper motor, sensors) and control (via microcontroller) the kinematic structures to complete it to a full mechatronic system. For the development of the gripper during the project, the students use general methods of structural synthesis and follow the development guidance for mechatronic systems (VDI 2206).
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended requirements: - mechanic (kinematic, dynamic) - mathemaitc I,II,III
References	- Lecture slides - Exercise slides Recommended literatur: - Siciliano, B.: Robotics; Modelling, Planning and Control, Springer International Publishing, 2009, eBook ISBN 978-1-84628-642-1, DOI 10.1007/978-1-84628-642-1

Robotic Systems (4018563)

	- Siciliano, B. (Hrsg.): Springer Handbook of Robotics, Springer International Publishing, 2016, eBook ISBN 978-3-319-32552-1, DOI 10.1007/978-3-319-32552-1
Language	English
Examination Terms	A written or an oral exam
Miscellaneous	-
Module coordinator	Modulverantwortlicher: apl. Professor Dr.-Ing. Mathias Hüsing
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Robotic Systems (401856301)	1st semester	2nd semester	5	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Robotic Systems	1st semester	2nd semester	-	2
Exercise Robotic Systems	1st semester	2nd semester	-	2

+ Advanced Robotic Kinematics and Dynamics (4018564)

Module titel	Advanced Robotic Kinematics and Dynamics (Compulsory subject)
Identifier	4018564
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2018
Valid until	-
Module level	Bachelor/Master
Content	1st Lecture Introduction of Robotic Systems (Industrial root brief introduction, Modelling, Planning and Control) 2nd Lecture Position, Orientation and Rotation Matrix (Pose of Rigid Body, Rotation Matrix, Composition of Rotation Matrices, Euler Angles, Axis and Angle, Unit Quaternion) 3rd Lecture Coordinate System/Homogeneous Transformations/Joints (Coordinate Systems, Homogeneous transformations, Joints) 4th Lecture Direct Kinematics – Serial/Parallel (Direct Kinematics -->; Two planar arm, Denavit-Hartenberg Convention, Kinematics of typical manipulator structures) 5th Lecture Inverse Kinematics (Joint and operational space, workspace, redundancy, Inverse kinematics, Problems and Properties, Analytical and Numerical Solutions) 6th Lecture Differential Kinematics (Definition, geometric Jacobian, Jacobian for typical manipulator Structures, Kinematic singularities) 7th Lecture Inverse Differential Kinematics and Statics (Definition, Calculation methods, Jacobian transpose and statics, velocity and force) 8th Lecture Modelling of Dynamics Model (Direct and Inverse Dynamics definition, Mechanics, Modelling of a rotary drive system, Lagrange Formulation, Examples) 9th Lecture Notable Properties of Dynamic Model (Analysis, Properties, Extensions, Parametrization, identification, uses) 10th Lecture Newton-Euler Formulation (Derivative of a vector in moving frame, Dynamics of a rigid body, recursive algorithm) 11th Lecture Trajectory Planning in Joint Space (Path and Trajectory, Point-to-Point motion, Motion through a sequence of points) 12th Lecture Trajectory Planning and Optimization in Cartesian Space (Path Primitives. Position and Orientation Planning, Optimal Trajectory Planning) 13th Lecture Kinematic Control (Definition of robot motion control and kinematic control, joint and cartesian space control) 14th Lecture Dynamic Control (Dynamic Model and its control properties, P/PD/PID control law)
Learning Objectives/ Learning Outcomes	Knowledge and Comprehension: The students have a profound comprehension of the fundamentals of robotic kinematics and dynamics. - Position, Orientation and Rotation Matrix + Homogeneous Transformations and Coordinate Systems - Direct and Inverse Kinematics - Differential and Inverse Differential Kinematics and Statics - Dynamic Model calculations - Trajectory Planning Skills and competencies: The students are able to set up the algorithms that are necessary to calculate position, velocities and accelerations of robotic systems and have a comprehensive understanding of the mathematical descriptions of the movement states. Particularly the students have the ability to deploy and use the DH-notation for robotic systems. At the same time, they consider the requirements of engineering science for different robotic structures. The Students are able, by knowledge and competence of methods, to select suitable robotic structures for the relevant handling tasks, to recognise important parameters and describe them mathematically correct to implement them into a programming. Furthermore, the students are able to program a robotic trajectory in joint and cartesian space and execute it in simulations.

+ Advanced Robotic Kinematics and Dynamics (4018564)

(Study-Specific) Prerequisites	-
(recommended) Requirements	- mechanics I,II,III - mathematics I, II, III - control theory
References	- Lecture slides - Exercise slides Recommended literature: - Siciliano, B.: Robotics; Modelling, Planning and Control, Springer International Publishing, 2009, eBook ISBN 978-1-84628-642-1, DOI 10.1007/978-1-84628-642-1 - Siciliano, B. (Hrsg.): Springer Handbook of Robotics, Springer International Publishing, 2016, eBook ISBN 978-3-319-32552-1, DOI 10.1007/978-3-319-32552-1
Language	English
Examination Terms	Written exam Die Endnote ergibt sich aus der Note der Klausur, der mündlichen Prüfung oder dem e-Test, je nachdem welche Prüfungsform zutrifft.
Miscellaneous	-
Module coordinator	Modulverantworlicher: Universitätsprofessor Dr.-Ing. Dr. h. c. (UPT) Burkhard Corves
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Advanced Robotic Kinematics and Dynamics (401856401)	1st semester	2nd semester	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Advanced Robotic Kinematics and Dynam	1st semester	2nd semester	-	2
Lecture Advanced Robotic Kinematics and Dynamics	1st semester	2nd semester	-	2

Computer Vision (1215724)

Module titel	Computer Vision (Compulsory subject)
Identifier	1215724
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2018
Valid until	-
Module level	Bachelor/Master
Content	Image Processing Basics, Image Segmentation, Object Recognition, Object Categorization, 3D Reconstruction, Application of current Machine Learning methods to the above-mentioned problems.
Learning Objectives/ Learning Outcomes	Knowledge: On successful completion of this module, lecture participants should be able to recall and explain the theoretical foundations underlying Computer Vision techniques in the areas mentioned under “Content”. | Skills: Lecture participants can derive and explain methods and techniques that enable a machine to analyze the content of images and videos and to derive an understanding of the image content. They know the current research trends and developments. This enables them to select the basic Computer Vision techniques necessary for those capabilities. | Competences: Lecture participants are able to apply the covered methods to real problems on their own. They are able to implement the covered algorithms themselves in a language of their choice.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Basic knowledge in linear algebra, probability theory and statistics is recommended.
References	R. Szeliski, Computer Vision - Algorithms and Applications, Springer, 2010 | K. Grauman, B. Leibe, Visual Object Recognition, Morgan & Kaufman publishers, 2011 | I. Goodfellow, Y. Bengio, A. Courville, Deep Learning, 2016 | R. Hartley, A. Zisserman. Multiple View Geometry in Computer Vision, 2nd Edition, Cambridge University Press, 2004.
Language	English
Examination Terms	Written exam or oral examination (100 %). Students must pass written homework to be admitted to the module examination.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. sc. techn. Bastian Leibe
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	15-45 (mündlich/oral) | 90-120 (schriftlich/written)
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

+ Computer Vision (1215724)

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Computer Vision (121572402)	2nd semester	no semester recommended	0	1
Exam Computer Vision (121572401)	2nd semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Computer Vision	2nd semester	no semester recommended	-	3

+ Machine Learning (1215744)

Module titel	Machine Learning (Compulsory subject)
Identifier	1215744
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	Basic concepts: Introduction to Probability Theory, Bayes decision Theory | Probability Density Estimation | Discriminative Methods for Classification: Linear discriminants, Support Vector Machines, AdaBoost | Deep Learning: Multi-Layer Perceptrons, Convolutional Neural Networks, Recurrent Neural Networks
Learning Objectives/ Learning Outcomes	Kenntnisse: Nach erfolgreicher Teilnahme an den Modulveranstaltungen haben die Vorlesungsteilnehmer Kenntnisse und Fähigkeiten in den Themenfeldern, die unter Inhalt beschrieben werden, erworben. | Fertigkeiten: Vorlesungsteilnehmer können Methoden und Techniken, die es einer Maschine ermöglichen, aus Daten zu lernen, herleiten und erklären. Sie kennen die aktuellen Forschungstrends und -entwicklungen. Dadurch sind sie in der Lage, die grundlegenden Machine Learning Techniken, die für diese Fähigkeiten benötigt werden, auszuwählen. | Kompetenzen: Vorlesungsteilnehmer sind in der Lage, die behandelten Methoden selbstständig auf reale Probleme anzuwenden. Sie sind in der Lage, die vorgestellten Algorithmen selbst zu implementieren und diese in einer Programmiersprache ihrer Wahl umzusetzen.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Basic knowledge in Linear Algebra, Probability Theory, and Statistics is recommended.
References	C.M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006. | I. Goodfellow, Y. Bengio, A. Courville, Deep Learning, 2016.
Language	English
Examination Terms	Written exam or oral examination (100 %). Students must pass written homework to be admitted to the module examination.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. sc. techn. Bastian Leibe
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	15-45 (mündlich/oral) | 90-120 (schriftlich/written)
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

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+ Machine Learning (1215744)

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Machine Learning (121574402)	1st semester	2nd semester	0	1
Exam Machine Learning (121574401)	1st semester	2nd semester	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Machine Learning	1st semester	2nd semester	-	3

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+ Robotic Sensor Systems (4018566)

Module titel	Robotic Sensor Systems (Compulsory subject)
Identifier	4018566
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2019
Valid until	-
Module level	Master
Content	Robotic Sensor Systems • Internal sensors (Position, speed, acceleration sensors, internal navigation systems) • External sensors (Tactile, proximitx, distance, position and visual sensors) • Basics about signal transmittance and processing • Special applications (space, Fukushima, under water) • Examples at IPT and WZL
Learning Objectives/ Learning Outcomes	Robotic Sensor Systems Overall goal: The aim is to familiarize the students with the different sensor systems a robot can contain, how these sensor work and why the robot needs these sensors. It is distinguished between internal and external sensors. In addition, some basics about signal transmission and signal processing are introduced. Knowledge / Understanding Students • know a large choice of internal and external sensors of a robot; • know work principles of all introduced kinds of sensor systems; • know the basics about signal processing and transmission, containing the corresponding mathematical and physical principles. Abilities / Skills Students • calculate the signal from recording it with the sensor to processing transmitting it; • explain how the sensor systems of a robot work and what they are applied for. Competencies Students • know which sensor system is indispensable to give the robot special skills and properties.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-none-
References	Lecture and exercise slides containing references
Language	English
Examination Terms	A written exam or an oral exam
Miscellaneous	-
Module coordinator	Modulverantwortlicher: Universitätsprofessor Dr.-Ing. Robert Schmitt

+ Robotic Sensor Systems (4018566)

ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Robotic Sensor Systems	3rd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Robotic Sensor Systems	3rd semester	no semester recommended	-	2
Exercise Robotic Sensor Systems	3rd semester	no semester recommended	-	2

+ Simulation of Robotic Systems, Sensors and Environment (6020083)

Module titel	Simulation of Robotic Systems, Sensors and Environment (Compulsory subject)
Identifier	6020083
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	Simulation of Robotic Systems, Sensors and Environment • General introduction: Simulation is the “representation of a system with its dynamic processes in an experimentable model to reach findings which are transferable to reality.” State-of-the-art simulation technology makes this possible even for complex networks of interacting Digital Twins. This makes simulation indispensable both for the development and operation of automation systems. • Terminology and basic concepts: (Technical) asset, system, model, simulation, simulator, verification, validation, calibration, adjustment • Requirements for simulation technology • The Digital Twin concept • Simulation and Industry 4.0 • The Virtual Testbed concept • Use of simulation in engineering processes in different application areas • Multi-disciplinary simulation for multi-disciplinary systems • Classification and comparison of simulation methods • Domain-independent simulation methods, e.g. equation-based simulation, signal-oriented simulation, object-oriented simulation, discrete-event simulation, agent-based simulation • Domain-specific simulation methods for robotics, e.g. Kinematics (orientation, pose, transformation, kinematic chains and trees, forward and inverse kinematics), equations of motion (Newton Euler, Lagrange), rigid body dynamics, sensor simulation • Coupling of simulation models and simulators • Simulation and the sense-think-act cycle • Simulation and model-based systems engineering • Digital Factory • Virtual Commissioning • Integration of simulation technology in engineering processes • Data management and data formats • Semantic world modelling • Simulation and optimization • Simulation and man-machine-interaction
Learning Objectives/ Learning Outcomes	Simulation of Robotic Systems, Sensors and Environment Overall goal: Students gain the basic knowledge concerning methods and processes to simulate robotic systems in their operational environment and to use such simulations throughout the life-cycle of the robot. After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students • understand why simulation of robotic systems is important for robot engineering and operation; • understand the Digital Twin concept and its relationship to engineering and real-world operation; • are familiar with the most important simulation methods used for the simulation of robots, their sensors and actuators as well as their dynamic environment; • know how to use these methods in different usage scenarios. Abilities / Skills Students

+ Simulation of Robotic Systems, Sensors and Environment (6020083)

	• use simulation technology to realize Digital Twins of robot manipulators, mobile robots, working machines etc. in different application areas (factory, space, construction, forestry); • analyse and understand the simulation results. Competencies Students • select and combine appropriate simulation methods for Digital Twins in different usage scenarios; • use and integrate Digital Twins in engineering processes and robot operation; • understand and present the simulation results.
(Study-Specific) Prerequisites	-
(recommended) Requirements	none
References	Lecture Notes Students also receive a list of relevant literature
Language	English
Examination Terms	-
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Jürgen Roßmann
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	oral examination 30 min. written examination 60-120 min.
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Examination Simulation of Robotic Systems, Sensors and Environment (602008301)	3rd semester	no semester recommended	5	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Simulation of Robotic Systems, Sensors and Environment	3rd semester	no semester recommended	-	2

+ Multibody Dynamics (4011462)

Module titel	Multibody Dynamics (Compulsory subject)
Identifier	4011462
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	• Introduction • Fundamentals • Fields of application • Model Building • Methods of Approach for Equivalent Models • Multi-body Systems • General mathematical description • Kinematics of Multi Body Systems • Position and Orientation of Bodies • Translational Kinematics • Rotational Kinematics • Equations of Motion • Lagrangian Equations of 2nd Kind • Newton-Euler equations • Lagrangian Equations of 1st Kind • Eigen Value Approach • Undamped non-gyroscopic systems • Damped gyroscopic systems • Eigen Value Stability Criteria Linear Systems with Harmonic Excitation • Real Frequency Matrix • Complex Frequency Matrix • State Equation • System Matrix • Eigen Value Approach • Fundamental Matrix • Modal Matrix • Theorem of Cayley-Hamilton • Analytical Solution • Numerical Solution • Step Excitation • Harmonic Excitation • Periodical Excitation Example • Modelling • Calculation • Evaluation
Learning Objectives/ Learning Outcomes	In this course, students shall acquire the following: <u>Knowledge / Understanding:</u> Students: • shall have a profound knowledge of theory of vibrations. • shall be capable of comprehending, describing and analyzing vibratory systems.

+ Multibody Dynamics (4011462)

	• shall be familiar with the most important matrix based procedures for the calculation of eigenmotions and the behaviour of linear systems under forced excitations. Abilities / Skills: Students • shall have the ability of describing mathematically any mechanical system with its inherent physical effects like elasticity, damping and friction. • shall be able to properly interpret simulation results especially under consideration of simplifications within the model compared to the real system. Competencies: Students • shall be able to derive from their knowledge the necessary methods and proceedings for the analysis and synthesis of the systems in regard. • shall be capable to solve - accessing their acquired theoretical knowledge - complex problems concerning the choice and design of industrial vibratory systems.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-none-
References	• Lecture Notes • Students also receive a list of relevant literature
Language	English
Examination Terms	Written/Oral Examination (Depending on registration numbers)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dr. h. c. Burkhard Corves
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Multibody Dynamics (401146201)	2nd semester	no semester recommended	5	0

+ Multibody Dynamics (4011462)

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Tutorial Multibody Dynamics	2nd semester	no semester recommended	-	2
Lecture Multibody Dynamics	2nd semester	no semester recommended	-	2

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+ Language Course (4023298)

Module titel	Language Course (Compulsory subject)
Identifier	4023298
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	The course is aimed at students who are looking for a university-specific foreign lan-guage education, who need a foreign language for their studies and/or are planning a stay abroad (study, internship, project). Depending on the level, the range of foreign languages on offer takes into account the training of language skills specific to the profession. In the course you will learn the essential elements of grammar and vocabulary of the respective language, depending on your level, so that you can assert yourself both in writing and orally in everyday communication situations. In addition, you will learn to extract the essential information from authentic and university-specific reading and lis-tening texts as well as from various types of texts such as: Write e-mails, letters, messages and notes.
Learning Objectives/ Learning Outcomes	To learn the basics of the respective language or to deepen and expand already existing skills for active participation in everyday and working life.
(Study-Specific) Prerequisites	-
(recommended) Requirements	none
References	-
Language	German/English
Examination Terms	100% written examination in reading, listening, writing and grammar
Miscellaneous	-
Module coordinator	-
ECTS Credits	2
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	60,0
Contact hours (h)	60,0
Self-study hours (h)	,0

+ Language Course (4023298)

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Language Course (402329801)	1st semester	no semester recommended	2	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Language Course	1st semester	no semester recommended	-	-
Exercise Language Course	1st semester	no semester recommended	-	-

+ Fundamentals of Machine Learning (4018565)

Module titel	Fundamentals of Machine Learning (Compulsory subject)
Identifier	4018565
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	The class "Fundamentals of Machine Learning" covers state-of-the-art machine learning methods and their application especially in engineering. It introduces the core basics in probability theory, develops main principles and methods from machine learning, and provides an introduction to its modern tools. The class combines both profound understanding of basic concepts and theory in machine learning, as well as hands-on programming techniques applied on problems in the context of engineering. Class outline: 1. Probability theory 2. Linear models for regression 3. Linear models for classification 4. Neural networks and deep learning 5. Gaussian processes 6. Introduction to reinforcement learningMedia
Learning Objectives/ Learning Outcomes	Knowledge and Understanding • The students know the fundamentals in probability theory and can apply them in advanced methods and problems • The students have an overview and understanding of core methodsand tools in machine learning (regression, classification, reinforcement learning) • They have an in-depth understanding of core principles, problems,and techniques in data science and machine learning • They develop an understanding for what problems and purposesmachine learning methods can be applied in mechanical engineering Abilities and Competencies: • The students acquire knowledge about methods and implementation of state-of-the-art machine learning (e.g., neural networks, Gaussian process regression) • They have the ability to apply the acquired knowledge to application problems (e.g., in engineering) by using appropriate methods and programming tools
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	Will be announced in class. Recommended further literature: Bishop, Christopher M., Pattern recognition and machine learning. Springer, 2006. Goodfellow, lan, Yoshua Bengio, and Aaron Courville, Deep learning. MIT press, 2016. Carl Edward Rasmussen and Christopher K. I. Williams, Gaussian pro-cesses for machine learning, MIT press, 2006.

+ Fundamentals of Machine Learning (4018565)

Language	English
Examination Terms	Written final exam (100 %)
Miscellaneous	-
Module coordinator	Modulverantworlicher: Univ.-Prof. Dr. Johann Sebastian Trimpe
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Fundamentals of Machine Learning (401856501)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Fundamentals of Machine Learning	1st semester	no semester recommended	-	2
Exercise Fundamentals of Machine Learning	1st semester	no semester recommended	-	2

+ Linear Control Systems (4011476)

Module titel	Linear Control Systems (Compulsory subject)
Identifier	4011476
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	Significance of control theory, examples of biological and biomedical control loops, functional diagrams, linearization, set up and solving of differential equations, stability, features in time domain of dynamical systems, Laplace transform, transfer function, frequency response, functional diagram algebra, features in frequency domain of dynamical systems, bode diagram, Nyquist plot, Linear control loop elements, principle and goals of controller design, algebraic stability criteria, steady state analysis and transient performance of a control loop, controller setting rules, Nyquist stability criterion, phase margin, gain margin, controller design in bode diagram.
Learning Objectives/ Learning Outcomes	After successfully completing this course, the student will have acquired the following learning outcomes: Knowledge / Understanding: • know, recognize and classify the most common linear control loop elements • the effects of feedback and apply different methods to set up feedback elements (controllers) such that predefined control goals are met Abilities / Skills: • to analyze dynamical, biological and biomedical systems and identify the relevant causalities • to employ different mathematical descriptions of dynamical systems • solve differential equations by means of Laplace transform • assess of the stability of dynamical systems using different methods • obtain, interpret and employ the frequency response of dynamical systems
(Study-Specific) Prerequisites	-
(recommended) Requirements	Basic knowledge in mathematics as defined in the examination regulations.
References	-
Language	English
Examination Terms	The module grading is weighted according to the CP-allocation • Written Exam (schriftliche Prüfung) or • Oral Exam (mündliche Prüfung)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dirk Abel
ECTS Credits	3
Contact time (WSH)	2

+ Linear Control Systems (4011476)

Examination duration (min)	-
Total hours (h)	90,0
Contact hours (h)	30,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Linear Control Systems (401147601)	1st semester	no semester recommended	3	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Linear Control Systems	1st semester	no semester recommended	-	1
Tutorial Linear Control Systems	1st semester	no semester recommended	-	1

+ Production Metrology (4011467)

Module titel	Production Metrology (Compulsory elective subject)
Identifier	4011467
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2019
Valid until	-
Module level	Master
Content	Introduction • Relevance of metrology for quality assurance and its integration in production processes. Metrological Basics • Metrological concepts and definitions (Calibration, Uncertainty etc.) Tolerancing • Form and positional tolerances, tolerancing principles and basics Inspection Planning • Tasks and workflow of inspection planning, Procedure for creation of inspection plans Shop floor measuring devices/ Measuring sensors • Commonly used manual inspection devices for the shop floor, Function and application of inductive, capacitive and pneumatical sensors Optoelectronic inspection devices • Optical inspection systems for geometry testing and applications Form and surface inspection devices • Tactile and optical system for the characterisation of forms and surfaces, surfaces parameters Coordinate measurement technology • Principles, types and applications of coordinate measuring machines Gauging inspection • Form and positional gauging, Gauging Procedures Statistical basics • Statistical parameters for the description of production and measuring processes, tests on normal distribution SPC, Process Capability • Statistical analysis and control of processes, Process capability indices Inspection device management • Tasks and procedures of inspection device management, Calculation of measuring device capability, Calibration chain
Learning Objectives/ Learning Outcomes	First of all, the elements of the application of the means of measurement concerning the production are pointed out. The theoretical fundamentals which have to be taken into consideration while the measuring process is planned, controlled, analysed, are discussed. Thereby, current measuring principles and devices in the field of industrial production will be considered and new measuring techniques and trends will be presented In this context the characteristics of the measured quantities and their fringe conditions are explained. A further subject of the lecture will be the statistical analysis of the measured values.

+ Production Metrology (4011467)

	The aim of this lecture is to create the awareness, that “measuring” comprehends a lot more than plain data acquisition and metrology is a vital part of modern production processes.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Robert Schmitt
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Production Metrology (401146701)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture/Exercise Production Metrology	2nd semester	no semester recommended	-	4

+ Machine Dynamics of Rigid Systems (4017428)

Module titel	Machine Dynamics of Rigid Systems (Compulsory elective subject)
Identifier	4017428
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2019
Valid until	-
Module level	Bachelor/Master
Content	1. introduction / basic principles / planar kinematics and dynamics of rigid bodies 2. dynamic force analysis of planar mechanisms with rigid links: graphical technique / analytical approach 3. dynamic motion analysis of planar mechanisms with rigid links (neglecting friction) 4. kinematics and dynamics in single slider reciprocating machines: dynamically equivalent system of connecting rod / determination of frame torque 5. mass balancing for single slider reciprocating machines: determination / balancing of inertia forces &; determination / balancing of inertial moments 6. mass balancing for multi slider reciprocating machines: determination (incl. graphical approach) / balancing of inertia forces &; determination / balancing of inertial moments 7. introduction into power smoothing in mechanisms and slider reciprocating machines 8. equations of motion: external forces and moments / kinetic energy / potential energy 9. solution of equation of motion: general / for constant mass moment of inertia / for constant angular velocity / for specified instantaneous speed and acceleration / for constant energy 10. fluctuation of angular velocity / non uniformity factor 11. influence of flywheel on angular velocity &; analytical / approximative calculation of flywheel
Learning Objectives/ Learning Outcomes	Wissen und Verstehen: The students know the fundamental means for mass balancing and power smoothing of single slider reciprocating machines and other general mechanical systems. The students have the ability to explain and derive the mass forces and mass moments of single and multi slider reciprocating machines. The students know about the basic relations, resulting in fluctuating angular velocities due to varying mass moments of inertia and varying loads as reduced to a reference shaft. The relations can be derived and explained. Fertigkeiten und Kompetenzen: The influencing factors for fluctuating speeds in single and multi slider reciprocating machines can be described. Based on that potential means for power smoothing can be derived. Students have the ability to derive the required kinematic and dynamic relations for the machines and mechanisms under investigation. Moreover, balancing of machines and mechanisms with high mass forces can be performed, including design issues and mathematical derivations. From the dynamic analyses, students learn to develop practical and innovative instructions for mass balancing and power smoothing. To sum up, student gain fundamental knowledge that can be applied to related industrial challenges (including special machine construction and specifications) in the field of design improvement by means of mass balancing and power smoothing.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Empfohlene Voraussetzungen: • Mechanics I, II, III • Mathematics I, II, III und numerical Mathematics
References	Veranstaltungsliteratur: • Lecture notes "Maschine Dynamics of Rigid Systems"

+ Machine Dynamics of Rigid Systems (4017428)

	• Lecture slides Empfohlene weiterführende Literatur: Dresig, H.; Holzweißig, F.: Maschinendynamik / VDI-Richtlinie 2149: Getriebedynamik (Fachausschuss A204, Ltng. Prof. Dresig) Blatt 1: Starrkörper-Mechanismen / Dresig, H.: Schwingungen mechanischer Antriebssysteme / Gasch, R.; Nordemann, R.; Pfützner, H.: Rotordynamik / Pfeiffer, F.: Einführung in die Dynamik / Magnus, K.; Popp, K.: Schwingungen / Heimann, B.; Gerth, W.; Popp, K.: Mechatronik / Ulbrich, H: Maschinendynamik
Language	English
Examination Terms	The final grade results from the oral exam, the written exam or the e-test, whichever applies.
Miscellaneous	-
Module coordinator	Modulverantwortlicher: apl. Professor Dr.-Ing. Mathias Hüsing
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Machine Dynamics of Rigid Systems (401742801)	2nd semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Machine Dynamics of Rigid Systems	2nd semester	no semester recommended	-	2
Lecture Machine Dynamics of Rigid Systems	2nd semester	no semester recommended	-	2

+ Industrial Logistics (4011473)

Module titel	Industrial Logistics (Compulsory elective subject)
Identifier	4011473
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2019
Valid until	-
Module level	Master
Content	• Objectives and tasks of logistics • Organisational involvement of logistics • Exercise: Prozess optimisation • Material flow design • Recitation by an external • Information logistics • Exercise: "Beergame" • Development and Procurement • Exercise: Development and Procurement • Material and finished goods disposition • Exercise: Workshop on the Enhancement of Disposition Quality • Distribution logistics • Exercise: Opening proceedings for tour planning • Spare part logistics • Recitation by an external • Logistics controlling • Exercise: ABC, XYZ Analysis
Learning Objectives/ Learning Outcomes	Students know objectives and tasks of industrial logistics as well as main aspects of industrial logistics from organisational involvement to logistics controlling. Students understand the meaning and the effects of individual aspects of industrial logistics and can place them in the overall context.They can apply the knowledge acquired to practical problems.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dipl.-Wirt. Ing. Günther Schuh apl. Professor Dr.-Ing. Volker Stich
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-

Industrial Logistics (4011473)

Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Industrial Logistics (401147301)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Industrial Logistics	2nd semester	no semester recommended	-	1
Lecture Industrial Logistics	2nd semester	no semester recommended	-	2

+ Artificial Intelligence and Data Analytics for Engineers ...

Module titel	Artificial Intelligence and Data Analytics for Engineers (Compulsory elective subject)
Identifier	4018567
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2019
Valid until	-
Module level	Master
Content	Artificial Intelligence and Data Analytics for Engineers • Introduction to Data Analytics and Artificial Intelligence in Engineering: Goals, Challenges, Obstacles, and Processes • Data Preparation: Cleansing and Transformation • Data Integration: Architectures, Challenges, and Approaches • Data Representation: Feature Extraction and Selection • Data-Driven Learning: Supervised (Classification, Regression) and Unsupervised Learning (Clustering) for Engineers • State-of-the-Art Methods: Reinforcement Learning and Deep Neural Networks (GANs, CNNs, Restricted Boltzman Machines etc.) • Data Mining and Visual Analytics
Learning Objectives/ Learning Outcomes	Artificial Intelligence and Data Analytics for Engineers Overall goal: Students gain the application-specific knowledge about artificial intelligence (especially: machine learning as supervised, unsupervised and reinforcement learning) and data analytics (especially: data exploration, data mining, data visualization and interpretation of analysis results) for application in the engineering domain. After successfully completing this course, the students will have achieved the following learning outcomes: Knowledge / Understanding Students • obtain a comprehensive view of the challenges in the application and usage of artificial intelligence and data analytics in the engineering domain; • are familiar with fundamental concepts and methods of machine learning and data mining in the engineering domain; • know and understand the different steps (cleansing, transformation and extraction) necessary to analyse and to use data in various engineering scenarios; • know about the application scope of specific methods and their strength as well as their limits; • obtain a view on specific evaluation methods with regards to the choice of analysis method and the underlying data; • are familiar with the intricacies of interpreting analysis results with regards to the utilized analysis methods and evaluation method. Abilities / Skills Students • learn how to use and apply the methods and concepts in engineering tasks correctly; • learn to distinguish between different analysis and learning scenarios and how to approach engineering related challenges; • learn the basics of state of the art tools that are used for AI data analytics in the engineering domain; • learn to choose the appropriate tools for the different steps of the knowledge discovery and artificial learning process. Competencies Students • independently evaluate analysis scenarios in the engineering context and select suitable methods accordingly; • find solutions for different analysis scenarios; • have practical and applicable knowledge about data analytics and machine learning for engineering purposes; • use tools used in the machine learning and data analytics domain and reflect the usage; • can combine single tools into a toolchain for an analysis pipeline to address complex problems in the engineering domain.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-none-
References	Lecture Notes; Students also receive a list of relevant literature
Language	English
Examination Terms	A written exam or an oral exam

+ Artificial Intelligence and Data Analytics for Engineers ...

Miscellaneous	-
Module coordinator	Dipl.-Inform. Christian Kohlschein
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Artificial Intelligence and Data Analytics for Engineers (401856701)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Artificial Intelligence and Data Analytics for Engineers	2nd semester	no semester recommended	-	2
Exercise Artificial Intelligence and Data Analytics for Engineers	2nd semester	no semester recommended	-	2

RWTH AACHEN UNIVERSITY

+ Advanced Machine Learning (1211912)

Module titel	Advanced Machine Learning (Compulsory elective subject)
Identifier	1211912
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	Regression techniques, Probabilistic Graphical Models, Exact Inference, Approximate Inference, Deep Generative Models, Deep Reinforcement Learning
Learning Objectives/ Learning Outcomes	Knowledge: On successful completion of this module, students should be able to recall and explain the theoretical foundations and concepts underlying advanced Machine Learning techniques, in particular * Linear regression * Regularization * Gaussian Processes * Bayesian Estimation * Probabilistic Graphical Models: Bayesian Networks, Markov Random Fields * Exact Inference: Belief Propagation, Junction Graphs * Approximate inference: Sampling techniques, MCMC, Variational Inference * Bayesian Non-Parametric Methods (Dirichlet Processes) * Deep Generative Models: Variational Auto-Encoders Skills: They should be able to derive, explain, and apply the following practical machine learning methods and algorithms: * Linear regression: Least-squares regression, Ridge regression, Kernel Ridge regression * Maximum Likelihood estimation, Maximum-A-Posteriori estimation, Bayesian estimation * Gaussian Process Regression * Sum-Product Belief Propagation, Max-Sum Belief Propagation * Rejection Sampling, Importance Sampling, Markov Chain Monte Carlo, Gibbs Sampling * Variational Inference * Dirichlet Processes: Stick-breaking construction Competences: Based on the knowledge and skills acquired, they should be able to * discuss the advantages and disadvantages of the covered machine learning techniques * find practical solutions to complex real-world machine learning problems * work on practical problems in a tea
(Study-Specific) Prerequisites	-
(recommended) Requirements	Basic knowledge in Linear Algebra, Probability Theory, and Statistics is recommended. Successful completion of the lecture Machine Learning is recommended.

+ Advanced Machine Learning (1211912)

References	C.M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006. | I. Goodfellow, Y. Bengio, A. Courville, Deep Learning, 2016. | R.S. Sutton, A.G. Barto, Reinforcement Learning: An Introduction, 2nd Edition, MIT Press, 2018.
Language	English
Examination Terms	Written exam or oral examination (100 %). Students must pass written homework to be admitted to the examination.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. sc. techn. Bastian Leibe
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	15-45 (mündlich/oral) | 90-120 (schriftlich/written)
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Advanced Machine Learning (121191202)	2nd semester	no semester recommended	0	1
Exam Advanced Machine Learning (121191201)	2nd semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Advanced Machine Learning	2nd semester	no semester recommended	-	3

+ Processes and Principles for Lightweight Design (4011411)

Module titel	Processes and Principles for Lightweight Design (Compulsory elective subject)
Identifier	4011411
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	1. Introduction to design methodology 1.1. Technical tasks: Purposes of technical systems; Methods to derive requirements and setting up requirements lists 1.2. Development of technical concepts/Conceptualization: Function structures; Discursive, heuristic and empiric methods for problem solving 1.3. Concept evaluation: Methods to evaluate and select among variants 1.4. Rules of Embodiment Design: Simple, clear and safe 1.5. Principles of Embodiment Design: Principles of force transmission, principle of the division of tasks, principle of self-help, principle of stability and bi-stability, principle of fault free design 1.6. Design for X: Allow for expansion, allow for creep and relaxation, ease of assembly 2. Introduction to lightweight design 2.1. Fundamentals 2.1.1. Definitions 2.1.2. Lightweight design as an optimization task 2.1.3. Costs 2.1.4. Design rules of lightweight design 2.1.5. Statically indeterminate systems 2.2. Nonlinearities 2.2.1. Material nonlinearities - plastic resistance 2.2.2. Material nonlinearities - combined loading 2.2.3. Material nonlinearities - composite beams 2.3. Phenomena of beam instability 2.3.1. Criterion for stability evaluation 2.3.2. Buckling 2.3.3. Euler cases 2.3.4. Imperfections 2.3.5. Introduction to lateral torsional buckling and lateral buckling 2.4. Torsion 2.5. Introduction to the shear web theory 2.6. Safety: Definition of failure and the RF
Learning Objectives/ Learning Outcomes	After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students learn • the engineering design process according to VDI 2221 • methods to analyse function structures of product • methods to evaluate and select among variants • the rule, principles and guidelines for embodiment design • basic principles in order to optimize structures in terms of lightweight design, • how to calculate cutting forces in statically indeterminate systems, • the shear stress calculation of thin-walled closed sections, • the structural mechanical treatment of physical nonlinearity, • the computational treatment of stability phenomena. Skills and Competencies

+ Processes and Principles for Lightweight Design (4011411)

	Students: • have the ability to analyse technical problems and tasks, identify existent restrictions and hence properly elaborate technical specifications • have a broad understanding of product development processes and can work on new technical tasks using design methodology • know how to systematically analyse, evaluate and combine partial solutions • are capable of applying basic rules and principles of Embodiment Design in order to create optimal products for the relevant requirements, in particular structural demands • are able to realize special aspects of thin-walled lightweight structures and to design them properly • are able to design and size lightweight structures on a preliminary level • are capable of identifying stability problems of slender structures
(Study-Specific) Prerequisites	-
(recommended) Requirements	• Mechanics I, II, III • Machine Design I, II, III • CAD
References	• Pahl, G.; Beitz, W.: Engineering Design. Springer, 2007. • Roark, R. J., Young, W. C.: Formulas for Stress and Strain, McGraw-Hill, 1975. • Jones, R. M.: Mechanics of Composite Materials, McGraw-Hill, 1975. • Bruhn, E. F.: Analysis and Design of Flight Vehicles Structures. • Niu, M. C. Y.: Airframe Structural Design, Conmilit Press Ltd., 1988.
Language	English
Examination Terms	One written examination
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Georg Jacobs Universitätsprofessor Dr.-Ing. Kai-Uwe Schröder
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Processes and Principles for Lightweight Design (401141101)	3rd semester	no semester recommended	6	0

+ Processes and Principles for Lightweight Design (4011411)

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Processes and Principles of Lightweight Design	3rd semester	no semester recommended	-	2
Lecture Processes and Principles of Lightweight Design	3rd semester	no semester recommended	-	2

+ Applied Numerical Optimization Engineering (4018569)

Module titel	Applied Numerical Optimization Engineering (Compulsory elective subject)
Identifier	4018569
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	Applied Numerical Optimization Engineering • Definition: Mathematical Optimization • Problem formulation: objective functional, model und constraints • Examples of Optimization Problems • Classification of Optimization Problems • Mathematical basics 1: continuity, differentiability • Mathematical basics 2: gradient, Hesse matrix, convexity • Optimality conditions for unconstrained problems • Solution concepts for unconstrained problems, direct, indirect numerical solution, principle of line search and trust region • Line search strategies: Armijo and Wolfe conditions • Methods for the Determination of the descent direction: Steepest Descent, Conjugate Gradients • Methods for the determination of a descent direction: Newton method • Practical Newton methods: Inexact, Modified and Quasi-Newton method • Trust Region methods: the Dogleg method • Regression problems: method of Least-Squares • Gauss-Newton solution method for regression problems • Levenberg-Marquardt solution method for regression problems • Example of an optimization problem: Ethanol extraction • Derivation of the KKT optimality conditions • Linear programming (LP) • Interior point methods for LPs • Simplex method for LPs • Quadratic programming (QP) • Solving the KKT system for QPs • Active-Set methods for QPs • Solution strategies for non-convex QPs • Gradient-Projection method for QPs • Interior-Point methods for QPs • Solution of general nonlinear problems (NLP) • Penalty Methods for NLPs • Log-Barrier method for NLPs • Augmented Lagrangian method for NLPs • SQP methods: Line Search SQP • Examples for optimization problems: Layer Crystalliser, Distillation Column • Introduction to mixed-integer optimization: • Branch and Bound • Outer-Approximation • Introduction to Dynamic Optimization: • Optimality conditions • Simultaneous solution methods: full discretisation • Continuous problem formulation: adjunct equations / Hamilton form • Dynamic Optimization: Sequential Solution Method • Derivation of the sensitivity equation • Examples for dynamic optimization problems • Short introduction to State Estimation • Optimization under Uncertainty • Two-Stage Stochastic Programming

+ Applied Numerical Optimization Engineering (4018569)

	• Introduction to Semi-Infinite Programming (SIP) • Solution Approaches for SIP
Learning Objectives/ Learning Outcomes	Applied Numerical Optimization Engineering Overall goal: In mechanical and chemical engineering numerical optimization methods are becoming more and more accepted. In the near future numerical optimization will be one of the standard tools of any engineer. In this lecture, the students learn to apply the basic techniques of mathematical optimization on applications from mechanical and chemical engineering. After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students • understand the statement of mathematical optimization problems with objective functional, model and constraints as a basis to solve arbitrary problems; • know which numerical solution method is to be used for the solution of such problems; • understand the classification of the optimization problems and is able to allocate arbitrary problems to the corresponding class; • understand the need for the numerical solution for arbitrary mathematical optimization problems and are able to implement the basic numerical concepts in their own algorithms. Abilities / Skills Students • master the derivation of the optimality conditions for constrained and unconstrained problems with non-linear constraints. Competencies Students • will be enabled to analyse the problem statement and to produce the concrete solution of the problem by means of the home-works (method competence).
(Study-Specific) Prerequisites	-
(recommended) Requirements	-none-
References	Lecture Notes Nocedal &; Wright (2006), Numerical Optimization Students also receive a list of further relevant literature
Language	English
Examination Terms	A written exam or an oral exam
Miscellaneous	-
Module coordinator	Modulverantworlicher: Universitätsprofessor Alexander Mitsos Ph. D.
ECTS Credits	4
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	120,0
Contact hours (h)	60,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Applied Numerical Optimization Engineering (401856901)	3rd semester	no semester recommended	4	0

+ Applied Numerical Optimization Engineering (4018569)

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Applied Numerical Optimization Engineering	3rd semester	no semester recommended	-	2
Lecture Applied Numerical Optimization Engineering	3rd semester	no semester recommended	-	2

+ Mechatronics and Control Techniques for Production Plants ...

Module titel	Mechatronics and Control Techniques for Production Plants (Compulsory elective subject)
Identifier	4011451
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master

Content	• Indroduction of Mechatronics and Control Techniques for Production Plants
	• Mechanical controls
	  ◦ Machine elements of mechanical controls
	  ◦ Application examples for mechanical controls
	• Information processing in mechatronic systems
	  ◦ Theory and examples of embedded systems
	  ◦ Programming of embedded systems and logical controls
	• Programmable Logic Control (PLC) and Motion Control (MC)
	  ◦ Programming of programmable logic controllers
	  ◦ Test methods of programmable logic controllers (HIL)
	• Numerical Control 1: Design, programming, CAM
	  ◦ NC programming procedures (manual and workshop-oriented)
	  ◦ NC programming of CAM systems
	• Numerical Control 2: Interpolation
	  ◦ Structure of an NC control
	  ◦ Tool offset, kinematic transformation and compensations, speed control and Interpolation
	• Position control of feed drives
	  ◦ Control concept of a machine axis
	  ◦ Accuracy and synchronous control of multi-axis systems
	• Measurement Systems and Sensors
	  ◦ Measured variables in production systems
	  ◦ Position, current acceleration, force, torque, temperature and angle measuring systems
	• Signal processing, process and condition monitoring
	  ◦ Tasks of the process and condition monitoring
	  ◦ Use of sensors and processing of sensor signals
	• Robots and handling systems, Robot Control (RC)
	  ◦ Areas of application
	  ◦ Construction and kinematics
	• Gripper technology
	  ◦ Gripping principles
	• Mechatronic and system-oriented engineering
	  ◦ Design and simulation software (drive design and behavior modeling)
	  ◦ Virtual Commissioning

Learning Objectives/ Learning Outcomes	Subject-related: The students know in particular • Construction and design of mechatronic systems for production equipment • Characteristics of logical and mechanical numerical motion controls of machines • Special features of the behavior and the modeling of mechatronic components, especially for measuring and gripping technology • Concepts of machine control in various development systems, as well as machine and process monitoring • Fields of application, possibilities of an industrial engineering system and the design

+ Mechatronics and Control Techniques for Production Plants ...

	After this course, the students are able to understand the structure of mechatronic systems in the area of application of the means of production in its complexity and its context and overarching concepts of machine control systems to classify. Not subject-related: The Students can explain application areas and display the characteristics of motion controls required in machine and process monitoring. In addition, you can theoretically explain the design of an application-oriented problem and apply it to application-relevant questions. This allows the students to analyze theory-based mechatronic systems for production systems and industrial monitoring solutions and to evaluate their quality in the industrial environment. With this competence, they are able to use their own creative ideas and within the framework of the concepts known to you to develop solutions and to establish the set-up of concepts. In addition to the problem solving, they can also create control programs in various development systems and evaluate their quality.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended: Machine Tools
References	Skripte lecture and exercise for download as PDF
Language	English
Examination Terms	Written examination
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Christian Brecher
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Mechatronics and Control Techniques for Production Plants (401145101)	3rd semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Mechatronics and Control Techniques for Production Plants	3rd semester	no semester recommended	-	2

+ Mechatronics and Control Techniques for Production Plants ...

Exercise Mechatronics and Control Techniques for Production Plants	3rd semester	no semester recommended	-	2

+ Advanced Control Systems (6010486)

Module titel	Advanced Control Systems (Compulsory elective subject)
Identifier	6010486
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	• Fundamentals of multivariable systems and representation • Analysis of multivariable systems, modelling of uncertainties • General control configuration, performance and robustness • H2- (LQR/LQG) control • Introduction to robust H#;-control • Implementation aspects of robust controllers ; • µ;-Synthesis
Learning Objectives/ Learning Outcomes	Students develop an advanced understanding of multivariable system analysis and apply modern robust control techniques. This includes the application of modern multivariable analysis and control tools for complex processes in order to design feedback controllers for processes with uncertainties and multiple and opposed design goals. Students understand and apply state-space, as well as frequency domains methods, for multivariable systems.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Systemtheorie 1 &; 2 or similar control systems lecture course covering classical control and state-space techniques.
References	• Skogestad und I. Postlethwaite, Multivariable Feedback Control, Wiley, 2005 • Morari und E. Zafiriou, Robust Process Control, Prentice-Hall International, 1989 • A. Francis, A Course in Hinf-Control Theory, Springer-Verlag, Berlin, 1987 • A. Hyde, Hinf-Aerospace Control Design, Prentice-Hall International, 1989
Language	English
Examination Terms	Course work (30%) and oral examination (70%). The final grade is calculated from coursework and oral examination achievement. Modalities of the examination will be discussed with students at the first lecture.
Miscellaneous	-
Module coordinator	RWTHModulverantworlicher: Universitätsprofessor Dr. med. Dr.-Ing. Klaus Steffen Leonhardt Dr.-Ing. Berno Misgeld
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	30
Total hours (h)	120,0
Contact hours (h)	45,0

+ Advanced Control Systems (6010486)

Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Advanced Control Systems (601048601)	3rd semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Advanced Control Systems	1st semester	no semester recommended	-	3

+ Summer School – Advanced Topics in Robotic Systems Engineering ...

Module titel	Summer School – Advanced Topics in Robotic Systems Engineering (Compulsory elective subject)
Identifier	4018568
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2019
Valid until	-
Module level	Master
Content	Students can choose a Summer School worth up to 3 CP
Learning Objectives/ Learning Outcomes	-
(Study-Specific) Prerequisites	-
(recommended) Requirements	-none-
References	-
Language	English
Examination Terms	A written or an oral exam
Miscellaneous	-
Module coordinator	Dr. Alexander Mertens
ECTS Credits	3
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	90,0
Contact hours (h)	60,0
Self-study hours (h)	30,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Examination Summer School – Advanced Topics in Robotic Systems Engineering	2nd semester	no semester recommended	3	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Summer School – Advanced Topics in Robotic Systems Engineering	2nd semester	no semester recommended	-	2
Lecture Summer School – Advanced Topics in Robotic Systems Engineering	2nd semester	no semester recommended	-	2

+ Numerical Methods in Mechanical Engineering (4011449)

Module titel	Numerical Methods in Mechanical Engineering (Compulsory elective subject)
Identifier	4011449
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2018
Valid until	-
Module level	Master
Content	The content of the course is to provide a map to follow the long and winding road from intuitional perception to the mathematical formulation of engineering problems. The content is summarized as follows: • Selected assumptions and mathematical tools to formulate problems • An overview of several solution methods: analytical solutions, approximate solutions, direct approximation, approximate solution after transformation of the problem • An overview of selected types of physical problems: discrete systems, continuous systems, equilibrium problems, eigenvalue problems, propagation problems • Integral formulations • Weak formulation of problems • The Method of Weighted Residuals • Introduction to variational calculus • Functionals • Functionals associated with an integral form • The stationarity principle • Stationarity conditions • Examples from mechanics • The method of Lagrange multipliers • Mixed and complementary formulations • Catalogue of functionals used in continuum mechanics and their specific features • Discretisation of integral forms • Collocation by points • Collocation by subdomains • Galerkin’s method Least Squares Method Examples • Ritz' method • Examples • Numerical integration • Newton-Cotes method • Gauss method Examples: • The Finite Element Method, Shape functions, construction of finite elements • Matrix representation in the FEM, Stiffness matrix, Boundary conditions • Examples from structural engineering, Software packages in engineering
Learning Objectives/ Learning Outcomes	Overall goal: The students will gain theoretical background of numerical methods commonly used in mechanical engineering. In particular, the physical formulations are discussed based on which the corresponding mathematical formulations for large-scale numerical methods are presented. In this course, students shall acquire the following:

+ Numerical Methods in Mechanical Engineering (4011449)

	Knowledge / Understanding The students will understand • the theoretical foundations of current numerical methods in engineering • the bridge between the physical formulation of a problem and the mathematical description suited to implement numerical approximation methods • the steps and transformations required to implement numerical methods Abilities / Skills The students are able to • apply approximation techniques and analyse the results obtained by various numerical methods • use their acquired knowledge to develop state-of-the-art approximation methods • critically judge the consistency and correctness of numerical methods • apply variational methods to obtain formulations of a problem of differential equations • construct basis functions compatible with the boundary conditions • construct and apply a variety of approximation methods based on the WRM (collocation by points, collocation by subdomains, Galerkin's method, least squares method, Ritz method) • solve constrained optimization problems by using the Lagrange Multipliers Method • construct the associated energy potential and to apply the stationary principle for a conservative mechanical problem • apply basic tools of numerical integration
(Study-Specific) Prerequisites	-
(recommended) Requirements	-none-
References	• Lecture Notes • Dhatt, G., Touzot, G.: The Finite Element Method Displayed. Wiley, New York, 1984. • Finlayson, B.A.: The Method of Weighted Residuals and Variational Principles. Academic Press, New York, 1972. • Reddy, J.N.: Energy and Variational Methods in Applied Mechanics. Wiley, New York, 1984. • Lemaitre, J., Chaboche, J.-L.: Mechanics of Materials, Cambridge Univ. Press, Cambridge, 1994. • König, J.A.: Shakedown of Elastic-Plastic Structures. Elsevier, Amsterdam, 1987.
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Bernd Markert Dr. rer. nat. Michael Ban
ECTS Credits	7
Contact time (WSH)	5
Examination duration (min)	-
Total hours (h)	210,0
Contact hours (h)	75,0
Self-study hours (h)	135,0

+ Numerical Methods in Mechanical Engineering (4011449)

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Numerical Methods in Mechanical Engineering (401144901)	1st semester	no semester recommended	7	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Numerical Methods in Mechanical Engineering	1st semester	no semester recommended	-	3
Tutorial Numerical Methods in Mechanical Engineering	1st semester	no semester recommended	-	2

+ Power Electronics - Control, Synthesis and Applications (6010377)

Module titel	Power Electronics - Control, Synthesis and Applications (Compulsory elective subject)
Identifier	6010377
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2018
Valid until	-
Module level	Master
Content	Power Electronics generally have the goal to perform electrical energy conversion at high efficiency. The course focuses on the following aspects of converter design: # Minimum converter losses # silicon and magnetics losses # thermal design # Soft switching of silicon devices to improve device ratings # Using snubbers # Soft-switching converter topologies # Galvanically isolated dc-dc converters # Transformers in power electronics, using uni- and bidirectional core excitation # AC-AC converters # Control of voltage source converters # High-power electronics # Examples
Learning Objectives/ Learning Outcomes	At the end of the module students are able: # to understand basic topologies for power electronic applications. # to analyze the dynamic behavior of components and circuits, the control concepts, parasitic effects and electromagnetic compatibility. # to design an appropriate power electronic solution for each application including hardware and control. # to evaluate existing power electronic solutions and to optimize them with regard to the application, e.g. for best efficiency.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	# Skript, # Mohan/Undeland/Robbins: "Power Electronics"
Language	English
Examination Terms	Written examination (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. ir. Dr. h. c. Rik W. De Doncker
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	90
Total hours (h)	150,0

+ Power Electronics - Control, Synthesis and Applications (6010377)

Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Power Electronics - Control, Synthesis and Applications (601037701)	3rd semester	2nd semester	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Power Electronics - Control, Synthesis and Applications	3rd semester	2nd semester	-	3

RWTH AACHEN UNIVERSITY

+ Introduction to Artificial Intelligence (1220228)

Module titel	Introduction to Artificial Intelligence (Compulsory elective subject)
Identifier	1220228
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	- Agent Architecture - Heuristic Search - Games - Knowledge Representation - Baysian Networks - Machine Learning - Robotics
Learning Objectives/ Learning Outcomes	Overall goal: The aim is to familiarize the student with basic concepts and methods of Artificial Intelligence and to enable the student to apply them in practice. After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding: Students are familiar with the methods underlying the design of intelligent agents, inclu-ding search methods, knowledge representation using first-order logic, planning, reason-ing under uncertainty, and inductive learning. Abilities / Skills: Students apply the methods taught in class to design intelligent agents him- or herself. Competencies: Students identify components and functionalities, which call for the use of Artificial Intel-ligence methods, and adapt and implement those methods for such purposes, when developing large software systems.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None.
References	Stuart Russell and Peter Norvig, Artificial Intelligence: A Modern Approach (2nd Edition), Addison Wesley, 2002.
Language	English
Examination Terms	Written exam or oral examination (100 %). Students must pass written homework to be admitted to the module examination.
Miscellaneous	-
Module coordinator	MAO Informatik (Schrader)
ECTS Credits	6

+ Introduction to Artificial Intelligence (1220228)

Contact time (WSH)	4
Examination duration (min)	120
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Introduction to Artificial Intelligence (Exercise) (122022802)	3rd semester	4th semester	0	2
Introduction to Artificial Intelligence (Exam) (122022801)	3rd semester	4th semester	6	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Introduction to Artificial Intelligence (Lecture)	3rd semester	4th semester	-	2

+ Advanced Electrical Drives (6017063)

Module titel	Advanced Electrical Drives (Compulsory elective subject)
Identifier	6017063
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	Electrical drives are used in many different fields: at home, in industry and for transportation. Dental drills as well as hybrid or fully electric vehicles and ships are powered by electrical motors. The advantages of electrical drives are that electricity is applicable almost everywhere and comparatively easy to decentralize, power and velocity are easy to control, the maximum machine torque is available at zero speed and wear and maintenance costs are low. Particularly due to their high efficiency, electrical drives score well. Since electrical drives consume about 60% of all electrical energy used in industry and gain more and more importance in the field of personal mobility, a huge amount of energy can be saved by an intelligent control of electrical motors. The above mentioned control of electrical motors is the topic of the lecture Electrical Drives. Subsequent to a short introduction to the mechanics of rotating systems the control of all common electrical machines (DC, synchronous, induction and switched reluctance machine) is presented. The universal field oriented (UFO) concept is explained which demonstrates the concepts of modern vector control and exemplifies the seamless transition between so called stator flux and rotor flux oriented control techniques. This powerful tool is used for the development of flux oriented machine models of rotating field machines. These models form the basis of UFO vector control techniques which are covered extensively together with traditional drive concepts. Attention is also given to the dynamic modeling of Switched Reluctance (SR) drives, where a comprehensive set of modelling tools and control techniques is presented. The lecture should appeal to students who have a desire to understand the intricacies of modern electrical drives without loosing sight of the fundamental principles. It brings together the concepts of the ideal rotating transformer (IRTF) and UFO which allows a comprehensive and insightful analysis of AC electrical drives in terms of modeling and control. Extensive use is made of build and play modules which provide the student with the ability to interactively examine and understand the presented topics.
Learning Objectives/ Learning Outcomes	At the end of the module students are able: • to remember the working principals of the most common electrical machine types. • to understand how modern drive systems can be modeled. • to distinguish between dynamic control strategies such as field-oriented and direct-torque control and their sensible applications. • to recall the requirements of the different machines concerning sensors and power electronics. • to choose electrical machines and converter topologies based on application requirements. • to design electric drive trains and their control.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification.
References	De Doncker, Pulle, Veltman: Advanced Electrical Drives
Language	English
Examination Terms	Written Examination
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. ir. Dr. h. c. (RTU) Rik W. De Doncker

+ Advanced Electrical Drives (6017063)

ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Advanced Electrical Drives (601706301)	2nd semester	no semester recommended	4	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Advanced Electrical Drives	2nd semester	no semester recommended	-	3

+ International Factory Planning (4011481)

Module titel	International Factory Planning (Compulsory elective subject)
Identifier	4011481
Version	V2_neu
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2021
Valid until	-
Module level	Master
Content	L1 - Introduction to Factory Planning & Project Management: • basic glossary, different viewpoints, challenges and requirements of factory planning L2 - Target Definition & Product/Process Planning: • definition of objectives with the involvement of different stakeholders and requirements • challenges and approaches of product and process planning within the framework of factory design L3 - Location Planning & Site Structure Planning: • current trends in site structure planning and methods for evaluating different plant structure alternatives in order to create a basis for one of the most essential decisions within the factory planning process L4 - Industrial Building & Building Planning: • factory planning on the building side, i.e. advantages and disadvantages of different bearing structures, roof constructions and facade types L5 - Production Structure Planning & Capacity Planning: • production structure within the plant according to the site structure planning • challenges and approaches of capacity planning L6 - Layout Planning & Workplace Design: • overview of the goals and challenges of layout planning and the even more detailed workplace design L7 - Highlight lecture: • state-of-art application of modern factory planning methods
Learning Objectives/ Learning Outcomes	Within the framework of the lecture Factory Planning, the state-of-the-art of the respective subject areas will be introduced, relevant methods and procedures will be explained and reference solutions will be presented. The contents will be deepened in the exercises and in the case study. In this way, future production managers will be able to comprehensively plan and develop individual production sites as well as entire production networks of internationally active companies. The lectures and exercises as weil as the case studies are only held in summer semesters. The case studies are conducted in group work. A successful registration for the module Factory Planning already at the very beginning of each summer semester is therefore vital in order to be integrated within the allocation to groups. Each group then collaborates as a planning team to work on the case study, but members are graded individually. However, the exam can be written each semester, which means that the requirement of the case study has to be fulfilled (passed with a grade of 4.0 or better) to take the exam. lf an exam is failed, but the case study has already been completed, the grade of the case study is credited in the following semester. The aim of these case studies is to deepen the contents conveyed in the lecture in a practical application. The students are presented with a real-world-oriented factory planning problem. In order to successfully perform an extensive analysis covering multiple planning levels and give decision-targeted recommendations, the concepts and methods learned from the lectures and excercises need to be rigorously applied. By emulating a real factory planning project, students are prompted to work together and transfer their knowledge into practice. In addition, the developed solutions are to be validated using

+ International Factory Planning (4011481)

	simulation tools provided by the chair, e.g. for verifying material flows. Finally, the used procedures and achieved results are compiled into a case study report. The case study work is expected to run from May to June in the summer semester and must therefore be submitted before the written exam phase. Knowledge / Understanding - describe the characteristics and challenges of factory planning and with regard to the global environment - formulate the object precisely and in a detailed way - have an extended understanding of state of the art planning process of factories - know and understand the definition of the own value adding scope, the choice and allocation of suitable production locations, the conception of production systems and the usage of suitable planning tools. - understand the procedures and methods in factory planning Abilities / Skills - apply the acquired methods to design a factory - apply this knowledge to analyse organizational structures and forms of production Competencies - analyse the initial situation of a factory planning project, draft and classify possible solutions - define and develop single production plants as well as production networks of globalized companies and explain them to different target groups
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	Lecture reprint Exercise reprint Sample solution reprint
Language	English
Examination Terms	The final grade is composed to 2/3 of the exam grade and to 1/3 of the case study grade (individual grading). Both parts have to be passed in order to pass the whole module. Bonus points are awarded for the e-Test in L2P: Tests with 5-6 questions per lecture unit; time limited to 30 minutes activation from the day of the lecture to the day before the following lecture or max. 1 week > 50% of questions correct (i.e. 3 questions) - > test passed! 1 bonus point per test-> Max. 6 bonus points reachable (5% of all points reachable in the exam)
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing.Günther Schuh
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

International Factory Planning (4011481)

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam International Factory Planning (401148101)	2nd semester	no semester recommended	4	0
Case Study International Factory Planning (401148102)	2nd semester	no semester recommended	2	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise International Factory Planning	2nd semester	no semester recommended	-	2
Lecture International Factory Planning	2nd semester	no semester recommended	-	2

+ Advanced Finite Element Methods for Engineers (4013866)

Module titel	Advanced Finite Element Methods for Engineers (Compulsory elective subject)
Identifier	4013866
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2016
Valid until	-
Module level	Master
Content	Content • General introduction, concept of the finite element method • Symbolic assembly procedure • Global and local coordinates • Stiffness matrix for trusses / coordinate transformation • Variational techniques • Solution of truss structures • Variational techniques, Euler-Lagrange equation • Natural and forced boundary conditions • Multiple integrals, Gauss-Theorem • Variations of elementary algebraic functions • Variational principle for linear self-adjoint diff. operators • Solution of some classical variational problems • Principle of virtual work as a weak form of the momentum balance, variational principles of mechanics (Lagrange, Hu-Washizu) • Differential equation of a linear elastic bar, analytic solution for various load cases • Rayleigh-Ritz method, weighted residual approximations, Point or subdomain collocation • Galerkin method, least-squares method, linear elastic bar approximated by a continuous shape function • Displacement formulation • Three-field (mixed) formulation • Examples to weighted residual approximations • Requirements to shape functions • Continuous shape functions, piecewise defined shape functions, approximation by piecewise defined shape functions. • 2-d problems of elasticity, triangular element, plain strain and plane stress problems, • Torsion of a prismatical bar • Examples for plain strain and plane stress problems discretized by linear triangular elements

+ Advanced Finite Element Methods for Engineers (4013866)

	• Axisymmetric stress analysis, 3-d stress analysis • Construction of 2-d and 3-d finite elements (Lagrange and serendipity family) • Concept of hierarchical shape functions • Concept of mapping in iso-parametric finite elements • Application of numerical integration in 1-d, 2-d and 3-d finite element problems • Non-linear finite element problems (Newton-Raphson method) • Dynamic (time-dependent) finite element problems, time step size and mass scaling
Learning Objectives/ Learning Outcomes	The aim of the course is to impart the basic knowledge about finite element methods and their application to solid and structural mechanics. The students will • understand why the FE-Method and the other numerical methods behind are important for engineering practice • understand the basic concept of FEM • be able to find solutions for trusses with a variety of boundary conditions • understand the fundamental concept of variational calculus • be able to find solutions for mechanical problems by using weighted residual methods • be able to use finite element method for plane strain, plane stress and torsion problems • be able to construct finite elements with linear and non-linear shape functions • understand the application of numerical integration in finite element method • understand the concept of non-linear and time-dependent finite element problems In addition, voluntary programming exercise sessions are offered to deepen the theoretical understanding. A simple FEM solver is developed in Python, numerical integration schemes are discussed and the FEniCS programming package is introduced.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. (RUS) Mikhail Itskov
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

+ Advanced Finite Element Methods for Engineers (4013866)

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Advanced Finite Element Methods for Engineers (401386601)	3rd semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Advanced Finite Element Methods for Engineers	3rd semester	no semester recommended	-	2
Tutorial Advanced Finite Element Methods for Engineers	3rd semester	no semester recommended	-	2

+ Reinforcement Learning and Learning-based Control (4026526)

Module titel	Reinforcement Learning and Learning-based Control (Compulsory elective subject)
Identifier	4026526
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2022
Valid until	-
Module level	Master
Content	Class outline: • Reinforcement learning problem and its relation to control • Markov decision process • Dynamic programming • Tabular reinforcement learning • Reinforcement learning with function approximation incl. deep RL • Policy gradient methods • Model learning • Controller learning
Learning Objectives/ Learning Outcomes	Wissen und Verstehen: The course “Reinforcement Learning and Learning-based Control” covers fundamentals and state-of-the art methods in reinforcement learning and learning-based control. Reinforcement learning (RL) is a machine learning paradigm that aims at learning action or control policies from data generated through interaction with an environment. It is one important subfield of learning-based control (LBC), which more broadly denotes the intersection of the areas of automatic control and machine learning. Both, RL and LBC are very active and interdisciplinary areas of research. The first part of the module introduces and formalizes the reinforcement learning problem and its connections with dynamical systems and control. Building on the formulation as a Markov decision process, core concepts of RL and optimal control will be developed. After establishing understanding and fundamental concepts of RL theory, modern algorithms including deep RL approaches are introduced. In addition to RL, the course covers further essential topics of learning-based control, including model learning and modern controller tuning techniques Fertigkeiten und Kompetenzen: The course combines profound understanding of theoretical foundations with the application of state-of-the-art techniques to engineering problems. Students acquire a solid foundation of reinforcement learning theory and learningbased control. They will gain insight into how machine learning and control techniques can be combined, and what special challenges exist. Further, students will be exposed to state-of-the-art algorithms and methods such as deep reinforcement learning and model learning, including hands-on programming exercises.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Empfohlene Voraussetzungen: Basic knowledge in probability theory and supervised machine learning (such as covered in Computer Science in Mechanical Engineering 2 or Machine Learning, for example)
References	Reinforcement Learning: An Introduction, 2nd edition; Richard S. Sutton, Andrew G. Barto; MIT Press; 2018 Empfohlene weiterführende Literatur:

+ Reinforcement Learning and Learning-based Control (4026526)

	Will be announced in the lecture.
Language	English
Examination Terms	100% grade of the exam.
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr. Sebastian Trimpe
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Reinforcement Learning and Learning-based Control (402652601)	no semester recommended	1st semester	6	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Reinforcement Learning and Learning-based Control	no semester recommended	1st semester	-	2
Exercise Reinforcement Learning and Learning-based Control	no semester recommended	1st semester	-	2

+ Strategic Technology Management (8015425)

Module titel	Strategic Technology Management (Compulsory elective subject)
Identifier	8015425
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	-
Learning Objectives/ Learning Outcomes	-
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	The course grade will be determined based on one of the following modes of evaluation: A. ; ; ; ; ; ; ; Colloquium and presentation (50%, graded) and written examination (50%, graded, 60 min.) B. ; ; ; ; ; ; ; Colloquium and presentation (50%, graded) and paper (50%, graded) C. ; ; ; ; ; ; ; Paper (50%, graded) and written examination (50%, graded, 60 min.) D. ; ; ; ; ; ; ; Written examination (100%, graded, 60 min.) or oral examination (100%, graded, 15-45 min.) E. ; ; ; ; ; ; ; Colloquium and presentation (50%, graded), written examination (50%, graded, 60min.) and Case Study Assignments + Peer-Reviews (not grad-ed but mandatory for passing) The exact form of examination (A, B, C, D or E) will be announced at the start of the course. Unless announced differently, option A applies
Miscellaneous	-
Module coordinator	-
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Strategic Technology Manage-ment (801542501)	3rd semester	no semester recommended	5	4

RWTH AACHEN UNIVERSITY

+ Research Project (4020070)

Module titel	Research Project (Compulsory subject)
Identifier	4020070
Version	V1
Duration (Semester)	-
Cycle (Semester)	-
Valid from	Summer semester 2018
Valid until	-
Module level	Master
Content	Research Project • Basics of project management • Basics of time planning • Planning experiments • Evaluation of results with statistical methods • Oral and written presentation of results • Actual project work on a subject chosen by student from a wide range of topics offered at IMGR
Learning Objectives/ Learning Outcomes	Research Project After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students • know how to plan a research project; • know how to design experiments to get a maximum output (effects and interactions of the parameters on the result); • know how to evaluate the results using advanced statistical methods. Abilities / Skills Students • work independently on a scientific topic. Competencies Students • analyse the problem at-hand; • determine possible ways to solve it, explain the best way to do so by comparing and assessing the given possibilities; • apply the chosen way to solve the problem; • document every step of the project; • present their results oral and written.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-none-
References	Lecture Notes Students also receive a list of relevant literature

+ Research Project (4020070)

Language	-
Examination Terms	A written exam, an oral exam or a project work
Miscellaneous	-
Module coordinator	-
ECTS Credits	10
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	300,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Examination Research Project (402007001)	4th semester	no semester recommended	10	-

RWTH AACHEN UNIVERSITY

+ Internship (4020069)

Module titel	Internship (Compulsory subject)
Identifier	4020069
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2018
Valid until	-
Module level	Master
Content	Internships in companies are neccessary to ensure the correct choice of the course of studies, a sufficient understandig of the technical and economic courses as well as in preparation for the professional life (also in Germany) in the future. The students should aquire knowledge about technical materials and processes used in practice corresponding economic considerations and procedures, and gain insights into social processes and structures in the companies. Zur Überprüfung der getroffenen Studienwahl, zum ausreichenden Verständnis der technischen Lehrveran-staltungen sowie zur Vorbereitung auf eine spätere Berufstätig-keit oder Forschungstätigkeit (auch in Deutschland), sind praktische Tätigkeiten (Prakti-ka) in Unternehmen oder Forschungseinrichtungen unerläss-lich. Die Studierenden sol-len Kenntnisse über die in der Praxis eingesetzten technischen Verfahren sowie die zu deren Auswahl und Steuerung verwendeten Verfahren erwerben und Einblicke in die sozialen Prozesse und Strukturen von Betrieben und Organisationen gewinnen.
Learning Objectives/ Learning Outcomes	After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students: • know different fields of activity in the desired occupational field • understand theoretical concepts during implementation Abilities / Skills Students: • put theory and practice in relation to each other • test their own abilities and knowledge on the basis of practical experience • follow and participate in textile engineering team meetings • eliminate misconceptions about the chosen profession Competencies Students: • assess their competences correctly • discern individual learning fields with regard to a professional activity • assess social processes and structures of companies and organisations • establish contacts with potential colleagues and employers
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	German/English

+ Internship (4020069)

Examination Terms	-
Miscellaneous	-
Module coordinator	Prof. Thomas Gries
ECTS Credits	10
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	300,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Examination Internship (402006901)	4th semester	no semester recommended	10	-

+ Master Thesis (4020127)

Module titel	Master Thesis (Compulsory subject)
Identifier	4020127
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	-
Valid until	-
Module level	Master
Content	Completed academic paper which shall show that the students are capable of independently processing a problem related to their subject according to academic methods within a set deadline.
Learning Objectives/ Learning Outcomes	The students learn the independent approach and processing of academic themes, their documentation and written interpretation within a set deadline. They acquire systematic academic research skills.
(Study-Specific) Prerequisites	mindestens 80 CP aus dem Studiengang
(recommended) Requirements	The topic of the Master thesis cannot be assigned until 80 CPs have been achieved. Reasonable exceptions are governed by the Board of Examiners upon request by the candidate. The Master´s defense colloquium must be held four weeks after the written completion of the Master´s Thesis.
References	According to the relevant research questions of the Master Thesis
Language	English
Examination Terms	The grade for the thesis is calculated from the arithmetic mean of the individual assessments according to § 9.
Miscellaneous	-
Module coordinator	-
ECTS Credits	30
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	900,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Master Thesis (4020127)	4th semester	no semester recommended	30	-

+ Master Thesis (4020127)