UNIVERSITÄT ZU LÜBECK

Module Guide for the Study Path

Master Robotics and Autonomous Systems 2019

Version from 22. November 2019

interdisciplinary competence

advanced curriculum

Robotics and Autonomous Systems

Elective

Compulsory courses

EC5010-KP04, EC5010 - Entrepreneurship in the digital economy (EEntre)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Master Entrepreneurship in Digital Technologies 2020 (compulsory), entrepreneurship, 3rd semester
- Master Media Informatics 2014 (optional subject), Interdisciplinary modules, arbitrary semester
- Master Interdisciplinary Courses (optional subject), Interdisciplinary modules, arbitrary semester
- Master Robotics and Autonomous Systems 2019 (optional subject), interdisciplinary competence, 1st or 2nd semester
- Master Entrepreneurship in Digital Technologies 2014 (compulsory), entrepreneurship, 3rd semester

Classes and lectures:

- Entrepreneurship in the digital economy (lecture, 2 SWS)
- Entrepreneurship in the digital economy (exercise, 1 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 15 Hours exam preparation

Contents of teaching:

- In this class students obtain a key insight into the entrepreneurial processes, the identification of business opportunities as well as the shaping and changing of young companies. In addition, students are able to understand business models on a basic level. At the same time, this class will include strategy development, fundamental aspects of corporate marketing, growth forms and strategies, entrepreneurship in the context of established enterprises and social entrepreneurship.
- Special emphasize will be on start-ups in the digital economy.

Qualification-goals/Competencies:

- Students are able to identify the central issues in the process of founding a new company and have a broad Knowledge including the scientific basis as well as the practical application of the importance of entrepreneurship in economic and in a business context. Students are able to apply this knowledge to their own examples and in a changing context.
- Students are able to develop features and factors of successful start-ups and independently develop, visualize and submit business concepts based oncriteria and methods acquired. This knowledge is also linked to practicaland current topics and representable applications.
- Individual aspects of the event will be studied on selected case studies.
- Students master the scientific foundations and have specialized and in-depth expertise in innovation and technology management.
- Students know how to structure and solve problems even in new, unfamiliarand multidisciplinary contexts of innovation and technology management.
- Students are able to define goals for their own development and canreflect their own strengths and weaknesses, plan their individualdevelopment and reflect the societal impact.
- Students can work cooperatively and responsibly in groups and reflect and enhance their own cooperative behavior in groups critical.

Grading through:

- presentation
- Written or oral exam as announced by the examiner
- written homework

Responsible for this module:

- Prof. Dr. Christian Scheiner

Teacher:

- Institute for Entrepreneurship and Business Development

- Prof. Dr. Christian Scheiner

Literature:

- Bygrave & Zacharakis: The Portable MBA in Entrepreneurship - Wiley-Verlag: 2010
- Bygrave & Zacharakis: Entrepreneurship - Wiley-Verlag: 3. Auflage 2013
- Hisrich, Peters & Shepherd: Entrepreneurship - McGraw-Hill: International Edition 2010

Language:

- English, except in case of only German-speaking participants

Notes:

(Formerly EC5010)

Prerequisites for admission to the (written) examination may be scheduled at the beginning of the semester. When prerequisites are defined, they should be completed and positively evaluated before the initial (written) examination.

Students for whom this module is compulsory will be given priority to enroll.

For FH students, the exam is the same as the portfolio study.

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- None

CS4503-KP12, CS4503 - Ambient Computing (AmbCompA)

Duration:	Turnus of offer:	Credit points:
2 Semester	normally each year in the summer semester	12

Course of study, specific field and term:

- Master Entrepreneurship in Digital Technologies 2020 (advanced module), technology field computer science, arbitrary semester
- Master Computer Science 2019 (optional subject), advence module, arbitrary semester
- Master Robotics and Autonomous Systems 2019 (advanced module), advanced curriculum, 1st or 2nd semester
- Master IT-Security 2019 (advanced module), Elective Computer Science, 1st or 2nd semester
- Master Entrepreneurship in Digital Technologies 2014 (advanced module), technology field computer science, 2nd and/or 3rd semester
- Master Computer Science 2014 (advanced module), advanced curriculum, 2nd and/or 3rd semester

Classes and lectures:

- CS4670 T: Ambient Computing (lecture, 3 SWS)
- Seminar Ambient Computing (seminar, 2 SWS)
- Lab Course Ambient Computing (project work, 3 SWS)

Workload:

- 120 Hours group work
- 120 Hours in-classroom work
- 70 Hours private studies
- 30 Hours oral presentation (including preparation)
- 20 Hours exam preparation

Contents of teaching:

- see module parts

Qualification-goals/Competencies:

- see module parts

Grading through:

- Oral examination

Responsible for this module:

- Prof. Dr.-Ing. Andreas Schrader

Teacher:

- Institute of Telematics
- Prof. Dr.-Ing. Andreas Schrader

Literature:

- : see module parts

Language:

- English, except in case of only German-speaking participants

CS4504-KP12, CS4504 - Cyber Physical Systems (CPS)

Duration:	Turnus of offer:	Credit points:
2 Semester	irregularly	12

Course of study, specific field and term:

- Master Entrepreneurship in Digital Technologies 2020 (advanced module), technology field computer science, arbitrary semester
- Master Computer Science 2019 (optional subject), advence module, arbitrary semester
- Master Robotics and Autonomous Systems 2019 (advanced module), advanced curriculum, 1st or 2nd semester
- Master IT-Security 2019 (advanced module), Elective Computer Science, 1st or 2nd semester
- Master Entrepreneurship in Digital Technologies 2014 (advanced module), technology field computer science, 2nd and/or 3rd semester
- Master Computer Science 2014 (advanced module), advanced curriculum, 2nd and/or 3rd semester

Classes and lectures:

- CS5150 T: Organic Computing (lecture with exercises, 3 SWS)
- CS5153 T: Wireless Sensor Networks (lecture with exercises, 3 SWS)
- Cyber Physical Systems (seminar, 2 SWS)

Workload:

- 220 Hours private studies
- 120 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- see module parts

Qualification-goals/Competencies:

- see module parts

Grading through:

- Oral examination

Responsible for this module:

- Prof. Dr.-Ing. Heiko Hamann

Teacher:

- Institute of Computer Engineering

- Prof. Dr.-Ing. Heiko Hamann

Literature:

- :

Language:

- German and English skills required

RO4500-KP12 - Advanced Control and Estimation (ACES)

Duration:	Turnus of offer:	Credit points:
2 Semester	each semester	12

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (advanced module), advanced curriculum, 1st and 2nd semester

Classes and lectures:

- Linear Systems Theory (lecture, 2 SWS)
- Linear Systems Theory (exercise, 2 SWS)
- Graphical Models in Systems and Control (lecture, 2 SWS)
- Graphical Models in Systems and Control (exercise, 1 SWS)
- Advanced Control and Estimation (seminar, 2 SWS)

Workload:

- 150 Hours in-classroom work
- 150 Hours private studies
- 30 Hours exam preparation
- 30 Hours in-classroom exercises

Contents of teaching:

- Content of teaching for course Linear Systems Theory:
- Vector spaces, norms, linear operators
- Eigenvalues, eigenvectors, Jordan normal form
- Singular value decomposition and operator norms
- Linear systems in continuous and discrete time
- Modeling of linear systems and linearization
- Fundamental solution to linear systems state equations
- Laplace transform and z-transform
- Content of teaching for course Graphical Models in Systems and Control:
- Introduction to Probability Theory, Discretely and Continuously Distributed Random Variables
- Fundamentals on Probabilistic Graphical Models
- Forney-Style Factor Graphs as a Probabilistic Graphical Model
- Message Passing via Sum- and Max-Produkt Algorithms
- Gaussian Message Passing
- State Estimation (Kalman Filtering and Smoothing including Nonlinear Extensions)
- Parameter Estimation via Expectation Maximization
- Expectation Propagation
- Control on Factor Graphs
- Content of teaching of the seminar Advanced Control and Estimation:
- Current state of the art algorithms in stochastic signal processing, estimation, identification and control.

Qualification-goals/Competencies:

- Educational objectives for course Linear Systems Theory:
- Students are familiar with the important basic concepts of linear algebra.
- Students have a solid background in the theory of linear systems in continuous and disrete time.
- Students are able to model linear systems in mechanical and electrical domain from first principles.
- Students are able to solve the state equations and analyze systems in the time and frequency domain.
- Students improve their problem solving and mathematical skills.
- Students develop their techniques for logical reasoning and and rigorous proofs.
- Students are enabled to perform reseaerch in the field of systems and control theory.
- Educational objectives for course Graphical Models in Systems and Control:
- Students develop and extend their fundamental knowledge on probability theory and the transformation of discretely as well as continuously distributed random variables.
- Students can understand simple linear algorithms, such as the Kalman filter, with the help of graphical probabilistic models.
- Students can combine elements of probabilistic algorithms to novel ones with the help of graphical probabilistic models.
- Students can understand, extend and apply advanced algorithms in signal processing, parameter and state estimation as well as control to relevant problems with the help of graphical probabilistic models.
- Educational objectives of the seminar Advanced Control and Estimation:
- Students are able to research and understand current literature.
- Students are able to reproduce and evaluate current algorithms based on research literature.
- Students are able reproduce, extend and present results from current research literature.

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr. Philipp Rostalski
- Prof. Dr. Georg Schildbach

Teacher:

- Institute for Electrical Engineering in Medicine

- Prof. Dr. Georg Schildbach
- Dr.-Ing. Christian Herzog

Literature:

- Loeliger, Hans-Andrea; Dauwels, Justin; Hu, Junli; Korl, Sascha; Ping, Li; Kschischang, Frank R.: The Factor Graph Approach to Model-Based Signal Processing - Proc. IEEE, Vol. 95, No. 6, 2007
- Loeliger, Hans-Andrea: An Introduction to factor graphs - IEEE Signal Process. Mag., Vol. 21, No. 1, 2004
- Hoffmann, Christian; Rostalski, Philipp: Current Publications from Research at the IME
- Miscellaneous: Current Publications from Research

Language:

- offered only in English

Notes:

Prerequisites for attending the module:
- None

RO5100-KP12 - Medical Robotics (MedRob12)

Duration:	Turnus of offer:	Credit points:
2 Semester	each summer semester	12

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (advanced module), advanced curriculum, 1st or 2nd semester

Classes and lectures:

- ME4030 T: Inverse Probleme bei der Bildgebung (lecture with exercises, 3 SWS)
- Siehe CS4270-KP04: Medizinische Robotik (lecture with exercises, 4 SWS)
- CS5280 T: Module Part: Seminar Robotics and Automation (seminar, 2 SWS)

Workload:

- 190 Hours private studies
- 150 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- see module parts

Qualification-goals/Competencies:

- see module parts

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr.-Ing. Achim Schweikard

Teacher:

- Institute of Computer Engineering
- Institute for Electrical Engineering in Medicine
- Institute of Medical Engineering
- Institute of Medical Informatics
- Institute for Robotics and Cognitive Systems

Language:

- offered only in English

Notes:

(Besteht aus ME4030 T, CS4270-KP04, CS5280 T)

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

RO5200-KP12 - Bio-inspired Robotics (BR)

Duration:	Turnus of offer:	Credit points:
2 Semester	each semester	12

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (advanced module), advanced curriculum, arbitrary semester

Classes and lectures:

- Collective Robotics (lecture, 2 SWS)
- Collective Robotics (exercise, 1 SWS)
- Evolutionary Robotics (lecture, 2 SWS)
- Evolutionary Robotics (exercise, 1 SWS)
- Seminar Bio-inspired Robotics (seminar, 2 SWS)

Workload:

- 220 Hours private studies
- 120 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Biological basics
- Self-organization, robustness, scalability, superlinear speedups
- Robot swarms by land, by sea, and by air
- Mathematical modeling of swarms and collective decision-making
- Evolutionary computation
- Artificial evolution of robot controllers and robot morphologies
- Optimization and learning in robot experiments
- Independent familiarization with an area of service robotics based on technical literature
- Writing and presentation of an own scientific paper

Qualification-goals/Competencies:

- Students get a comprehensive overview of biologically inspired.
- Students are able to assess chances and challenges of robust and scalable robot systems.
- Students are able to implement reactive control for swarm robots in simulation and on mobile robots.
- Students are able to implement evolutionary algorithms and artificial neural networks and are able to apply them to problems of mobile robots in.
- Students are able to name challenges of evolutionary robotics in applications and to discuss potential solutions.
- Die Teilnehmer sind in der Lage, eine wissenschaftliche Arbeit eigenständig zu verfassen und vorzutragen.
- The students are able to investigate self-dependently scientific publications, to analyze and understand their contents.
- The participants can analyze and reproduce the tenor with regard to their scope of work. The students are competent to write and present their own scientific work.

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr.-Ing. Heiko Hamann

Teacher:

- Institute for Robotics and Cognitive Systems

- Prof. Dr.-Ing. Heiko Hamann

Literature:

- Nolfi, S., Floreano, D.: The Biology, Intelligence, and Technology of Self-Organizing Machines - MIT Press, 2001
- Hamann, H.: Swarm Robotics: A Formal Approach - Springer 2018

Language:

- offered only in English

Notes:

Prerequisites for attending the module:
- None

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Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

RO5500-KP12 - Autonomous Vehicles (AVS)

Duration:	Turnus of offer:	Credit points:
2 Semester	starts every winter semester	12

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (advanced curriculum), advanced curriculum, 1st and 2nd semester

Classes and lectures:

- Vehicle Dynamics and Control (lecture, 2 SWS)
- Vehicle Dynamics and Control (exercise, 2 SWS)
- Perception for Autonomous Vehicles (lecture, 2 SWS)
- Perception for Autonomous Vehicles (exercise, 2 SWS)
- Technology of Autonomous Vehicles (seminar, 2 SWS)

Workload:

- 220 Hours private studies
- 80 Hours in-classroom work
- 60 Hours exam preparation

Contents of teaching:

- Content of teaching of the course Vehicle Dynamics and Control:
- Review of control methods and rigid body dynamics
- Basic terminology of vehicle dynamics
- Vehicle dynamic models (lateral, longitudinal, vertical)
- Component models (engine, transmission, brake, steering)
- Tire modeling
- Stability analysis
- Handling performance
- Active safety systems
- Autonomous driving
- Content of teaching of the course Perception for Autonomous Driving:
- The architecture of autonomous-driving systems
- Tracking, detection, classification
- Models of stochastic signals
- Transform-based analysis of stochastic signals
- System theory
- Parameter estimation
- Linear optimal filters and adaptive filters
- Graphical models and dynamic Bayes networks
- Neural networks
- Hidden Markov Models, Kalman Filter, Particle Filter, etc.
- Applications in the domain of autonomous driving
- Content of teaching of the seminar Current Topics in Autonomous Vehicles:
- Current algorithms in machine learning and artificial intelligence related to autonomous driving

Qualification-goals/Competencies:

- Educational objectives of the course Vehicle Dynamics and Control:
- Students master basic terminology and concepts of vehicle dynamics.
- Students obtain a comprehensive understanding of the dynamics of a vehicle.
- Students understand the main objectives of vehicle control.
- Students can derive basic vehicle dynamics models for control design.
- Students are able to apply concepts of basic and advanced control and estimation to practical problems.
- Students get an insight into the field of active safety systems, driver assistance, and autonomous driving.
- Students are able to perform independent design, research and development work in this field.
- Educational objectives of the course Perception for Autonomous Driving:
- Students get an overview on autonomous-driving systems.
- Students become thoroughly acquainted with the perception layer of the architecture of an autonomous-driving system.
- Students get a comprehensive introduction to stochastic signals.
- Students master tools for the analysis of stochastic signals.
- Students are able to make use of various models for stochastic signals.
- Students are able to design tracking algorithms.
- Students are able devise algorithmic solutions to decision problems, while making use of prior knowledge.
- Educational objectives of the seminar Current Topics in Autonomous Vehicles:

- Students are able to research and understand current literature.
- Students are able to reproduce and evaluate current algorithms based on research literature.
- Students are able reproduce, extend and present results from current research literature.

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Control Systems (RO4400-KP08)
- Technical Mechanics (RO1500-KP08)

Responsible for this module:

- Prof. Dr. Georg Schildbach

Teacher:

- Institute for Electrical Engineering in Medicine

- Prof. Dr. Georg Schildbach
- PD Dr.-Ing. habil. Alexandru Paul Condurache

Literature:

- Rajamani, R: Vehicle Dynamics and Control (2nd edition) - Springer, 2012, ISBN 978-1-4614-1432-2
- Mitschke, M; Wallentowitz, H.: Dynamik der Kraftfahrzeuge (5th edition) - Springer, 2014 (ISBN: 978-3-658-05067-2)
- Charles W. Therrien: Decision estimation and classification - J. Wiley and Sons, 1991.
- Simon Haykin: Adaptive Filter Theory - Prentice Hall, 1996
- Christopher M. Bishop: Pattern recognition and machine learning - Springer, 2006
- A. Mertins: Signaltheorie: Grundlagen der Signalbeschreibung, Filterbänke, Wavelets, Zeit-Frequenz-Analyse, Parameter- und Signalschätzung - Springer-Vieweg, 3. Auflage, 2013

Language:

- offered only in English

Notes:

(RO5500-L1 Partial Exam Vehicle Dynamics and
Control (Graded Exam, 4 KP))
(RO5500-L2 Partial Exam Perception for
Autonomous Vehicles (Graded Exam, 4 KP))
(RO5500-L3 Partial Exam Technology of Autonomous Vehicles (Ungraded Seminar, 4 KP))

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

RO5800-KP12 - Advanced Topics in Robotics (ATRS)

Duration:	Turnus of offer:	Credit points:
2 Semester	each semester	12

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (advanced curriculum), advanced curriculum, 1st or 2nd semester

Classes and lectures:

- Advanced Topics in Robotics (lecture, 2 SWS)
- Advanced Topics in Robotics (exercise, 1 SWS)
- Rescue Robotics (lecture, 2 SWS)
- Rescue Robotics (exercise, 2 SWS)
- Machine Learning in Medicine (seminar, 2 SWS)

Workload:

- 135 Hours in-classroom work
- 95 Hours private studies
- 90 Hours work on an individual topic with written and oral presentation or group work
- 40 Hours exam preparation

Contents of teaching:

- Content of teaching of the course Advanced Topics in Robotics:
- Motion Planning for Robots
- Augmented Reality
- Design of Robot Systems
- Intracorporal Robotics
- Dynamics and Control of Robots
- Content of teaching of the course Rescue Robotics:
- Special requirements for disaster management and response and the resulting consequences on rescue robot design.
- Information structures for rescue systems
- Information exchange between rescue robots
- Command and control systems for search and rescue robots
- Tactical communication for cooperative SAR robot missions as well as interoperability in heterogeneous teams.
- Design guidelines for human interfaces to rescue robots
- Casualty and vital sign detection in rescue scenarios
- Medical assistance at the scene of incident and determination of vital signs
- Evaluation and benchmarking of SAR robots
- Content of teaching of the seminar Machine Learning in Medicine:
- Access to a scientific field
- Work towards a scientific solution to a problem with appropriate methods
- Presentations and discussions in English
- Possible topics: Computer Aided Diagnosis, Gaussian Processes for Sensor Data Analysis, Motion Prediction, Correlation Methods for Motion Estimation, Tissue Thickness Estimation, Sensor Calibration

Qualification-goals/Competencies:

- Educational objectives of the course Advanced Topics in Robotics:
- Students understand the connection to underlying mathematical methods, especially in dynamics, optimization, and sensor data processing and analysis of algorithms.
- Students have an extended overview of application areas for robotics.
- They are able to implement such methods and derive new applications based on such methods.
- Educational objectives of the course Rescue Robotics:
- The students can applz the tools to program and simulate mobile rescue robots. They have developed a good overview about mobile robotics, localization and path planning in difficult scenarios.
- The students have knowledge about the work and command structures of rescue personell and the requirements on control, communcation and interaction of rescue robots with the personnel.
- The students have developed a notion of medical first response by rescue personnel as well as technical solutions to locate missing persons, determine vital signs and realize medical assistance at the scene of incident.
- Educational objectives of the course Seminar Machine Learning in Medicine:
- The students can analyze, develop and evaluate a research topic.
- The students can comprehensibly present research results in written or spoken presentations.
- The students can elaborate on a scientific field in the English language.
- The students can frame a topic within the scientific context.

Grading through:

- written exam, oral exam and/or presentation as announced by the examiner

Requires:

- Robotics (CS2500-KP04, CS2500)

Responsible for this module:

- Prof. Dr.-Ing. Achim Schweikard

Teacher:

- Institute for Robotics and Cognitive Systems

- Prof. Dr.-Ing. Achim Schweikard
- Prof. Dr. rer. nat. Floris Ernst

Literature:

- Achim Schweikard, Floris Ernst: Medical Robotics - Springer, 2015, Jocelyne Troccaz (ed.): Medical Robotics, Wiley, 2009
- Tadokoro, Satoshi, ed.: Rescue robotics: DDT project on robots and systems for urban search and rescue. - Springer Science & Business Media, 2009. (ISBN: 978-1447157656).
- Siciliano, Bruno, and Oussama Khatib, eds.: Springer handbook of robotics. - Springer, 2016. (ISBN: 978-3319325507)

Language:

- offered only in English

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

RO5990-KP30 - Master Thesis Robotics and Autonomous Systems (MScRAS)		
Duration: 1 Semester	**Turnus of offer:** each semester	**Credit points:** 30

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (compulsory), Robotics and Autonomous Systems, 4th semester

Classes and lectures:

- Master's Thesis (supervised self studies, 1 SWS)
- Colloquium (presentation (incl. preparation), 1 SWS)

Workload:

- 870 Hours private studies
- 30 Hours oral presentation (including preparation)

Contents of teaching:

- individual studies under supervision

Qualification-goals/Competencies:

- Students are able to solve a complex scientific problem by the means of their discipline.
- They have the expertise to plan, organize and carry out a project work.
- They can present complex information in written and oral form.
- They are experts for a roughly defined topic.

Grading through:

- Written report

Responsible for this module:

- Studiengangsleitung Robotik und Autonome Systeme

Teacher:

- Institutes of the Department of Computer Science/ Engineering

- Alle prüfungsberechtigten Dozentinnen/Dozenten des Studienganges

Literature:

- links will be given by the supervisor:

Language:

- offered only in English

Notes:

requirement for starting a master's thesis are 75 credit points

CS4130-KP06, CS4130 - Information Systems (InfoSys)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	6

Course of study, specific field and term:

- Master Computer Science 2019 (compulsory), Canonical Specialization Data Science and AI, arbitrary semester
- Master Entrepreneurship in Digital Technologies 2020 (basic module), technology field computer science, 1st or 2nd semester
- Master Media Informatics 2020 (optional subject), computer science, arbitrary semester
- Master Computer Science 2019 (basic module), systems informatics, 1st or 2nd semester
- Master Medical Informatics 2019 (basic module), systems informatics, 1st or 2nd semester
- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st or 2nd semester
- Master IT-Security 2019 (basic module), systems informatics, 1st or 2nd semester
- Master Medical Informatics 2014 (basic module), ehealth / infomatics, 1st or 2nd semester
- Master Media Informatics 2014 (optional subject), computer science, arbitrary semester
- Master Entrepreneurship in Digital Technologies 2014 (basic module), technology field computer science, 1st or 2nd semester
- Master Computer Science 2014 (optional subject), specialization field software systems engineering, 2nd or 3rd semester
- Master Computer Science 2014 (basic module), systems informatics, 1st or 2nd semester

Classes and lectures:

- Information Systems (lecture, 2 SWS)
- Information Systems (exercise, 2 SWS)

Workload:

- 100 Hours private studies
- 60 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Fundamentals of databases, conceptual modeling languages (ontologies), query languages, processes, and agents
- Ontology based data access (OBDA)
- Ontology evolution and ontology integration
- Data exchange and data integration (schema mappings, duplicate detection, inconsistency handling, integration with relational and ontological constraints as well as with incomplete data)
- Data stream processing (e.g., for sensor networks, robotics, web agents) with OBDA and complex event processing (CEP)
- Non-symbolic data and their symbolic annotations (e.g., for applications in bioinformatics/computational biology and for media interpretation), syntax, semantics, hybrid decision and computation problems and their complexity, (analysis of) algorithms
- Data- and ontology-oriented process analysis (e.g., for biological pathways) and process design (e.g., for non-trivial business processes)

Qualification-goals/Competencies:

- Knowledge: The module aims at introducing the students to the formal basics of databases and ontologies, so that they get an overview of concepts, methods, and theories for understanding, analyzing, and designing information systems in open large contexts, such as the web.
- Skills: The students get a basic understanding of logical and formal methods, which allows them to assess the possibilities and limitations of information systems, be it concrete ones or those that still have to be designed. Assessment parameters are correctness and completeness (Does the system produce what is expected? If so, does it produce all results?) as well as expressiveness (Is it possible to formulate all required queries? What are equivalent query languages?) and, last but not least, performance (How long does it take the system to come up with an answer? How much space does it need?). In addition to these analysis skills, students receive logical modeling skills using real application scenarios from industry (business processing, integration of data resources, processing of time-based and event data), and medicine (sensor networks, genomic ontologies, annotation). Based on these, the student not only acquires the ability to assess which logical model is suitable for which application scenario, but also the ability to construct their own logical models where necessary.
- Social Competence und Independent Work: Students work in groups to solve small exercises and project problems and sketch their solutions in short presentations. Independent work is promoted by exercises with practical ontology and database systems.

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr. rer. nat. habil. Ralf Möller
- PD Dr. Sven Groppe

Teacher:

- Institute of Information Systems

- PD Dr. Sven Groppe
- Prof. Dr. rer. nat. habil. Ralf Möller
- PD Dr. Özgür Özçep

Literature:

- S. Abiteboul, R. Hull, V. Vianu: Foundations of Databases - Addison-Wesley, 1995
- M. Arenas, P. Barcelo, L. Libkin, and F. Murlak: Foundations of Data Exchange - Cambridge University Press, 2014
- F. Baader, D. Calvanese, D.L. McGuinness, D. Nardi, and P.F. Patel-Schneider (Eds.): The Description Logic Handbook: Theory, Implementation, and Applications - Cambridge University Press, 2010
- S. Chakravarthy, Q. Jiang: Stream Data Processing A Quality of Service Perspective - Springer, 2009
- L. Libkin: Elements Of Finite Model Theory (Texts in Theoretical Computer Science. An Eatcs Series) - SpringerVerlag, 2004

Language:

- German and English skills required

Notes:

Previous name: Web Based Information Systems

Prerequisites for attending the module:
- Algorithm and Data Structures (CS1001)
- Linear Algebra and Discrete Structures I+II (MA1000, MA1500)
- Databases (CS2700)

Recommended additional modules:
- Logic (CS1002)
- Bachelor Project Computer Science (CS3701), topic: logic programming
- Nonstandard Database Systems (CS3202)

Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

CS4150-KP06, CS4150SJ14 - Distributed Systems (VertSys14)

Duration:	**Turnus of offer:**	**Credit points:**
1 Semester	each winter semester	6

Course of study, specific field and term:

- Master Computer Science 2019 (compulsory), Canonical Specialization SSE, arbitrary semester
- Master Entrepreneurship in Digital Technologies 2020 (basic module), technology field computer science, 1st or 2nd semester
- Master Media Informatics 2020 (optional subject), computer science, arbitrary semester
- Master Computer Science 2019 (basic module), systems informatics, 1st or 2nd semester
- Master Medical Informatics 2019 (basic module), systems informatics, 1st or 2nd semester
- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st or 2nd semester
- Master IT-Security 2019 (basic module), systems informatics, 1st or 2nd semester
- Master Medical Informatics 2014 (basic module), ehealth / infomatics, 1st or 2nd semester
- Master Media Informatics 2014 (optional subject), computer science, arbitrary semester
- Master Entrepreneurship in Digital Technologies 2014 (basic module), technology field computer science, 1st or 2nd semester
- Master Computer Science 2014 (optional subject), specialization field software systems engineering, 2nd or 3rd semester
- Master Computer Science 2014 (basic module), systems informatics, 1st or 2nd semester

Classes and lectures:

- Distributed Systems (lecture, 2 SWS)
- Distributed Systems (exercise, 2 SWS)

Workload:

- 60 Hours private studies
- 60 Hours in-classroom work
- 40 Hours e-learning
- 20 Hours exam preparation

Contents of teaching:

- Introduction and motivation
- Protocols and layered models
- Message representations
- Realization of network services
- Communication mechanisms
- Addresses, names and directory services
- Synchronisation
- Replication and consistency
- Fault tolerance
- Distributed transactions
- Security

Qualification-goals/Competencies:

- The participants will accquire a deep understanding for problems to be solved in distributed systems, such as synchronization, error handling, naming etc.
- They know the most important services in distributed systems such as name service, distributed file systems etc.
- They are able to program simple distributed applications and systems themselves.
- They know the most important algorithms in distributed systems, for instance for time synchronization, for leader election, or for mutual exclsuion.
- They have a good feeling for when it makes sense to use distributed instead of centralized systems.
- They have a good feeling for what kind of solutions could best be used for what kind of problems in distributed Internet applications.

Grading through:

- written exam

Responsible for this module:

- Prof. Dr. Stefan Fischer

Teacher:

- Institute of Telematics

- Prof. Dr. Stefan Fischer

Literature:

- A. Tanenbaum, M. van Steen: Distributed Systems: Principles and Paradigms - Prentice Hall 2006
- G. Coulouris, J. Dollimore, T. Kindberg, G. Blair: Distributed Systems - Concepts and Design - Addison Wesley 2012

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Prerequisites for admission to the (written) examination may be scheduled at the beginning of the semester. When prerequisites are defined, they should be completed and positively evaluated before the initial (written) examination.

CS4170-KP06, CS4170SJ14 - Parallel Computer Systems (ParaRSys14)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	6

Course of study, specific field and term:

- Master Entrepreneurship in Digital Technologies 2020 (advanced module), technology field computer science, arbitrary semester
- Master Computer Science 2019 (basic module), technical computer science, 1st or 2nd semester
- Master Medical Informatics 2019 (optional subject), technical computer science, 1st or 2nd semester
- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st or 2nd semester
- Master IT-Security 2019 (basic module), technical computer science, 1st or 2nd semester
- Master Medical Informatics 2014 (basic module), computer science, 1st or 2nd semester
- Master Entrepreneurship in Digital Technologies 2014 (basic module), technology field computer science, 1st or 2nd semester
- Master Computer Science 2014 (basic module), technical computer science, 1st or 2nd semester

Classes and lectures:

- Parallel Computer Systems (lecture, 2 SWS)
- Parallel Computer Systems (exercise, 2 SWS)

Workload:

- 100 Hours private studies
- 60 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Motivation and limitations for parallel processing
- Parallel computing models
- Taxonomy of parallel computers
- Multi/manycore-systems
- Graphic Processing Units (GPUs)
- OpenCL
- Specification languages
- Hardware architectures
- System management of many-core systems

Qualification-goals/Competencies:

- Students are able to characterize different parallel computing architectures.
- They are able to explain models of parallel computing.
- They are able to make use of common programming interfaces for parallel computing systems.
- They are able to judge which kind of parallel computing system is best suited for a dedicated problem and how many cores should be used.
- They are able to evaluate the pros and cons of different hardware architectures.
- They are able to write programs for parallel computing systems under considerations of the underlying hardware architecture.
- They are able to compare methods for dynamic voltage and frequency scaling (DVFS) for manycore systems.

Grading through:

- written exam

Responsible for this module:

- Prof. Dr.-Ing. Mladen Berekovic

Teacher:

- Institute of Computer Engineering

- Prof. Dr.-Ing. Mladen Berekovic

Literature:

- G. Bengel, C. Baun, M. Kunze, K. U. Stucky: Masterkurs Parallele und Verteilte Systeme - Vieweg + Teubner, 2008
- M. Dubois, M. Annavaram, P. Stenström: Parallel Computer Organization and Design - University Press 2012
- B. R. Gaster, L. Howes, D. R. Kaeli, P. Mistry, D. Schaa: Heterogeneous Computing with OpenCL - Elsevier/Morgan Kaufman 2013
- B. Wilkinson; M. Allen: Parallel Programming - Englewood Cliffs: Pearson 2005
- J. Jeffers, J. Reinders: Intel Xeon Phi Coprozessor High-Performance Programming - Elsevier/Morgan Kaufman 2013
- D. A. Patterson, J. L. Hennessy: Computer Organization and Design - Morgan Kaufmann, 2013

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

CS4220-KP04, CS4220 - Pattern Recognition (Muster)

Duration:	Turnus of offer:	Credit points:
1 Semester	every second semester	4

Course of study, specific field and term:

- Master MES 2020 (optional subject), medical engineering science, arbitrary semester
- Master Media Informatics 2020 (optional subject), computer science, arbitrary semester
- Master MES 2014 (optional subject), medical engineering science, arbitrary semester
- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st or 2nd semester
- Master CLS 2016 (compulsory), mathematics, 2nd semester
- Master Medical Informatics 2019 (optional subject), Medical Data Science / Artificial Intelligence, 1st or 2nd semester
- Master Medical Informatics 2014 (optional subject), medical image processing, 1st or 2nd semester

Classes and lectures:

- Pattern Recognition (lecture, 2 SWS)
- Pattern Recognition (exercise, 1 SWS)

Workload:

- 55 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Introduction to probability theory
- Principles of feature extraction and pattern recognition
- Bayes decision theory
- Discriminance functions
- Neyman-Pearson test
- Receiver Operating Characteristic
- Parametric and nonparametric density estimation
- kNN classifiers
- Linear classifiers
- Support vector machines and kernel trick
- Random Forest
- Neural Nets
- Feature reduction and feature transforms
- Validation of classifiers
- Selected application scenarios: acoustic scene classification for the selection of hearing-aid algorithms, acoustic event recognition, attention classification based on EEG data, speaker and emotion recognition

Qualification-goals/Competencies:

- Students are able to describe the main elements of feature extraction and pattern recognition.
- They are able to explain the basic elements of statistical modeling.
- They are able to use feature extraction, feature reduction and pattern classification techniques in practice.

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr.-Ing. Alfred Mertins

Teacher:

- Institute for Signal Processing

- Prof. Dr.-Ing. Alfred Mertins

Literature:

- R. O. Duda, P. E. Hart, D. G. Storck: Pattern Classification - New York: Wiley

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

CS4290-KP04, CS4290 - Current Issues Robotics and Automation (RobAktuell)

Duration:	Turnus of offer:	Credit points:
1 Semester	each semester	4

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st and/or 2nd semester
- Master Computer Science 2014 (compulsory), specialization field robotics and automation, 2nd or 3rd semester

Classes and lectures:

- CS4160 TSJ14: Real-Time Systems (lecture with exercises, 4 SWS)
- CS4170 TSJ14: Parallel Computer Systems (lecture with exercises, 4 SWS)
- CS4220 T: Pattern Recognition (lecture with exercises, 3 SWS)
- CS466 T: Process Control Systems (lecture with exercises, 3 SWS)
- CS5150 T: Organic Computing (lecture with exercises, 3 SWS)
- CS5153 T: Wireless Sensor Networks (lecture with exercises, 3 SWS)
- CS5170 T: Hardware/Software Co-Design (lecture with exercises, 3 SWS)
- CS5275 T: Selected Topics of Signal Analysis and Enhancement (lecture with exercises, 3 SWS)
- CS5280 T: Seminar Robotics and Automation (seminar, 2 SWS)
- CS5410 T: Artificial Life (lecture with exercises, 3 SWS)
- CS5450 T: Machine Learning (lecture with exercises, 3 SWS)
- ME4030 T: Inverse Probleme bei der Bildgebung (lecture with exercises, 3 SWS)
- ME4500: Advanced Methods in Control (lecture with exercises, 3 SWS)
- RO5700 T: Evolutionary Robotics (lecture with exercises, 3 SWS)
- RO5600 T: Social Robotics (lecture and exercise, 4 SWS)
- RO5402 T: Seminar Machine Learning for Medicine (seminar, 2 SWS)
- RO5202 T: Collective Robotics (lecture with exercises, 3 SWS)

Workload:

- 60 Hours private studies
- 45 Hours in-classroom work
- 15 Hours exam preparation

Contents of teaching:

-

Qualification-goals/Competencies:

-

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr.-Ing. Mladen Berekovic

Teacher:

- Institute for Electrical Engineering in Medicine
- Institute for Multimedia and Interactive Systems
- Institute for Signal Processing
- Institute for Neuro- and Bioinformatics
- Institute for Robotics and Cognitive Systems
- Institute of Computer Engineering

Language:

- German and English skills required

Notes:

One of the modules parts.

Prerequisites for attending the module:
- None

CS4374-KP06 - Medical Deep Learning (MDL)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	6

Course of study, specific field and term:

- Master MES 2020 (optional subject), computer science / electrical engineering, arbitrary semester
- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st or 2nd semester
- Master Medical Informatics 2014 (optional subject), medical computer science, 1st or 2nd semester
- Master MES 2014 (optional subject), computer science / electrical engineering, 1st or 2nd semester
- Master Medical Informatics 2019 (advanced module), medical computer science, 1st or 2nd semester

Classes and lectures:

- Medical Deep Learning (lecture, 2 SWS)
- Medical Deep Learning (exercise, 2 SWS)

Workload:

- 80 Hours private studies
- 60 Hours in-classroom work
- 40 Hours exam preparation

Contents of teaching:

- Cardiac Healthcare:
- ECG signal analysis for arrhythmia detection or sleep apnea and for mobile low-cost devices
- MRI sequence analysis for anatomical segmentation and temporal modelling
- Multimodal Clinical Case Retrieval / Prediction:
- Pathology and Semantic Image Retrieval and Localisation
- Analysis of text / natural language (radiology reports/study articles) for multimodal data mining in Electronic Health Records (EHR)
- Computer Aided Detection and Disease Classification:
- CT Lung nodule detection for cancer screening with data augmentation and transfer learning
- Weakly-supervised abnormality detection and biomarker discovery
- Interpretable and reliable deep learning systems
- Human interaction and correction within deep learning models
- Visualisation of uncertainty and internally learned representations
- Deep Learning Concepts, Architectures and Hardware
- Convolutional Neural Networks, Layers, Deep Residual Learning
- Losses, Derivatives, Large-scale Stochastic Optimisation
- Directed Acyclic Graph Networks, Generative Adversarial Networks
- Cloud Computing, GPUs, Low Precision Computing, DL Frameworks

Qualification-goals/Competencies:

- Students know the importance of data security, patient anonymisation and ethics for clinical studies involving sensitive data
- They know methods and tools to collect, preprocess, store and annotate large datasets for deep learning from medical data
- They have an in-depth understanding of deep / convolutional neural networks for general data (signals / text / images) processing, their learning process and evaluation of their performance on unseen data
- They understand the principles of weakly-supervised learning, transfer learning, concept discovery and generative adversarial networks
- They know how to explore learned feature representations for retrieval and visualisation of high-dimensional abstract data
- They can implement modern network architectures in DL frameworks and are able to adapt and extend them to given problems in medicine
- They have a broad overview of current applications of deep learning in medicine in both research and clinical practice and can transfer their knowledge to newly emerging domains

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr. Mattias Heinrich

Teacher:

- Institute of Medical Informatics

- Prof. Dr. Mattias Heinrich

Language:

- English, except in case of only German-speaking participants

Notes:

Examination prerequisites can be determined at the beginning of the semester. If pre-exam prerequisites have been defined, they must have been completed before the initial examination and evaluated positively.

CS4405-KP04, CS4405 - Neuroinformatics (NeuroInf)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	4

Course of study, specific field and term:

- Master MES 2020 (optional subject), computer science / electrical engineering, arbitrary semester
- Master CLS 2016 (compulsory), computer science, 2nd semester
- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st or 2nd semester
- Master MES 2014 (optional subject), computer science / electrical engineering, arbitrary semester
- Master MES 2011 (optional subject), mathematics, 2nd semester
- Bachelor MES 2011 (optional subject), optional subject medical engineering science, 6th semester
- Master Computer Science 2012 (optional subject), advanced curriculum organic computing, 2nd or 3rd semester
- Master MES 2011 (advanced curriculum), imaging systems, signal and image processing, 2nd semester
- Master Computer Science 2012 (optional subject), advanced curriculum intelligent embedded systems, 2nd or 3rd semester
- Master Computer Science 2012 (compulsory), specialization field robotics and automation, 2nd semester
- Master Computer Science 2012 (compulsory), specialization field bioinformatics, 2nd semester
- Master CLS 2010 (compulsory), computer science, 2nd semester

Classes and lectures:

- Neuroinformatics (lecture, 2 SWS)
- Neuroinformatics (exercise, 1 SWS)

Workload:

- 55 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- The human brain and abstract neuron models
- Learning with a single neuron:* Perceptrons* Max-Margin Classification* LDA and logistic Regression
- Network architectures:* Hopfield-Networks* Multilayer-Perceptrons* Deep Learning
- Unxupervised Learning:* k-means, Neural Gas and SOMs* PCA & ICA* Sparse Coding

Qualification-goals/Competencies:

- The students are able to understand the principle function of a single neuron and the brain as a whole.
- They know abstract neuronal models and they are able to name practical applications for the different variants.
- They are able to derive a learning rule from a given error function.
- They are able to apply (and implement) the proposed learning rules and approaches to solve unknown practical problems.

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr. rer. nat. Thomas Martinetz

Teacher:

- Institute for Neuro- and Bioinformatics

- Prof. Dr. rer. nat. Thomas Martinetz
- Prof. Dr. rer. nat. Amir Madany Mamlouk

Literature:

- S. Haykin: Neural Networks - London: Prentice Hall, 1999
- J. Hertz, A. Krogh, R. Palmer: Introduction to the Theory of Neural Computation - Addison Wesley, 1991
- T. Kohonen: Self-Organizing Maps - Berlin: Springer, 1995
- H. Ritter, T. Martinetz, K. Schulten: Neuronale Netze: Eine Einführung in die Neuroinformatik selbstorganisierender Netzwerke - Bonn: Addison Wesley, 1991

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

CS5170-KP04, CS5170 - Hardware/Software Co-Design (HWSWCod)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Master Computer Science 2019 (compulsory), Canonical Specialization SSE, arbitrary semester
- Master Computer Science 2019 (optional subject), Elective, arbitrary semester
- Master Media Informatics 2020 (optional subject), computer science, arbitrary semester
- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st or 2nd semester
- Master Computer Science 2014 (compulsory), specialization field software systems engineering, 1st or 2nd semester
- Master MES 2011 (advanced curriculum), imaging systems, signal and image processing, 1st or 3rd semester
- Master Media Informatics 2014 (optional subject), computer science, arbitrary semester
- Master Computer Science 2012 (optional subject), specialization field robotics and automation, 2nd or 3rd semester
- Master Computer Science 2012 (optional subject), advanced curriculum parallel and distributed system architecutres, 2nd or 3rd semester
- Master Computer Science 2012 (optional subject), advanced curriculum intelligent embedded systems, 2nd or 3rd semester
- Master Computer Science 2012 (compulsory), specialization field software systems engineering, 2nd semester

Classes and lectures:

- Hardware/Software Co-Design (lecture, 2 SWS)
- Hardware/Software Co-Design (exercise, 1 SWS)

Workload:

- 55 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- System design flow
- Basic architectures for HW/SW systems
- System design and modelling
- System synthesis
- Algorithms for scheduling
- System partitioning
- Algorithms for system partitioning
- Design systems
- Performance analysis
- System design and specification with SystemC
- Application examples

Qualification-goals/Competencies:

- Students are able to determine a suitable hardware/software architecture for a given system description
- They are able to determine and describe the pros and cons of implementation alternatives
- They are able to apply methods for system partitioning
- They are able to translate non-formal system descriptions into formal models
- They are able to explain the different steps in system synthesis
- They are able to estimate the quality of system designs
- They are able to create system descriptions in SystemC

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr.-Ing. Mladen Berekovic

Teacher:

- Institute of Computer Engineering

- Prof. Dr.-Ing. Mladen Berekovic

Literature:

- F. Kesel: Modellierung von digitalen Systemen mit SystemC - Oldenbourg Verlag 2012
- Teich, J., Haubelt, C.: Digital Hardware/Software-Systeme. Synthese und Optimierung - Berlin: Springer 2007

Language:

- offered only in German

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

CS5204-KP04, CS5204 - Artificial Intelligence 2 (KI2)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4

Course of study, specific field and term:

- Master MES 2020 (optional subject), computer science / electrical engineering, arbitrary semester
- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st or 2nd semester
- Master Biophysics 2019 (optional subject), Elective, 1st semester
- Master MES 2014 (optional subject), computer science / electrical engineering, arbitrary semester
- Master Biomedical Engineering (optional subject), Interdisciplinary modules, 2nd semester
- Master CLS 2016 (optional subject), computer science, 3rd semester
- Master Computer Science 2012 (optional subject), advanced curriculum intelligent embedded systems, 2nd or 3rd semester
- Master Computer Science 2012 (optional subject), specialization field robotics and automation, 3rd semester

Classes and lectures:

- Artificial Intelligence 2 (lecture, 2 SWS)
- Artificial Intelligence 2 (exercise, 1 SWS)

Workload:

- 55 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Support Vector Machines and Dualization
- Classification
- Regression
- Time-Series Prediction
- Lagrange Multipliers
- Sequential Minimal Optimization
- Geometric Reasoning

Qualification-goals/Competencies:

- The students are able to choose a method for machine learning for a given application amongst a variety of such methods.
- The chosen method can be customized to the needs of the application. The process of customization goes well beyond straightforward search of parameters and involves adjustments to the basic mathematical techniques.This leads to innovative applications for machine learning, designed and implemented by the students.The starting point are support vector machines.

Grading through:

- Oral examination

Responsible for this module:

- Prof. Dr.-Ing. Achim Schweikard

Teacher:

- Institute for Robotics and Cognitive Systems

- Prof. Dr.-Ing. Achim Schweikard

Literature:

- P. Norvig, S. Russell: Künstliche Intelligenz - München: Pearson 2004

Language:

- offered only in English

Notes:

Prerequisites for attending the module:
- None

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Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

RO4500-KP08 - Advanced Control and Estimation (ACE)

Duration:	Turnus of offer:	Credit points:
2 Semester	each semester	8

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st and 2nd semester

Classes and lectures:

- Linear Systems Theory (lecture, 2 SWS)
- Linear Systems Theory (exercise, 2 SWS)
- Graphical Models in Systems and Control (lecture, 2 SWS)
- Graphical Models in Systems and Control (exercise, 1 SWS)

Workload:

- 120 Hours in-classroom work
- 70 Hours private studies
- 30 Hours in-classroom exercises
- 20 Hours exam preparation

Contents of teaching:

- Content of teaching for course Linear Systems Theory:
- Vector spaces, norms, linear operators
- Eigenvalues, eigenvectors, Jordan normal form
- Singular value decomposition and operator norms
- Linear systems in continuous and discrete time
- Modeling of linear systems and linearization
- Fundamental solution to linear systems state equations
- Laplace transform and z-transform
- Content of teaching for course Graphical Models in Systems and Control:
- Introduction to Probability Theory, Discretely and Continuously Distributed Random Variables
- Fundamentals on Probabilistic Graphical Models
- Forney-Style Factor Graphs as a Probabilistic Graphical Model
- Message Passing via Sum- and Max-Produkt Algorithms
- Gaussian Message Passing
- State Estimation (Kalman Filtering and Smoothing including Nonlinear Extensions)
- Parameter Estimation via Expectation Maximization
- Expectation Propagation
- Control on Factor Graphs

Qualification-goals/Competencies:

- Educational objectives for course Linear Systems Theory:
- Students are familiar with the important basic concepts of linear algebra.
- Students have a solid background in the theory of linear systems in continuous and disrete time.
- Students are able to model linear systems in mechanical and electrical domain from first principles.
- Students are able to solve the state equations and analyze systems in the time and frequency domain.
- Students improve their problem solving and mathematical skills.
- Students develop their techniques for logical reasoning and and rigorous proofs.
- Students are enabled to perform reseaerch in the field of systems and control theory.
- Educational objectives for course Graphical Models in Systems and Control:
- Students develop and extend their fundamental knowledge on probability theory and the transformation of discretely as well as continuously distributed random variables.
- Students can understand simple linear algorithms, such as the Kalman filter, with the help of graphical probabilistic models.
- Students can combine elements of probabilistic algorithms to novel ones with the help of graphical probabilistic models.
- Students can understand, extend and apply advanced algorithms in signal processing, parameter and state estimation as well as control to relevant problems with the help of graphical probabilistic models.

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr. Philipp Rostalski
- Prof. Dr. Georg Schildbach

Teacher:

- Institute for Electrical Engineering in Medicine

- Prof. Dr. Georg Schildbach
- Dr.-Ing. Christian Herzog

Literature:

- Loeliger, Hans-Andrea; Dauwels, Justin; Hu, Junli; Korl, Sascha; Ping, Li; Kschischang, Frank R.: The Factor Graph Approach to Model-Based Signal Processing - Proc. IEEE, Vol. 95, No. 6, 2007
- Loeliger, Hans-Andrea: An Introduction to factor graphs - IEEE Signal Process. Mag., Vol. 21, No. 1, 2004
- Hoffmann, Christian; Rostalski, Philipp: Current Publications from Research at the IME
- Miscellaneous: Current Publications from Research

Language:

- offered only in English

Notes:

Prerequisites for attending the module:
- None

RO5100-KP08 - Medical Robotics (MedRob08)

Duration:	Turnus of offer:	Credit points:
2 Semester	every summer semester	8

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st or 2nd semester

Classes and lectures:

- ME4030 T: Inverse Probleme bei der Bildgebung (lecture with exercises, 3 SWS)
- Siehe CS4270: Medizinische Robotik (lecture with exercises, 4 SWS)

Workload:

- 125 Hours private studies
- 90 Hours in-classroom work
- 25 Hours exam preparation

Contents of teaching:

- see module parts

Qualification-goals/Competencies:

- see module parts

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr.-Ing. Achim Schweikard

Teacher:

- Institute of Computer Engineering
- Institute for Electrical Engineering in Medicine
- Institute of Medical Engineering
- Institute of Medical Informatics
- Institute for Robotics and Cognitive Systems

Language:

- offered only in English

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

RO5200-KP08 - Bio-inspired Robotics (BRS)

Duration:	Turnus of offer:	Credit points:
2 Semester	each semester	8

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, arbitrary semester

Classes and lectures:

- Collective Robotics (lecture, 2 SWS)
- Collective Robotics (exercise, 1 SWS)
- Evolutionary Robotics (lecture, 2 SWS)
- Evolutionary Robotics (exercise, 1 SWS)

Workload:

- 110 Hours in-classroom work
- 110 Hours private studies
- 20 Hours exam preparation

Contents of teaching:

- Biological basics
- Self-organization, robustness, scalability, superlinear speedups
- Robot swarms by land, by sea, and by air
- Mathematical modeling of swarms and collective decision-making
- Evolutionary computation
- Artificial evolution of robot controllers and robot morphologies
- Optimization and learning in robot experiments

Qualification-goals/Competencies:

- Students get a comprehensive overview of biologically inspired.
- Students are able to assess chances and challenges of robust and scalable robot systems.
- Students are able to implement reactive control for swarm robots in simulation and on mobile robots.
- Students are able to implement evolutionary algorithms and artificial neural networks and are able to apply them to problems of mobile robots in.
- Students are able to name challenges of evolutionary robotics in applications and to discuss potential solutions.

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr.-Ing. Heiko Hamann

Teacher:

- Institute of Computer Engineering

- Prof. Dr.-Ing. Heiko Hamann

Literature:

- Nolfi, S., Floreano, D.: The Biology, Intelligence, and Technology of Self-Organizing Machines - MIT Press, 2001
- Hamann, H.: Swarm Robotics: A Formal Approach - Springer 2018

Language:

- offered only in English

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

RO5500-KP08 - Autonomous Vehicles (AV)

Duration:	**Turnus of offer:**	**Credit points:**
2 Semester	each semester	08

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st and 2nd semester

Classes and lectures:	**Workload:**
• Vehicle Dynamics and Control (lecture, 2 SWS) • Vehicle Dynamics and Control (exercise, 2 SWS) • Perception for Autonomous Vehicles (lecture, 2 SWS) • Perception for Autonomous Vehicles (exercise, 2 SWS)	• 140 Hours private studies • 60 Hours in-classroom work • 40 Hours exam preparation

Contents of teaching:

- Content of teaching of the course Vehicle Dynamics and Control:
- Review of control methods and rigid body dynamics
- Basic terminology of vehicle dynamics
- Vehicle dynamic models (lateral, longitudinal, vertical)
- Component models (engine, transmission, brake, steering)
- Tire modeling
- Stability analysis
- Handling performance
- Active safety systems
- Autonomous driving
- Content of teaching of the course Perception for Autonomous Driving:
- The architecture of autonomous-driving systems
- Tracking, detection, classification
- Models of stochastic signals
- Transform-based analysis of stochastic signals
- System theory
- Parameter estimation
- Linear optimal filters and adaptive filters
- Graphical models and dynamic Bayes networks
- Neural networks
- Hidden Markov Models, Kalman Filter, Particle Filter, etc.
- Applications in the domain of autonomous driving

Qualification-goals/Competencies:

- Educational objectives of the course Vehicle Dynamics and Control:
- Students master basic terminology and concepts of vehicle dynamics.
- Students obtain a comprehensive understanding of the dynamics of a vehicle.
- Students understand the main objectives of vehicle control.
- Students can derive basic vehicle dynamics models for control design.
- Students are able to apply concepts of basic and advanced control and estimation to practical problems.
- Students get an insight into the field of active safety systems, driver assistance, and autonomous driving.
- Students are able to perform independent design, research and development work in this field.
- Educational objectives of the course Perception for Autonomous Driving:
- Students get an overview on autonomous-driving systems.
- Students become thoroughly acquainted with the perception layer of the architecture of an autonomous-driving system.
- Students get a comprehensive introduction to stochastic signals.
- Students master tools for the analysis of stochastic signals.
- Students are able to make use of various models for stochastic signals.
- Students are able to design tracking algorithms.
- Students are able devise algorithmic solutions to decision problems, while making use of prior knowledge.

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Control Systems (RO4400-KP08)
- Technical Mechanics (RO1500-KP08)

Responsible for this module:

- Prof. Dr. Georg Schildbach

Teacher:

- Institute for Electrical Engineering in Medicine

- Prof. Dr. Georg Schildbach
- PD Dr.-Ing. habil. Alexandru Paul Condurache

Literature:

- Rajamani, R: Vehicle Dynamics and Control (2nd edition) - Springer, 2012, ISBN 978-1-4614-1432-2
- Mitschke, M; Wallentowitz, H.: Dynamik der Kraftfahrzeuge (5th edition) - Springer, 2014 (ISBN: 978-3-658-05067-2)
- Charles W. Therrien: Decision estimation and classification - J. Wiley and Sons, 1991.
- Simon Haykin: Adaptive Filter Theory - Prentice Hall, 1996
- Christopher M. Bishop: Pattern recognition and machine learning - Springer, 2006
- A. Mertins: Signaltheorie: Grundlagen der Signalbeschreibung, Filterbänke, Wavelets, Zeit-Frequenz-Analyse, Parameter- und Signalschätzung - Springer-Vieweg, 3. Auflage, 2013

Language:

- offered only in English

Notes:

(RO5500-L1 Partial Exam Vehicle Dynamics and
Control (Graded Exam, 4 KP))
(RO5500-L2 Partial Exam Perception for
Autonomous Vehicles (Graded Exam, 4 KP))

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

RO5800-KP04, RO5801-KP04 - Advanced Topics in Robotics (ATiR)

Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	4

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st or 2nd semester

Classes and lectures:

- Advanced Topics in Robotics (lecture, 2 SWS)
- Advanced Topics in Robotics (exercise, 1 SWS)

Workload:

- 55 Hours private studies
- 45 Hours in-classroom work
- 20 Hours exam preparation

Contents of teaching:

- Dynamics and Control of Robots
- Motion Planning for Robots
- Augmented Reality
- Design of Robot Systems
- Intracorporal Robotics

Qualification-goals/Competencies:

- Students understand the connection to underlying mathematical methods, especially in dynamics, optimization, and sensor data processing and analysis of algorithms.
- Students have an extended overview of application areas for robotics.
- They are able to implement such methods and derive new applications based on such methods.

Grading through:

- written exam, oral exam and/or presentation as announced by the examiner

Requires:

- Robotics (CS2500-KP04, CS2500)

Responsible for this module:

- Prof. Dr.-Ing. Achim Schweikard

Teacher:

- Institute for Robotics and Cognitive Systems

- Prof. Dr.-Ing. Achim Schweikard

Literature:

- Achim Schweikard, Floris Ernst: Medical Robotics - Springer, 2015, Jocelyne Troccaz (ed.): Medical Robotics, Wiley, 2009

Language:

- offered only in English

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

RO5800-KP08 - Advanced Topics in Robotics (ATR)

Duration:	Turnus of offer:	Credit points:
2 Semester	each year, can be started in winter or summer semester	8

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 1st or 2nd semester

Classes and lectures:

- Advanced Topics in Robotics (lecture, 2 SWS)
- Advanced Topics in Robotics (exercise, 1 SWS)
- Rescue Robotics (lecture, 2 SWS)
- Rescue Robotics (exercise, 2 SWS)

Workload:

- 105 Hours in-classroom work
- 95 Hours private studies
- 40 Hours exam preparation

Contents of teaching:

- Content of teaching of the course Advanced Topics in Robotics:
- Motion Planning for Robots
- Augmented Reality
- Design of Robot Systems
- Intracorporal Robotics
- Dynamics and Control of Robots
- Content of teaching of the course Rescue Robotics:
- Special requirements for disaster management and response and the resulting consequences on rescue robot design.
- Information structures for rescue systems
- Information exchange between rescue robots
- Command and control systems for search and rescue robots
- Tactical communication for cooperative SAR robot missions as well as interoperability in heterogeneous teams.
- Design guidelines for human interfaces to rescue robots
- Casualty and vital sign detection in rescue scenarios
- Medical assistance at the scene of incident and determination of vital signs
- Evaluation and benchmarking of SAR robots

Qualification-goals/Competencies:

- Educational objectives of the course Advanced Topics in Robotics:
- Students understand the connection to underlying mathematical methods, especially in dynamics, optimization, and sensor data processing and analysis of algorithms.
- Students have an extended overview of application areas for robotics.
- They are able to implement such methods and derive new applications based on such methods.
- Educational objectives of the course Rescue Robotics:
- The students can applz the tools to program and simulate mobile rescue robots. They have developed a good overview about mobile robotics, localization and path planning in difficult scenarios.
- The students have knowledge about the work and command structures of rescue personell and the requirements on control, communcation and interaction of rescue robots with the personnel.
- The students have developed a notion of medical first response by rescue personnel as well as technical solutions to locate missing persons, determine vital signs and realize medical assistance at the scene of incident.

Grading through:

- written exam, oral exam and/or presentation as announced by the examiner

Requires:

- Robotics (CS2500-KP04, CS2500)

Responsible for this module:

- Prof. Dr.-Ing. Achim Schweikard

Teacher:

- Institute for Robotics and Cognitive Systems

- Prof. Dr.-Ing. Achim Schweikard

- Prof. Dr. rer. nat. Floris Ernst

Literature:

- Achim Schweikard, Floris Ernst: Medical Robotics - Springer, 2015, Jocelyne Troccaz (ed.): Medical Robotics, Wiley, 2009
- Tadokoro, Satoshi, ed.: Rescue robotics: DDT project on robots and systems for urban search and rescue. - Springer Science & Business Media, 2009. (ISBN: 978-1447157656).
- Siciliano, Bruno, and Oussama Khatib, eds.: Springer handbook of robotics. - Springer, 2016. (ISBN: 978-3319325507)

Language:

- offered only in English

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

PS5000-KP06, PS5000 - Student Conference (ST)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	6 (Typ B)

Course of study, specific field and term:

- Master MES 2020 (compulsory), interdisciplinary competence, 3rd semester
- Master Medical Informatics 2019 (compulsory), interdisciplinary competence, 3rd semester
- Master Biophysics 2019 (compulsory), biophysics, 3rd semester
- Master Auditory Technology 2017 (compulsory), Auditory Technology, 3rd semester
- Master Interdisciplinary Courses (optional subject), Interdisciplinary modules, arbitrary semester
- Master Robotics and Autonomous Systems 2019 (compulsory), Compulsory courses, 3rd semester
- Master Medical Informatics 2014 (compulsory), interdisciplinary competence, 3rd semester
- Master MES 2014 (compulsory), interdisciplinary competence, 3rd semester

Classes and lectures:

- Student Conference (seminar, 4 SWS)

Workload:

- 155 Hours work on an individual topic (research and development) and written elaboration
- 25 Hours in-classroom work

Contents of teaching:

- Preparation of a scientific publication in English based on the results of at least one of the project internships
- Preparation of a scientific poster in English based on the results of at least one of the project internships
- Presentation of a scientific poster in German or English, based on the results of at least one of the project internships
- Talk in English based on the results of at least one of the project internships
- Active participation in scientific discussions
- Active participation in a scientific peer-review process

Qualification-goals/Competencies:

- Students have experience in a comprehensive review of a scientific topic
- They are able to get an extensive overview of a complex scientific area
- They have the experience and ability to take an active part in scientific discussions
- They are able to defend one's work successfully in a scientific discourse
- They have knowledge of the peer-review process of publications
- They are able to constructively criticize in a blind peer-review process
-

Grading through:

- B-Certificate (not graded)

Responsible for this module:

- Prof. Dr. rer. nat. habil. Heinz Handels
- Prof. Dr. rer. nat. Thorsten Buzug

Teacher:

- All Institutes and Clinics of the Universität zu Lübeck

Literature:

- is selected individually:

Language:

- offered only in English

Notes:

Admission requirements for the module:
- Successful completion of at least one project internship.
- Registration for at least one project internship is required.

Admission requirements for the examination:
- Regular and successful participation

Since the content of the presentation should reflect the results of at least one of the project internships, the students will be supervised by the same university lecturer that supervised the internships. Internships can be carried out at home or abroad in medical technology companies, audiology companies and IT companies in the healthcare industry as well as hospitals and scientific institutions. The supervision by an university lecturer is obligatory.

Students for whom this course is a compulsory module have priority.

(The share of the Institute of Medical Technology in all is 75%)
(Share of medical informatics in all is 25%)

RO4000-KP12 - Autonomous Systems (AS)

Duration:	**Turnus of offer:**	**Credit points:**
2 Semester	each winter semester	12

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (compulsory), Compulsory courses, 1st and 2nd semester

Classes and lectures:

- Real-Time Systems (lecture, 2 SWS)
- Real-Time Systems (exercise, 2 SWS)
- Model Predictive Control (lecture, 2 SWS)
- Model Predictive Control (exercise, 2 SWS)

Workload:

- 140 Hours private studies
- 120 Hours in-classroom work
- 40 Hours exam preparation

Contents of teaching:

- Content of teaching of the course Real-Time Systems:
- Real-time processing (definitions, requirements)
- Process automation systems
- Real-time programming
- Process connectivity and networking
- Modelling of discrete event systems (automata, state charts)
- Modelling of continuous systems (differential equations, Laplace transformation)
- Application of design tools (Matlab/Simulink, Stateflow)
- Content of teaching of the course Model Predictive Control:
- LQ optimal control and Kalman filter
- Convex optimization
- Invariant sets
- Theory of Model Predictive Control (MPC)
- Algorithms for numerical optimization
- Explicit MPC
- Practical aspects (Robust MPC, Offset-free tracking, etc.)
- MPC applications

Qualification-goals/Competencies:

- Educational objectives of the course Real-Time Systems:
- The students are able to describe the fundamental problems of real-time processing.
- They are able to explain real-time computer systems for process automation, in particular SPS.
- They are able to program real-time systems in the IEC languages.
- They are able to elucidate process interfaces and real-time bus system.
- They are able to model, analyze and implement event discrete systems, in particular process control systems.
- They are able to model, analyze and implement continuous systems, in particular feedback control systems.
- They are able to make use of design tools for real-time systems.
- Educational objectives of the course Model Predictive Control:
- Students get a comprehensive introduction to methods of optimal control.
- Students get an overview of the fundamentals of numerical optimization.
- Students are able to design model predictive controllers for linear and nonlinear systems.
- Students get acquainted with several tools to implement model predictive controllers.
- Students are able to establish system theoretic properties of model predictive controllers.
- Students gain insight into possible applications areas for MPC.

Grading through:

- Written or oral exam as announced by the examiner

Requires:

- Control Systems (RO4400-KP08)

Responsible for this module:

- Prof. Dr. Georg Schildbach

- Prof. Dr.-Ing. Mladen Berekovic

Teacher:

- Institute for Electrical Engineering in Medicine
- Institute of Computer Engineering

- Prof. Dr.-Ing. Mladen Berekovic
- MitarbeiterInnen des Instituts
- Prof. Dr. Georg Schildbach
- MitarbeiterInnen des Instituts

Literature:

- R. C. Dorf, R. H. Bishop: Modern Control Systems - Prentice Hall 2010
- L. Litz: Grundlagen der Automatisierungstechnik - Oldenbourg 2012
- M. Seitz: Speicherprogrammierbare Steuerungen - Fachbuchverlag Leipzig 2012
- H. Wörn, U. Brinkschulte: Echtzeitsysteme - Berlin: Springer 2005
- S. Zacher, M. Reuter: Regelungstechnik für Ingenieure - Springer-Vieweg 2014
- F. Borrelli, A. Bemporad, M. Morari: Predictive Control for Linear and Hybrid Systems - Cambridge University Press, 2017 (ISBN: 978-1107016880)

Language:

- German and English skills required

Notes:

Prerequisites for attending the module:
- None

Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

RO4100-KP08 - Robot Learning (RobLe)		
Duration:	**Turnus of offer:**	**Credit points:**
2 Semester	each winter semester	8

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (compulsory), Compulsory courses, 1st and 2nd semester

Classes and lectures:

- Probabilistic Machine Learning (lecture, 2 SWS)
- Probabilistic Machine Learning (exercise, 1 SWS)
- Reinforcement Learning (lecture, 2 SWS)
- Reinforcement Learning (exercise, 1 SWS)

Workload:

- 120 Hours work on project
- 120 Hours private studies
- 60 Hours in-classroom exercises
- 60 Hours in-classroom work

Contents of teaching:

- Introduction to Probability Theory (Statistics refresher, Bayes Theorem, Common Probability distributions, Gaussian Calculus).
- Linear Probabilistic Regression (Linear models, Maximum Likelihood, Bayes & Logistic Regression).
- Nonlinear Probabilistic Regression (Radial basis function networks, Gaussian Processes, Recent research results in Robotic Movement Primitives, Hierarchical Bayesian & Mixture Models).
- Probabilistic Inference for Filtering, Smoothing and Planning (Classic, Extended & Unscented Kalman Filters, Particle Filters, Gibbs Sampling, Recent research results in Neural Planning).
- Probabilistic Optimization (Stochastic black-box Optimizer Covariance Matrix Analyses-Evolutionary Strategies & Natural Evolutionary Strategies, Bayesian Optimization).
- Introduction to Robotics and Reinforcement Learning (Refresher on Robotics, kinematics, model learning and learning feedback control strategies).
- Foundations of Decision Making (Reward Hypothesis, Markov Property, Markov Reward Process, Value Iteration, Markov Decision Process, Poicy Iteration, Bellman Equation, Link to Optimal Control).
- Principles of Reinforcement Learning (Exploration and Exploitation strategies, On & Off-policy learning, model-free and model-based policy learning, Algorithmic principles: Q-Learning, SARSA, TD-Learning, Function Approximation, Fitted Q-Iteration).
- Advanced Policy Gradient Methods (Introduction to Gradient Descent, Finite Differences, Likelihood Ratio Trick & Policy Gradient, Natural Policy Gradient, Step Size Adaptation Mechanisms, Recent research results in Relative Entropy Policy Search).
- Deep Reinforcement Learning (Introduction to Deep Networks, Stochastic Gradient Descent, Deep Q-Learning, Recent research results in Stochastic Deep Neural Networks).

Qualification-goals/Competencies:

- Students get a comprehensive understanding of basic probability theory concepts and methods.
- Students learn to analyze the challenges in a task and to identify promising machine learning approaches.
- Students will understand the difference between deterministic and probabilistic algorithms and can define underlying assumptions and requirements.
- Students understand and can apply advanced regression, inference and optimization techniques to real world problems.
- Students know how to analyze the models   results, improve the model parameters and can interpret the model predictions and their relevance.
- Students understand how the basic concepts are used in current state of the art research in robot movement primitive learning and in neural planning.
- Students get a comprehensive understanding of basic decision making theories, assumptions and methods.
- Students learn to analyze the challenges in a reinforcement learning application and to identify promising learning approaches.
- Students will understand the difference between deterministic and probabilistic policies and can define underlying assumptions and requirements for learning them.
- Students understand and can apply advanced policy gradient methods to real world problems.
- Students know how to analyze the learning results and improve the policy learner parameters.
- Students understand how the basic concepts are used in current state of the art research in robot reinforcement learning and in deep neural networks.

Grading through:

- Written or oral exam as announced by the examiner

Responsible for this module:

- Prof. Dr. Elmar Rückert

Teacher:

- Institute for Robotics and Cognitive Systems

- Prof. Dr. Elmar Rückert
- MitarbeiterInnen des Instituts

Literature:

- Daphne Koller, Nir Friedman: Probabilistic Graphical Models: Principles and Techniques - ISBN 978-0-262-01319-2
- Christopher M. Bishop: Pattern Recognition and Machine Learning - Springer (2006), ISBN 978-0-387-31073-2
- David Barber: Bayesian Reasoning and Machine Learning - Cambridge University Press (2012), ISBN 978-0-521-51814-7
- Kevin P. Murphy: Machine Learning: A Probabilistic Perspective - ISBN 978-0-262-01802-9

Language:

- offered only in English

Notes:

The course is accompanied by three graded assignments on Probabilistic Regression, Probabilistic Inference and on Probabilistic Optimization. The assignments will include algorithmic implementations in Matlab, Python or C++ and will be presented during the exercise sessions. The Robot Operating System (ROS) will also be part in some assignments as well as the simulation environment Gazebo.

The course is accompanied by three pieces of course work on Policy Search for discrete state and action spaces (grid world example), policy learning in continuous spaces using function approximations and policy gradient methods in challenging simulated robotic tasks. The assignments will include both written tasks and algorithmic implementations in Python, and will be presented during the exercise sessions. The OpenAI Gym platform will used in the project works.

Prerequisites for attending the module:
- None
▯
Prerequisites for the exam:
- Successful completion of homework assignments during the semester.

RO4300-KP08 - Machine Learning and Computer Vision (MLRAS)

Duration:	Turnus of offer:	Credit points:
2 Semester	normally each year in the winter semester	8

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (compulsory), Compulsory courses, 1st and 2nd semester

Classes and lectures:

- Machine Learning (lecture, 2 SWS)
- Machine Learning (exercise, 1 SWS)
- Computer Vision (lecture, 2 SWS)
- Computer Vision (exercise, 1 SWS)

Workload:

- 110 Hours private studies
- 90 Hours in-classroom work
- 40 Hours exam preparation

Contents of teaching:

-
- Representation learning, including manifold learning
- Statistical learning theory
- VC dimension and support vector machines
- Boosting
- Deep Learning
- Limits of induction and importance of data ponderation
-
- Introduction to human and computer vision
- Sensors, cameras, optics and projections
- Image features: edges, intrinsic dimension, Hough transform, Fourier descriptors, snakes
- Range imaging and 3-D cameras
- Motion and optical flow
- Object recognition
- Example applications

Qualification-goals/Competencies:

-
- Students can understand and explain various machine-learning problems.
- They can explain and apply different machine learning methods and algorithms.
- They can chose and then evaluate an appropriate method for a particular learning problem.
- They can understand and explain the limits of automatic data analysis.
-
- Students can understand the basics of computer vision.
- They can explain and perform camera choice and calibration.
- They can explain and apply the basic methods for feature extraction, motion estimation, and object recognition.
- They can indicate appropriate methods for different kinds of computer-vision applications.

Grading through:

- Oral examination

Responsible for this module:

- Prof. Dr.-Ing. Erhardt Barth

Teacher:

- Institute for Neuro- and Bioinformatics

- Prof. Dr.-Ing. Erhardt Barth
- Prof. Dr. rer. nat. Thomas Martinetz

Literature:

- Chris Bishop: Pattern Recognition and Machine Learning - Springer ISBN 0-387-31073-8
- Vladimir Vapnik: Statistical Learning Theory - Wiley-Interscience, ISBN 0471030031
- Richard Szeliski: Computer Vision: Algorithms and Applications - Springer, Boston, 2011

- David Forsyth and Jean Ponce: Computer Vision: A Modern Approach - Prentice Hall, 2003

Language:

- English, except in case of only German-speaking participants

Notes:

Prerequisites for admission to the examination can be determined at the beginning of the semester. If such prerequisites are defined, they must have been fulfilled prior to the first attempt at the examination and must have been rated as positive.

Prerequisites for admission to the examination:
Successful participation in the exercises,
minimum pass percentage: 70 %

Prerequisites for attending the module:
- None

RO5000-KP12 - Internship Robotics and Autonomous Systems 1 (ProPraRAS1)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	12

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (compulsory), Compulsory courses, 3rd semester

Classes and lectures:

- Internship 1 (block practical course, 12 SWS)

Workload:

- 320 Hours work on project
- 40 Hours written report

Contents of teaching:

- project task in a specific application scenario
- documentation, presentation, motivation in a heterogeneous environment
- the project task is embedded in a heterogeneous and vivid environment with substantial communication and integration demands

Qualification-goals/Competencies:

- The students have a deep understanding of selected aspects of robotics and autonomous systems.
- They are able to implement selected aspects of robotics and autonomous systems.
- They are able to document and present project results.
- They are capacble of presenting to particular audiences or under time restrictions (eg elevator pitch etc.).
- They have project experience in concrete application scenarios.
- They have basic skills in the field of project management.

Grading through:

- documentation

Responsible for this module:

- Prof. Dr. Philipp Rostalski

Teacher:

- Institute of Computer Engineering
- Institute for Robotics and Cognitive Systems
- Institute for Electrical Engineering in Medicine

Language:

- English, except in case of only German-speaking participants

Notes:

The internship may be completed at the University of Lübeck or any external domestic or foreign university, research laboratory, or company in the domain of robotics and autonomous systems.

Prerequisites for attending the module:
- None

RO5001-KP12 - Internship Robotics and Autonomous Systems 2 (ProPraRAS2)

Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	12

Course of study, specific field and term:

- Master Robotics and Autonomous Systems 2019 (compulsory), Compulsory courses, 3rd semester

Classes and lectures:

- Internship 2 (block practical course, 12 SWS)

Workload:

- 320 Hours work on project
- 40 Hours written report

Contents of teaching:

- project task in a specific application scenario
- documentation, presentation, motivation in a heterogeneous environment
- the project task is embedded in a heterogeneous and vivid environment with substantial communication and integration demands

Qualification-goals/Competencies:

- The students have a deep understanding of selected aspects of medical engineering.
- They are able to implement selected aspects of medical engineering.
- They are able to document and present project results.
- They are capacble of presenting to particular audiences or under time restrictions (eg elevator pitch etc.).
- They have project experience in concrete application scenarios.
- They have basic skills in the field of project management.

Grading through:

- documentation

Responsible for this module:

- Prof. Dr. Philipp Rostalski

Teacher:

- Institute of Computer Engineering
- Institute for Robotics and Cognitive Systems
- Institute for Electrical Engineering in Medicine

- Alle prüfungsberechtigten Dozentinnen/Dozenten des Studienganges

Language:

- English, except in case of only German-speaking participants

Notes:

The internship may be completed at the University of Lübeck or any external domestic or foreign university, research laboratory, or company in the domain of robotics and autonomous systems.

Prerequisites for attending the module:
- None