

UNIVERSITÄT ZU LÜBECK

Module Guide for the Study Path

Master Robotics and Autonomous Systems 2019

Version from 1. April 2025



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interdisciplinary competence

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

advanced curriculum

Cyber Physical Systems (CS4504-KP12, CS4504, CPS)1Advanced Control and Estimation (RO4500-KP12, ACES)1Medical Robotics (RO5100-KP12, MedRob12)1Bio-inspired Robotics (RO5200-KP12, BR)1Autonomous Vehicles (RO5500-KP12, AVS)1	Ambient Computing and Applications (CS4503-KP12, CS4503, AmbCompA)	3
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Additionally recognized elective module

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Energy Efficiency in Emebedded Systems (CS4720-KP06, EEE)	81
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Optimization (MA4030-KP08, MA4030, Opti)	86
Rescue Robotics (RO5803-KP04, RR)	88



EC5010-KP04, EC5010 - Entrepreneurship in the digital economy (EEntre)			
uration: 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:		Workload:	
 Entrepreneurship in the digital ecor Entrepreneurship in the digital ecor 	Classes and lectures: Entrepreneurship in the digital economy (lecture, 2 SWS) Entrepreneurship in the digital economy (exercise, 1 SWS)		
 In this class students obtain a key in shaping and changing of young cor time, this class will include strategy entrepreneurship in the context of o Special emphasize will be on start-u Qualification-goals/Competencies: 	sight into the entrepreneur npanies. In addition, studer development, fundamental established enterprises and ps in the digital economy.	ial processes, the identificants are able to understand laspects of corporate mark social entrepreneurship.	ation of business opportunities as well as the business models on a basic level. At the same seting, growth forms and strategies,
 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 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: • portfolio exam			
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: 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 			
English, except in case of only German-speaking participants			
Notes:			



Prerequisites for attending the module: - none

Prerequisites for participation in module exam(s):

- none

- 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.

Module exam(s):

- EC5010-L1: Entrepreneurship in the Digital Economy, portfolio exam, 100 % of module grade

The portfolio exam consists of the following:

- Group work(s) (Presentation), 40 %

- (Online)exams, 60 %

The commercial rounding is used to determine the overall grade.

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

Registration takes place at the beginning of the semester via Moodle. Further questions related to registration and exam will be clarified during the first lectures.

(Formerly EC5010-KP04)



CS4503-KP12, CS4503 - Ambient Computing and Applications (AmbCompA)				
Duration:	ration: Turnus of offer:		Credit points:	
2 Semester	normally each year in the summer semester		12	
Course of study, specific field and term Master Robotics and Autonomous Master Entrepreneurship in Digital Master Computer Science 2019 (op Master IT-Security 2019 (advanced Master Entrepreneurship in Digital Master Computer Science 2014 (advanced)	: Systems 2019 (advanced mo Technologies 2020 (advanc otional subject), advanced m module), Elective Compute Technologies 2014 (advanced dvanced module), advanced	odule), advanced curriculum ed module), specific, Arbitra odule, Arbitrary semester r Science, 1st or 2nd semest ed module), specific, 2nd an curriculum, 2nd and/or 3rd	n, Arbitrary semester ıry semester er ıd/or 3rd semester semester	
Classes and lectures:		Workload:		
 CS4670 T: Ambient Computing (le Seminar Ambient Computing (sen Lab Course Ambient Computing (cture, 3 SWS) ninar, 2 SWS) project work, 3 SWS)	 120 Hours group 120 Hours in-clas 70 Hours private 30 Hours oral pre 20 Hours exam p 	work sroom work studies sentation (including preparation) reparation	
Contents of teaching:				
 Current paradigms in computer tee Smart components Software architectures Context-sensitive systems Ambient Intelligence Interactive ambient media system Ambient Computing Applications Ethical, Legal and Social Implication Qualification-goals/Competencies: Ambient Computing: The students are able to evaluate 	s (AAL) ons (ELSI) possibilities, concepts and cl	nallenges of Ambient Syster	ns	
 They have an overview about current technologies and systems for developing Ambient Systems They are able to follow and judge state-of-the-art research in the area of Ambient Computing 				
Grading through: • portfolio exam				
Responsible for this module:				
• Prof. DrIng. Andreas Schrader				
Institute of Telematics				
Prof. DrIng. Andreas Schrader				
Literature: • John Krumm: Ubiquitous Computi • Stefan Poslad: Ubiquitous Comput	ing Fundamentals - CRC Pres ting: Smart Devices, Environr	is, 2009 nents and Interactions - Wil	ey, 2009	
• German and English skills required	1			
Notes:				



Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s):

- Successful completion of the project assignment as specified at the beginning of the semester.
- Seminar lecture with elaboration according to the requirements at the beginning of the semester

Module Exam(s):

- CS4503-L1: Ambient Computing and Applications, Portfolio exam consisting of: 20 points in the form of a seminar paper with presentation, 20 points in the form of a project paper and 60 points in the form of an oral exam, 100% of module grade.

(Consists of CS4670 T)

(share of Institute of Telematics in S is 100%) (share of Institute of Telematics in P is 100%)



CS4504-KP12, CS4504 - Cyber Physical Systems (CPS)				
Duration:	Turnus of offer:		Credit points:	
2 Semester	each year, can be started in	winter or summer semester	12	
Course of study, specific field and ter Master Entrepreneurship in Dig Master Computer Science 2019 Master Robotics and Autonomo Master IT-Security 2019 (advance Master Entrepreneurship in Dig Master Computer Science 2014	m: ital Technologies 2020 (advance (optional subject), advanced mo us Systems 2019 (advanced mo ed module), Elective Computer ital Technologies 2014 (advanced (advanced module), advanced c	ed module), specific, Arbitra odule, Arbitrary semester dule), advanced curriculum Science, 1st or 2nd semeste ed module), specific, 2nd an curriculum, 2nd and/or 3rd	ary semester n, 1st or 2nd semester er nd/or 3rd semester semester	
Classes and lectures:		Workload		
 CS5150 T: Organic Computing (CS5153 T: Wireless Sensor Netw SWS) CS4504-S: Cyber Physical System 	Classes and lectures: Workload: • CS5150 T: Organic Computing (lecture with exercises, 3 SWS) • 220 Hours private studies • CS5153 T: Wireless Sensor Networks (lecture with exercises, 3 SWS) • 120 Hours in-classroom work • CS4504-S: Cyber Physical Systems (seminar, 2 SWS) • 20 Hours exam preparation			
Contents of teaching:				
 basic principles of organic com from motion to intelligent beha design for self-organization, rol analyzing, reverse-engineering, designing experiments and me modeling system/machine beh complexity, opacity, obscurity, i architecture of organic comput applications of self-x systems basics of wireless sensor netwo hardware aspects of sensor noc physics and protocols of wireles routing in wireless networks time synchronization and locali data management and data pro applications of wireless sensor 	outing / self-x system properties wior and system/machine behavior bustness, adaptivity, flexibility, tr debugging machine behavior asuring behavior avior trust of (AI) systems and explain ing systems rks les ss communication zation in wireless networks ocessing in wireless sensor networks	s vior rust able Al		
Qualification-goals/Competencies: Students are able to utilize the They are able to explain princip They are able to analyze system Students are able to present th They are able to cope with anal They are able to interpret and p 	principles of organic computing les of organic computing/self-x n/machine behaviors in a structu pros and cons of sensor netwo ysis, design, and evaluation of p pursue current research activities	J/self-x systems on exempla systems. Ired, sound approach. orks. orotocols in sensor network s for sensor networks.	ary designs. s.	
Crading through				
Oral examination				
Responsible for this module: • Prof. DrIng. Mladen Berekovic Teacher: • Institute of Computer Engineeri • Dr. rer. nat. Javad Ghofrani Literature:	ng			
 C. Müller-Schloer, S. Tomforde: H. Karl, A. Willig: Protocols and 	Organic Computing Technical Architectures of Wireless Sensor	Systems for Survival in the Networks - Wiley, 2005	Real World - Birkhäuser, 2017	



Language:

• offered only in English

Notes:

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s):

- Successful completion of exercises as specified at the beginning of the semester.
- Seminar lecture and elaboration according to the requirements at the beginning of the semester

Module Exam(s):

- CS4504-L1: Cyber Physical Systems, oral exam, 100% of the module grade.

(Consists of CS5150 T, CS5153 T)



RO	04500-KP12 - Advanced O	Control and Estimation	n (ACES)	
Duration:	Turnus of offer:		Credit points:	
2 Semester	each semester		12	
Course of study, specific field and to • Master Robotics and Autonom	e rm: ous Systems 2019 (advanced m	odule), advanced curriculun	n, 1st and 2nd semester	
Classes and lectures:		Workload:		
 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) 		e studies ssroom work room exercises reparation		
 Contents of teaching: Content of teaching for course Vector spaces, norms, linear of Eigenvalues, eigenvectors, Jor Singular value decomposition Linear systems in continuous a Modeling of linear systems and Fundamental solution to linea Laplace transform and z-transfor Content of teaching for course Introduction to Probability The Fundamentals on Probabilistic Forney-Style Factor Graphs as Message Passing via Sum- and Gaussian Message Passing State Estimation (Kalman Filte Parameter Estimation via Experience Expectation Propagation Content of teaching of the ser Current state of the art algorit 	e Linear Systems Theory: berators dan normal form and operator norms and discrete time d linearization r systems state equations form e Graphical Models in Systems an eory, Discretely and Continuousl Graphical Models a Probabilistic Graphical Model Max-Produkt Algorithms ring and Smoothing including N ctation Maximization	nd Control: ly Distributed Random Varia lonlinear Extensions) imation: ing, estimation, identificatio	bles on and control.	
Qualification-goals/Competencies: Educational objectives for cou Students are familiar with the Students have a solid backgro Students are able to model lin Students are able to solve the Students improve their proble Students develop their technic Students are enabled to perfo Educational objectives for cou Students develop and extend continuously distributed randor Students can understand simp Students can understand, exter control to relevant problems v Educational objectives of the sistents are able to reproduce Students are able to reproduce 	rse Linear Systems Theory: important basic concepts of line und in the theory of linear syste ear systems in mechanical and e state equations and analyze sys m solving and mathematical ski ques for logical reasoning and a rm reseaerch in the field of syste rse Graphical Models in Systems their fundamental knowledge o om variables. de linear algorithms, such as the ts of probabilistic algorithms to and and apply advanced algorith with the help of graphical probal eminar Advanced Control and E and understand current literatur e and evaluate current algorithm extend and present results from	ear algebra. ms in continuous and disret electrical domain from first p tems in the time and freque lls. nd rigorous proofs. ems and control theory. and Control: n probability theory and the e Kalman filter, with the help novel ones with the help of ms in signal processing, par bilistic models. Estimation: re. ns based on research literature.	re time. principles. ency domain. e transformation of discretely as well as o of graphical probabilistic models. f graphical probabilistic models. rameter and state estimation as well as	
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 Prof. DrIng. 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:
Admission requirements for taking the module: - None
Admission requirements for participation in module examination(s): - Successful completion of exercises as specified at the beginning of the semester.
Module Exam(s): - RO4500-L1: Advanced Control and Estimation, One oral examination on the contents of both submodules, 40min, 100% of the module grade. - RO4500-S: Seminar Advanced Control and Estimation, must be passed



RO5100-KP12 - Medical Robotics (MedRob12)			
Duration:	Turnus of offer:		Credit points:
2 Semester	each year, can be started in winter or summer semester		12
Course of study, specific field and term • Master Robotics and Autonomous	: Systems 2019 (advanced m	odule), advanced curriculum	1, 1st or 2nd semester
Classes and lectures:		Workload:	
 Inverse Problems in Image Proces Inverse Problems in Image Proces Medical Robotics (lecture, 2 SWS) Medical Robotics (exercise, 1 SWS) Seminar Robotics und Automation 	 Inverse Problems in Image Processing (lecture, 2 SWS) Inverse Problems in Image Processing (exercise, 1 SWS) Medical Robotics (lecture, 2 SWS) Medical Robotics (exercise, 1 SWS) Seminar Robotics und Automation (seminar, 2 SWS) 		
Contents of teaching:			
 Introduction to inverse and ill-pose conduction, computed tomograph Concept of ill-posedness of the initial Singular value decomposition and Regularization methods (eg Tikhonia) Deconvolution Image restoration (deblurring, definition) Statistical methods (Bayes, maximing) Computed Tomography, Magnetic 	ed problems on the basis of hy, acoustics) verse problem (Hadamard) I generalized inverse nov, Phillips, Ivanov) focusing) um likelihood) c Particle Imaging	selected examples (includin	ıg seismology, impedance tomography, heat
Qualification-goals/Competencies:			
 Students are able to explain the congood or bad posedness. They are able to formulate inverse They can assess the condition of a They master different regularization They know methods to determine They can use methods of image reference Students are able to explain the control of the students are able to transfer methon Students are able to transfer methon Students are able to modify temp 	encept of ill-posedness of the problems of mathematical problem and the stability of on methods and are able to a a suitable regularization. econstruction and restoration oncepts of forward and invest f medical robot systems and nods of motion learning to si lates for dynamic calculation	e inverse problem and distir imaging and solve (approxir f a method. apply them to practical prob n on real measurement data rse kinematics for the examp to simple practical applicati mple practical problems. Is in order to create the calcu	nguish given inverse problems regarding mate) with suitable numerical methods. plems. ples of 3-joint and 6-joint robots. ions. ulations for their own constructions.
Grading through:			
Written or oral exam as announce	d by the examiner		
Responsible for this module: • Prof. DrIng. Achim Schweikard Teacher: • Institute of Computer Engineering • Institute for Electrical Engineering • Institute of Medical Engineering • Institute of Medical Informatics • Institute for Robotics and Cognitive	in Medicine re Systems		
Literature:			
 Kak and Slaney: Principles of Com Natterer and Wübbeling: Mathem Bertero and Boccacci: Inverse Prol 	puterized Tomographic Imag atical Methods in Image Rec olems in Imaging - IoP Press,	ging - SIAM Series 33, New Y onstruction - SIAM Monogra London, 2002	′ork, 2001 aphs, New York 2001

- Andreas Rieder: Keine Probleme mit inversen Problemen Vieweg, Wiesbaden, 2003
- Buzug: Computed Tomography Springer, Berlin, 2008



- J. -C. Latombe: Robot Motion Planning Dordrecht: Kluwer 1990
- J.J. Craig: Introduction to Robotics Pearson Prentice Hall 2002
- : Vorlesungsskript: Med. Robotics

Language:

• offered only in English

Notes:

Admission requirements for taking the module:

- - - - - - - - - - - - - - - -

- None

Admission requirements for participation in module examination(s):

- Successful completion of exercise assignments as specified at the beginning of the semester

Module Exam(s):

- RO5100-L1: Medical Robotics, one oral examination on the contents of both submodules, 100% of the module grade

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- CS5280-S: Seminar Robotics and Automation, must be passed



RO5200-KP12 - Bio-inspired Robotics (BR)			
Duration:	Turnus of offer:		Credit points:
2 Semester	each year, can be started i	n winter or summer semester	12
Course of study, specific field and term: • Master Robotics and Autonomous S	ystems 2019 (advanced mo	dule), advanced curriculum	ı, Arbitrary semester
Classes and lectures: Collective Robotics (lecture, 2 SWS) Collective Robotics (exercise, 1 SWS Evolutionary Robotics (lecture, 2 SW Evolutionary Robotics (exercise, 1 S' Seminar Bio-inspired Robotics (sem) /S) WS) inar, 2 SWS)	Workload: • 220 Hours private • 120 Hours in-clas • 20 Hours exam pr	e studies sroom work reparation
Contents of teaching: Biological basics Self-organization, robustness, scalal Robot swarms by land, by sea, and Mathematical modeling of swarms Evolutionary computation Artificial evolution of robot controll Optimization and learning in robot Independent familiarization with an Writing and presentation of an own	bility, superlinear speedups by air and collective decision-mal ers and robot morphologie experiments area of service robotics ba scientific paper	sing s sed on technical literature	
 Qualification-goals/Competencies: Students get a comprehensive over Students are able to assess chances Students are able to implement rea Students are able to implement evo mobile robots in. Students are able to name challeng Die Teilnehmer sind in der Lage, eir The students are able to investigate The participants can analyze and re present their own scientific work. 	view of biologically inspire and challenges of robust a ctive control for swarm rob olutionary algorithms and a es of evolutionary robotics wissenschaftliche Arbeit self-dependently scientific produce the tenor with reg	d. nd scalable robot systems. ots in simulation and on mo rtificial neural networks and in applications and to discu eigenständig zu verfassen u publications, to analyze an ard to their scope of work. T	obile robots. I are able to apply them to problems of iss potential solutions. ind vorzutragen. d understand their contents. The students are competent to write and
Grading through: • Written or oral exam as announced	by the examiner		
Responsible for this module: • Prof. DrIng. Mladen Berekovic Teacher: • Institute of Computer Engineering • Dr. rer. nat. Javad Ghofrani			
Literature: • Nolfi, S., Floreano, D.: The Biology, In • Hamann, H.: Swarm Robotics: A For	ntelligence, and Technolog mal Approach - Springer 20	y of Self-Organizing Machin 18	es - MIT Press, 2001
Language: • offered only in English			
Notes:			



Admission requirements for taking the module: - None

Admission requirements for participation in module examination(s):

- Successful completion of exercises of both sub-modules as specified at the beginning of the respective semester.

Module Exam(s):

- RO5200-L1: Bio-inspired Robotics, oral examination on the contents of both submodules, 2/3 of the module grade

- RO5200-S: Seminar Bio-inspired Robotics, 1/3 of the module grade



RO5500-KP12 - Autonomous Vehicles (AVS)				
Duration:	Turnus of offer:		Credit points:	
2 Semester	starts every winter ser	nester	12	
Course of study, specific field and • Master Robotics and Autono	term: mous Systems 2019 (advanced	curriculum), advanced curri	culum, 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) Technology of Autonomous Vehicles (seminar, 2 SWS) 		 220 Hours priv 80 Hours in-cla 60 Hours exan 	vate studies assroom work n preparation	
Contents of teaching:				
 Content of teaching of the c Review of control methods a Basic terminology of vehicle Vehicle dynamic models (late Component models (engine, Tire modeling Stability analysis Handling performance Active safety systems Autonomous driving Content of teaching of the c The architecture of autonom Tracking, detection, classifica Models of stochastic signals Transform-based analysis of System theory Parameter estimation Linear optimal filters and ada Graphical models and dynam Neural networks Hidden Markov Models, Kaln Applications in the domain of Content of teaching of the sec Current algorithms in maching 	ourse Vehicle Dynamics and Co nd rigid body dynamics dynamics eral, longitudinal, vertical) transmission, brake, steering) ourse Perception for Autonomo ous-driving systems tition stochastic signals aptive filters nic Bayes networks nan Filter, Particle Filter, etc. of autonomous driving eminar Current Topics in Auton ne learning and artificial intellig	omous Vehicles: Jence related to autonomou	s driving	
Qualification-goals/Competencies	:			
 Educational objectives of the Students master basic termin Students obtain a comprehe Students understand the ma Students can derive basic ve Students are able to apply co Students get an insight into Students are able to perform Educational objectives of the Students get an overview or Students become thoroughl Students master tools for the Students are able to make us Students are able to design to Students are able to design to 	a course venicle Dynamics and in hology and concepts of vehicle in objectives of vehicle control. hicle dynamics models for cont oncepts of basic and advanced the field of active safety system independent design, research course Perception for Autonor autonomous-driving systems. y acquainted with the perceptic ve introduction to stochastic signals. analysis of stochastic signals. se of various models for stochast cracking algorithms.	dynamics. dynamics. hamics of a vehicle. control and estimation to p hs, driver assistance, and aut and development work in t mous Driving: on layer of the architecture of gnals. stic signals.	ractical problems. onomous driving. his field. of an autonomous-driving system. of prior knowledge.	
·		12		



 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 DrIng. 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. Richen: Pattern recognition and machine learning. Springer, 2006
 Christopher M. Dishop: Pattern recognition and machine learning - springer, 2000 A Mertins: Signaltheorie: Grundlagen der Signalbeschreibung. Filterhänke Wavelets. Zeit-Frequenz-Analyse. Parameter- und
Signalschätzung - Springer-Vieweg, 3. Auflage, 2013
Language:
offered only in English
Notes:
Admission requirements for taking the module:
- None
Admission requirements for participation in module examination(s):
- Successful completion of exercises as specified at the beginning of the semester.
Module Examination(s):
- RO5500-L1: Vehicle Dynamics and Control, written exam, 60min, 50% of module grade
- KU5500-L2: Perception for Autonomous Vehicles, written exam, 60min, 50% of the module grade
- Nosson-es recimology of Autonomous venicles, seminar, ungraded; 0% of module grade, must be passed



Duration: Turnus of offer: Credit points: 2 Semester each year, can be started in winter or summer semester 12 Course of study, specific field and term: each year, can be started in winter or summer 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 (exercise, 2 SWS) • 135 Hours in-classroom work • Advanced topics in Robotics (exercise, 2 SWS) • 95 Hours private studies • 90 Hours work on an individual topic with written and oral presentation or group work • Machine Learning in Medicine (seminar, 2 SWS) • 40 Hours exam preparation • Outputs of teaching of the course Advanced Topics in Robotics: • 00 Hours work on an individual topic with written and oral presentation or group work • Augmented Reality • Design of Robot Systems • Intracorporal Robotics: • Augmented Reality • Design of Robot Systems for seach and rescue robots • Totacking of the course Advanced Topics in Robotics: • Spical requirements for disaster management and rescue robots • Totacking of Robot Systems • Information exchange between rescue robots • Totacking of the course Advanced Topics in Robotics: • Comman Systems for se	RO5800-KP12 - Advanced Topics in Robotics (ATRS)			
2 Semester each year, can be started in winter or summer senester 2 Course of study, specific field and term: Master Robotics and Autonomous Systems 2019 (advanced curriculum), advanced curriculum, 1st or 2nd semester Courses and lectures: Advanced Topics in Robotics (lecture, 2 SWS) Advanced Topics in Robotics (lecture, 2 SWS) Advanced Topics in Robotics (lecture, 2 SWS) Rescue Robotics (lecture, 2 SWS) Contents of teaching of the course Advanced Topics in Robotics: Motion Planning for Robots Content of teaching of the course Advanced Topics in Robotics: Motion Planning for 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 acthange between rescue robots Command and cornor Systems for search rescue robots Casualty and vital sign detection in rescue scenarios Medical assistance at the senion if Adohtican teaming in Medicine: Access to a scientific field Work towards a scientific solution to a problem with appropriate methods Presentation and discussions in English Presentation and discussions in English Presentation and discussions in English Presentation and discussions in Advanced Topics in Robotics: Students underlift, field Work towards a scientific solution to a problem with appropriate methods Presentation and discussions in English Presentation and discussions	Duration:	Turnus of offer:		Credit points:
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 (sectrice, 2 SWS) Rescue Robotics (sectrice, 2 SWS) Rescue Robotics (sectrice, 2 SWS) Machine Learning in Medicine (seminar, 2 SWS) Machine Learning in Medicine (seminar, 2 SWS) Content of teaching of the course Advanced Topics in Robotics: Motion Planning for Robots Advanced Topics in Robotics A	2 Semester	each year, can be started	in winter or summer semester	12
Classes and lectures: Workload: Advanced Topics in Robotics (lecture, 2 SWS) 135 Hours in-classroom work Advanced Topics in Robotics (lecture, 2 SWS) 90 Hours work on an Individual topic with written and oral presentation or group work Rescue Robotics (service, 2 SWS) 90 Hours work on an Individual topic with written and oral presentation or group work • Advanced Topics in Robotics (lecture, 2 SWS) • 40 Hours exam preparation Content of teaching • Content of teaching of the course Advanced Topics in Robotics: • Motion Plannin for Robots • advanced Topics in Robotics • Dynamics and Control of Robots • Special requirements for disaster management and response and the resulting consequences on rescue robot design. • Information surfuctures of rescue systems • Information exchange between rescue robots • Command and control systems for searcue robots • Casuality 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 leasimics in the scene of rice discussions in English • Possible topics: Computer Aided Diagnosis, Gaussian Processes for Sensor Data Analysis, Motion Prediction, Correlation Methods for Motion Stimation, Tissue Thickenses Stimation, Sensor Calibration Obstimation sub-topic bit ho too to problem with appropriate methods • Presentations and discussions in Eng	Course of study, specific field and • Master Robotics and Autone	l term: omous Systems 2019 (advanced c	urriculum), advanced curricu	lum, 1st or 2nd semester
Contents of teaching: Content of teaching of the course Advanced Topics in Robotics: Motion Planning for Robots Augmented Reality Design of Robot Systems Thracoporal Robots Content of teaching of the course Rescue Robotics: Content of teaching between rescue robots Command and control systems for search and rescue robots Command and control systems for search and rescue robots Contain of nor 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 Content of teaching of the semaner findent and determination of vital signs Evaluation and benchmarking of SAR robots Content of teaching of the semaner 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 Metric Batimation, Tissue Thickness Estimation, Sensor Calibration Coulification-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. Educational objectives of the course Rescue Robotics: The students have knowledge about the work and command structures of rescue personel as well as technical soluti	Classes and lectures: • Advanced Topics in Robotic • Advanced Topics in Robotic • Rescue Robotics (lecture, 2 S • Rescue Robotics (exercise, 2 • Machine Learning in Medici	s (lecture, 2 SWS) s (exercise, 1 SWS) SWS) SWS) ne (seminar, 2 SWS)	Workload: • 135 Hours in-clas • 95 Hours private • 90 Hours work or presentation or g • 40 Hours exam p	ssroom work studies n an individual topic with written and oral group work yreparation
 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 apply 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 personnell 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 elaborate on a scientific field in the English language. 	Contents of teaching: Content of teaching of the of Motion Planning for Robots Augmented Reality Design of Robot Systems Intracorporal Robotics Dynamics and Control of Ro Content of teaching of the of Special requirements for dis Information structures for re Information exchange betw Command and control syste Tactical communication for Design guidelines for huma Casualty and vital sign deter Medical assistance at the sco Evaluation and benchmarkin Content of teaching of the s Access to a scientific field Work towards a scientific so Presentations and discussio Possible topics: Computer A Motion Estimation, Tissue T	iourse Advanced Topics in Robot bots course Rescue Robotics: aster management and response scue systems een rescue robots ms for search and rescue robots cooperative SAR robot missions a n interfaces to rescue robots ction in rescue scenarios ene of incident and determinatio ng of SAR robots seminar Machine Learning in Mec lution to a problem with appropins in English ided Diagnosis, Gaussian Process hickness Estimation, Sensor Calib	ics: e and the resulting consequer as well as interoperability in h n of vital signs dicine: riate methods ses for Sensor Data Analysis, M ration	nces on rescue robot design. neterogeneous teams. Motion Prediction, Correlation Methods for
The students can frame a topic within the scientific context.	Qualification-goals/Competencie Educational objectives of th Students understand the co processing and analysis of a Students have an extended They are able to implement Educational objectives of th The students can apply the robotics, localization and pa The students have knowled communcation and interact The students have developed persons, determine vital sig Educational objectives of th The students can analyze, d The students can comprehe The students can frame a to	e course Advanced Topics in Rob nnection to underlying mathema lgorithms. overview of application areas for such methods and derive new ap e course Rescue Robotics: tools to program and simulate m ith planning in difficult scenarios. ge about the work and command ion of rescue robots with the per ed a notion of medical first respoi ns and realize medical assistance e course Seminar Machine Learni evelop and evaluate a research to nsibly present research results in on a scientific field in the English pic within the scientific context.	potics: atical methods, especially in d robotics. pplications based on such me obile rescue robots. They hav d structures of rescue persone rsonnel. nse by rescue personnel as we at the scene of incident. ing in Medicine: opic. written or spoken presentati language.	lynamics, optimization, and sensor data ethods. /e developed a good overview about mobile ell and the requirements on control, ell as technical solutions to locate missing



 written exam, oral exam and/or presentation as announced by the examiner 	
Requires:	
• Robotics (CS2500-KP04, CS2500)	
Responsible for this module:	
Prof. DrIng. Achim Schweikard	
Teacher:	
Institute for Robotics and Cognitive Systems	
Prof. DrIng. 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 2000 (ISBN: 978-1447157656) 	;
 Siciliano, Bruno, and Oussama Khatib, eds.: Springer handbook of robotics Springer, 2016. (ISBN: 978-3319325507) 	
Language:	
offered only in English	
Notes:	
Admission requirements for taking the module:	
- None (the competencies of the modules listed under competencies)	



CS	CS4130-KP06, CS4130 - Information Systems (InfoSys)				
Duration:	Turnus of offer:	Credit points:			
1 Semester	each summer semester	6			
Course of study, specific field and terr Master Computer Science 2019 (Master Entrepreneurship in Digit Master Media Informatics 2020 (Master Computer Science 2019 (Master Computer Science 2019 (Master Medical Informatics 2019 Master Robotics and Autonomou Master IT-Security 2019 (basic mo Master Medical Informatics 2014 Master Media Informatics 2014 (Master Entrepreneurship in Digit Master Computer Science 2014 (Master Computer Science 2014 (n: compulsory), Canonical Specialization al Technologies 2020 (basic module), optional subject), computer science, A pasic module), Applied computer scie (basic module), Applied computer sci s Systems 2019 (optional subject), Ele odule), Applied computer science, 1st (basic module), ehealth / infomatics, optional subject), computer science, A al Technologies 2014 (basic module), optional subject), specialization field s pasic module), Applied computer science	n Data Science and AI, Arbitrary semester Applied computer science, 1st or 2nd semester Arbitrary semester ence, 1st or 2nd semester ience, 1st or 2nd semester ective, 1st or 2nd semester t or 2nd semester 1st or 2nd semester Arbitrary semester Applied computer science, 1st or 2nd semester software systems engineering, 2nd or 3rd semester ence, 1st or 2nd semester			
Classes and lectures:	Wor	rkload:			
 Information Systems (lecture, 2 S Information Systems (exercise, 2 	WS) SWS)	100 Hours private studies60 Hours in-classroom work20 Hours exam preparation			
Contents of teaching: • Motivation of knowledge graphs • Overview over the W3C Semantie • Comparison between and the int • Graph Neural Networks and their	and their relationship to the Semanti Web family of languages eraction of knowledge graphs and ge applications for tasks of knowledge g	ic Web enerative artificial intelligence such as large language models graphs			
 Qualification-goals/Competencies: Knowledge: Students acquire an as large language models and gr Skills: Students can assess the poconsequences of the Semantic W develop Semantic Web application networks to solve tasks for and in graphs and the semantic web as Social skills and independence: Swork is encouraged through exemantic set and the semantic web as 	overview of knowledge graphs and th aph neural networks. ssibilities and limitations of knowledg (eb approach for data modeling, data ons. They can use generative artificial n addition to knowledge graphs. They well as in comparison to generative a tudents work in groups to complete e rcises, some of them directly on the co	the Semantic Web as well as generative artificial intelligence such ge graphs and the Semantic Web. They can estimate the a administration and processing and for applications. They can l intelligence such as large language models and graph neural y can discuss open research questions in the area of knowledge artificial intelligence and graph neural networks. exercises and small projects. Students' independent practical computer.			
Grading through:					
Written or oral exam as announc	ed by the examiner				
Responsible for this module: Prof. Dr. Sven Groppe Teacher: Institute of Information Systems Prof. Dr. Sven Groppe 					
Literature: M. Kejriwal, C. Knoblock: Knowlever S. Groppe: Data Management an W. L. Hamilton: Graph Represent International Publishing, 2020 D. Jurafsky, J. H. Martin: Speech a D. Foster: Generative deep learni	dge graphs - MIT Press, 2021 d Query Processing in Semantic Web ation Learning. In Synthesis Lectures o nd language processing - Upper Sado ng - Sebastopol, CA: O Reilly Media, 2	Databases - Springer, 2011 on Artificial Intelligence and Machine Learning - Springer dle River, NJ: Pearson, 2008 2023			



Language:

• German and English skills required

Notes:

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s): - Successful completion of exercises as specified at the beginning of the semester

Module Exam(s):

- CS4130-L1: Information Systems, written exam or oral exam, 100% of module grade

Previous name: Web Based Information Systems





CS4150-K	P06, CS4150SJ14 - D	istributed Systems (V	/ertSys14)
Duration:	Turnus of offer:		Credit points:
1 Semester	each winter semester		6
Course of study, specific field and term: Master Computer Science 2019 (comp Master Entrepreneurship in Digital Tea Master Media Informatics 2020 (option Master Computer Science 2019 (basic Master Medical Informatics 2019 (basi Master Robotics and Autonomous Sys Master IT-Security 2019 (basic module Master Medical Informatics 2014 (basi Master Medical Informatics 2014 (option Master Entrepreneurship in Digital Tea Master Computer Science 2014 (option Master Computer Science 2014 (basic	pulsory), Canonical Special chnologies 2020 (basic mo nal subject), computer scie module), Applied comput c module), Applied comput tems 2019 (optional subje c), Applied computer scien c module), ehealth / infon nal subject), computer scie chnologies 2014 (basic mo nal subject), specializatior module), Applied comput	ization SSE, Arbitrary seme odule), Applied computer s ence, Arbitrary semester ter science, 1st or 2nd seme ect), Elective, 1st or 2nd ser face, 1st or 2nd semester natics, 1st or 2nd semester ence, Arbitrary semester odule), Applied computer s n field software systems en ter science, 1st or 2nd seme	ister cience, 1st or 2nd semester ester nester nester cience, 1st or 2nd semester gineering, 2nd or 3rd semester ester
Classes and lectures:		Workload:	
 Distributed Systems (lecture, 2 SWS) Distributed Systems (exercise, 2 SWS) 		 60 Hours in-class 60 Hours private 40 Hours e-learni 20 Hours exam p 	room work studies ng reparation
 Protocols and layered models Message representations Realization of network services Communication mechanisms Addresses, names and directory service Synchronisation Replication and consistency Fault tolerance Distributed transactions Security 	ces		
 Qualification-goals/Competencies: The participants will accquire a deep thandling, naming etc. They know the most important service They are able to program simple distribution. They know the most important algorithmutual exclsuion. They have a good feeling for when it They have a good feeling for what king 	understanding for probler es in distributed systems s ibuted applications and sy thms in distributed systen makes sense to use distrib id of solutions could best	ns to be solved in distribut such as name service, distri ystems themselves. ns, for instance for time syr puted instead of centralized be used for what kind of pi	ed systems, such as synchronization, error buted file systems etc. nchronization, for leader election, or for d systems. roblems in distributed Internet applications.
Grading through: • written exam			
Responsible for this module: • Prof. Dr. Stefan Fischer Teacher: • Institute of Telematics • Prof. Dr. Stefan Fischer • Dr. rer. nat. Florian-Lennert Lau			



 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: Admission requirements for taking the module: - None
Admission requirements for participation in module examination(s): - None
Module Exam(s): - CS4150-L1 Distributed Systems, written exam, 90min, 100% of module grade.



CS41	70-KP06, CS4170SJ14 - Para	Illel Computer Systems (ParaRSys14)
Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	6
Course of study, specific field ar Certificate in Artificial Intel Master Entrepreneurship in Master Computer Science Master Medical Informatics Master Robotics and Autor Master IT-Security 2019 (ba Master Medical Informatics Master Entrepreneurship in Master Computer Science	nd term: ligence (compulsory), Artificial Inten n Digital Technologies 2020 (advan- 2019 (basic module), technical com s 2019 (optional subject), technical nomous Systems 2019 (optional sub asic module), technical computer so s 2014 (basic module), computer so n Digital Technologies 2014 (basic r 2014 (basic module), technical com	lligence, 1st semester ced module), specific, Arbitrary semester puter science, 1st or 2nd semester computer science, 1st or 2nd semester oject), Elective, 1st or 2nd semester cience, 1st or 2nd semester ience, 1st or 2nd semester module), specific, 1st or 2nd semester uputer science, 1st or 2nd semester
Classes and lectures:		Workload:
 Parallel Computer Systems Parallel Computer Systems 	s (lecture, 2 SWS) s (exercise, 2 SWS)	 100 Hours private studies 60 Hours in-classroom work 20 Hours exam preparation
Contents of teaching:		
 Parallel computing models Taxonomy of parallel composition Multi/manycore-systems Graphic Processing Units (OpenCL Specification languages Hardware architectures System management of m Qualification-goals/Competenci Students are able to chara They are able to explain m They are able to make use They are able to judge wh used. They are able to evaluate to 	s outers GPUs) any-core systems es: cterize different parallel computing odels of parallel computing. of common programming interfac ich kind of parallel computing syste	g architectures. es for parallel computing systems. em is best suited for a dedicated problem and how many cores should be ware architectures.
 They are able to write prog They are able to compare 	grams for parallel computing syster methods for dynamic voltage and f	ns under considerations of the underlying hardware architecture. requency scaling (DVFS) for manycore systems.
Grading through: • written exam		
Responsible for this module: • Prof. DrIng. Mladen Berek Teacher: • Institute of Computer Engi • Prof. DrIng. Mladen Berek	ovic neering ovic	
Literature:		
 G. Bengel, C. Baun, M. Kun M. Dubois, M. Annavaram, B. R. Gaster, L. Howes, D. R B. Wilkinson; M. Allen: Para 	ze, K. U. Stucky: Masterkurs Parallel P. Stenström: Parallel Computer Or . Kaeli, P. Mistry, D. Schaa: Heteroge Illel Programming - Englewood Clif	e und Verteilte Systeme - Vieweg + Teubner, 2008 ganization and Design - University Press 2012 eneous Computing with OpenCL - Elsevier/Morgan Kaufman 2013 fs: 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: Admission requirements for taking the module: None Admission requirements for participation in module examination(s): Successful completion of exercise assignments as specified at the beginning of the semester Module Exam(s): CS4170-L1: Parallel Computer Systems, oral exam, 100% of the module grade





	CS4220-KP04, CS4220 -	Pattern Recognition (M	Muster)
Duration:	Turnus of offer:		Credit points:
1 Semester	not available anymore		4
Course of study, specific field Master MES 2020 (option Master Media Information Master MES 2014 (option Master Robotics and Au Master CLS 2016 (comp Master Medical Information Master Medical Information Master Medical Information	d and term: onal subject), medical engineering sc cs 2020 (optional subject), computer onal subject), medical engineering sc utonomous Systems 2019 (optional s oulsory), mathematics, 2nd semester tics 2019 (optional subject), Medical tics 2014 (optional subject), medical	ence, Arbitrary semester science, Arbitrary semester ence, Arbitrary semester ubject), Elective, 1st or 2nd se Data Science / Artificial Intell image processing, 1st or 2nc	emester ligence, 1st or 2nd semester l semester
Classes and lectures:		Workload:	
 Pattern Recognition (le Pattern Recognition (ex 	ern Recognition (lecture, 2 SWS) ern Recognition (exercise, 1 SWS) 45 Hours in-classroom work 20 Hours exam preparation		e studies ssroom work preparation
Contents of teaching:			
 Frinciples of feature ex Bayes decision theory Discriminance function Neyman-Pearson test Receiver Operating Cha Parametric and nonpar kNN classifiers Linear classifiers Support vector machin Random Forest Neural Nets Feature reduction and Validation of classifiers Selected application sc attention classification 	s aracteristic ametric density estimation es and kernel trick feature transforms enarios: acoustic scene classification based on EEG data, speaker and emo	for the selection of hearing-a tion recognition	id algorithms, acoustic event recognition,
Qualification-goals/Compete • Students are able to de • They are able to explai • They are able to use fe	ncies: escribe the main elements of feature n the basic elements of statistical mo ature extraction, feature reduction ar	extraction and pattern recog deling. d pattern classification techr	nition. niques in practice.
Grading through:			
Written or oral exam as	announced by the examiner		
Responsible for this module: • Prof. DrIng. Alfred Me Teacher: • Institute for Signal Proc • Prof. DrIng. Alfred Me	rtins ressing rtins		
Literature: • R. O. Duda, P. E. Hart, D	. G. Storck: Pattern Classification - Ne	w 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 (at least 50% of max. points) and successful project task.

Modul exam:

- CS4220-L1:Pattern Recognition, written exam, 90 Min, 100% of modul grade



CS4290-K	P04, CS4290 - Current Issues	Robotics and Automation (RobAktuell)	
Duration:	Turnus of offer:	Credit points:	
1 Semester	each semester	4	
Course of study, specific field an Master Robotics and Auton Master Computer Science 2 	d term: omous Systems 2019 (optional subje 2014 (compulsory), specialization field	ct), Elective, 1st and/or 2nd semester I robotics and automation, 2nd or 3rd semester	
 Classes and lectures: CS4660-KP04: Process Cont 3 SWS) CS5275 T: Selected Topics of (lecture with exercises, 3 SV) CS5280 T: Seminar Robotico RO4210-KP04: Path Plannin (PPaCWR) (lecture with exercise) 	crol Systems (lecture with exercises, of Signal Analysis and Enhancement NS) s and Automation (seminar, 2 SWS) og and Control of Wheeled Robots rcises, 3 SWS)	 Workload: 60 Hours private studies 45 Hours in-classroom work 15 Hours exam preparation 	
Contents of teaching: • see module parts			
Qualification-goals/Competencie • see module parts	25:		
Grading through: • Written or oral exam as anr	nounced by the examiner		
Responsible for this module: • Prof. Dr. Philipp Rostalski Teacher: • Institute for Electrical Engin • Institute for Multimedia and • Institute for Multimedia and • Institute for Signal Processi • Institute for Robotics and C • Institute of Computer Engin	eering in Medicine d Interactive Systems ng ognitive Systems heering		
Literature: • see module parts:			
Language: • German and English skills r	equired		
Notes: One of the listed submodules	amounting to 4 ECTS must be chose	n.	
Admission requirements for t - See selected module Admission requirements for p	aking the module: participation in module examination(s	s):	
- See selected module Module Exam(s): - CS4290-L1: Current Issues Re	obotics and Automation, see selected	l module	



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), Master Robotics and Autonomous Sy Master Medical Informatics 2014 (op Master MES 2014 (optional subject), Master Medical Informatics 2019 (ad 	computer science / electric ystems 2019 (optional subj tional subject), medical con computer science / electric vanced module), medical c	cal engineering, Arbitrary se ect), Elective, 1st or 2nd se mputer science, 1st or 2nd cal engineering, 1st or 2nd omputer science, 1st or 2n	emester mester semester semester d semester	
 Classes and lectures: Medical Deep Learning (lecture, 2 SV Medical Deep Learning (exercise, 2 SV 	Classes and lectures:Workload:• Medical Deep Learning (lecture, 2 SWS)• 80 Hours private studies• Medical Deep Learning (exercise, 2 SWS)• 60 Hours in-classroom work• 40 Hours exam preparation			
 Cardiac Healthcare: ECG signal analysis for arrhythmia dd MRI sequence analysis for anatomica Multimodal Clinical Case Retrieval / Pathology and Semantic Image Retrivation Analysis of text / natural language (r Computer Aided Detection and Dise CT Lung nodule detection for cancel Weakly-supervised abnormality dete Interpretable and reliable deep learri Human interaction and correction w Visualisation of uncertainty and inte Deep Learning Concepts, Architectu Convolutional Neural Networks, Laye Losses, Derivatives, Large-scale Stoc Directed Acyclic Graph Networks, Ge Cloud Computing, GPUs, Low Precis 	etection or sleep apnea and al segmentation and tempo Prediction: ieval and Localisation adiology reports/study arti base Classification: r screening with data augm ection and biomarker disco ning systems within deep learning models rnally learned representation res, Deep Residual Learning hastic Optimisation enerative Adversarial Netwo ion Computing, DL Framew	d for mobile low-cost devic oral modelling cles) for multimodal data n nentation and transfer learn very 5 ons 9 orks	res nining in Electronic Health Records (EHR) ning	
 Qualification-goals/Competencies: Students know the importance of da They know methods and tools to co They have an in-depth understandir their learning process and evaluatio They understand the principles of w They know how to explore learned f They can implement modern netwo medicine They have a broad overview of curre their knowledge to newly emerging 	ata security, patient anonyr llect, preprocess, store and og of deep / convolutional i n of their performance on u eakly-supervised learning, eature representations for rk architectures in DL frame ent applications of deep lea domains	nisation and ethics for clini annotate large datasets fo neural networks for genera unseen data transfer learning, concept o retrieval and visualisation o eworks and are able to ada	ical studies involving sensitive data r deep learning from medical data l data (signals / text / images) processing, discovery and generative adversarial networks of high-dimensional abstract data pt and extend them to given problems in research and clinical practice and can transfer	
Grading through: • Oral examination				
Responsible for this module: • Prof. Dr. Mattias Heinrich Teacher: • Institute of Medical Informatics • Prof. Dr. Mattias Heinrich				



Literature:

Ian Goodfellow, Yoshua Bengio and Aaron Courville: Deep Learning - The MIT Press
inguage:
English, except in case of only German-speaking participants
otes:
Admission requirements for taking the module: - None
Admission requirements for taking module examination(s): - Successful completion of exercise assignments and programming tasks as specified at the beginning of the semester.
Module Exam(s): - CS4374-L1 Medical Deep Learning, , oral examination.



CS4405-KP04, CS4405 - Neuroinformatics (NeuroInf)					
Duration: T	urnus of offer:	Credit points:			
1 Semester e	ach summer semester	4			
1 Semester 4 Course of study, specific field and term: • Master CLS 2023 (compulsory), computer science, 2nd semester • Master Auditory Technology 2022 (optional subject), Auditory Technology, 2nd semester • Master Auditory Technology 2017 (optional subject), Auditory Technology, 2nd semester • Master MES 2020 (optional subject), computer science / electrical engineering, Arbitrary semester • Master CLS 2016 (compulsory), computer science, 2nd 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), omputer science / electrical engineering, Arbitrary semester • Master MES 2011 (optional subject), computer science / electrical engineering, Arbitrary semester • Master 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 MES 2011 (advanced curriculum), imaging systems, signal and image processing, 2nd or 3rd 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)	Workloa • 5 • 4 • 2	 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 Unsupervised 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 Mamlou	k				
Literature: • S. Haykin: Neural Networks - London: P • J. Hertz, A. Krogh, R. Palmer: Introducti • T. Kohonen: Self-Organizing Maps - Ber • H. Ritter, T. Martinetz, K. Schulten: Neu Addison Wesley, 1991	rentice Hall, 1999 on to the Theory of Neural Computa lin: Springer, 1995 ronale Netze: Eine Einführung in die	ation - Addison Wesley, 1991 e Neuroinformatik selbstorganisierender Ne	tzwerke - Bonn:		



• offered only in German

Notes:

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s): - Successful completion of exercises as specified at the beginning of the semester

Module Exam(s):

- CS4405-L1: Neuroinformatics, written exam, 90 min, 100% of module grade

According to the old version of the MES Bachelor Examination Regulations (until WS 2011/2012), an elective subject is scheduled for the 4th semester instead of the 6th 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 (co Master Computer Science 2019 (o Master Media Informatics 2020 (op Master Robotics and Autonomous Master Computer Science 2014 (co Master MES 2011 (advanced curric Master Media Informatics 2014 (op Master Computer Science 2012 (op	: pmpulsory), Canonical Specia ptional subject), Elective, Arb ptional subject), computer so Systems 2019 (optional sub pmpulsory), specialization fie culum), imaging systems, sign ptional subject), computer so ptional subject), advanced cu ptional subject), advanced cu ptional subject), advanced cu	alization SSE, Arbitrary seme bitrary semester ience, Arbitrary semester ject), Elective, 1st or 2nd se Id software systems engine hal and image processing, ience, Arbitrary semester in field robotics and autom rriculum parallel and distrib urriculum intelligent embed Id software systems engine	ester eering, 1st or 2nd semester 1st or 3rd semester ation, 2nd or 3rd semester puted system architecutres, 2nd or 3rd semester dded systems, 2nd or 3rd semester eering, 2nd semester			
Classes and lectures:		Workload:				
 Hardware/Software Co-Design (led Hardware/Software Co-Design (ex 	 /Software Co-Design (lecture, 2 SWS) /Software Co-Design (exercise, 1 SWS) Software Co-Design (exercise, 1 SWS) 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 solution • They are able to determine and de • They are able to apply methods for • They are able to translate non-form • They are able to explain the differ • They are able to estimate the qua • They are able to create system de	suitable hardware/software a escribe the pros and cons of or system partitioning mal system descriptions into ent steps in system synthesis lity of system designs scriptions in SystemC	architecture for a given syst implementation alternative formal models	em description es			
Grading through: • Written or oral exam as announce	d by the examiner					
Responsible for this module: • Prof. DrIng. Mladen Berekovic Teacher: • Institute of Computer Engineering • Prof. DrIng. Mladen Berekovic	1					
Literature: • F. Kesel: Modellierung von digitale • Teich, J., Haubelt, C.: Digital Hardv	en Systemen mit SystemC - C vare/Software-Systeme. Synt)Idenbourg Verlag 2012 hese und Optimierung - Be	rlin: Springer 2007			



Language:

• offered only in German

Notes:

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s):

- Successful completion of exercise assignments as specified at the beginning of the semester

Module Exam(s):

- CS5170-L1: Hardware/Software Co-Design, oral exam, 100% of the module grade



C	S5204-KP04, CS5204 - A	rtificial 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 subjection) Master Robotics and Autonomous Master Biophysics 2019 (optional Master MES 2014 (optional subjection) Master CLS 2016 (optional subjection) Master CLS 2016 (optional subjection)	n: ct), computer science / electric is Systems 2019 (optional subje subject), Elective, 1st semeste ct), computer science / electric optional subject), Interdisciplin it), computer science, 3rd seme	al engineering, Arbitrary se ect), Elective, 1st or 2nd sem r al engineering, Arbitrary se ary modules, 2nd semester ester	mester nester mester
Master Computer Science 2012 (Master Computer Science 2012 (optional subject), advanced cu	n field robotics and automat	tion, 3rd semester
Classes and lectures:		Workload:	
 Artificial Intelligence 2 (lecture, 2 Artificial Intelligence 2 (exercise, 	SWS)• 55 Hours private studies1 SWS)• 45 Hours in-classroom work• 20 Hours exam preparation		
Contents of teaching:			
 Regression Time-Series Prediction Lagrange Multipliers Sequential Minimal Optimization Geometric Reasoning 			
Qualification-goals/Competencies:			
 The students are able to choose a The chosen method can be custor search of parameters and involve learning, designed and implement 	a method for machine learning omized to the needs of the app adjustments to the basic ma nted by the students.The starti	for a given application am lication. The process of cus thematical techniques.This ng point are support vector	ongst a variety of such methods. tomization goes well beyond straightforward leads to innovative applications for machine r machines.
Grading through:			
Oral examination			
Responsible for this module:			
Prof. DrIng. Achim Schweikard			
Teacher: • Institute for Pobetics and Cogniti	ivo Systems		
Prof. Dr. Ing. Achim Schweikard	ve systems		
• Ploi. DIing. Achim Schweikard			
Literature:P. Norvig, S. Russell: Künstliche In	ntelligenz - München: Pearson 2	2004	
Language:			
 offered only in English 			
Notes:			



Note: Module will not be offered in winter semester 2024/2025

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s): - None

Module Exam(s): - CS5204-L1: Artificial Intelligence 2, written exam, 90min, 100% of the module grade




CS5260-KP04, CS5	260SJ14 - Speech an	d Audio Signal Proces	ssing (SprachAu14)
Duration:	Turnus of offer:		Credit points:
1 Semester	every second semester		4
Course of study, specific field and term: Master CLS 2023 (optional subject), E Master Robotics and Autonomous Sy Master MES 2020 (optional subject), Master Media Informatics 2020 (optional Master Medical Informatics 2019 (optional Master MES 2014 (optional subject), Master CLS 2010 (optional subject), co Master Medical Informatics 2014 (optional Master Medical Informatics 2014 (optional Master Medical Informatics 2014 (optional Master Medical Informatics 2014 (optional Master Media Informatics 2014 (optional M	Elective, Arbitrary semester (stems 2019 (optional sub) medical engineering science onal subject), computer sci tional subject), Medical Dar medical engineering science omputer science, Arbitrary sci tional subject), computer sci onal subject), computer sci	ect), Elective, Arbitrary sem ce, Arbitrary semester ence, Arbitrary semester ta Science / Artificial Intelli <u>c</u> ce, Arbitrary semester semester cience, 1st or 2nd semester ence, Arbitrary semester	ester gence, 1st or 2nd semester
Classes and lectures:		Workload:	
 Speech and Audio Signal Processing Speech and Audio Signal Processing 	(lecture, 2 SWS) (exercise, 1 SWS)	55 Hours private45 Hours in-classi20 Hours exam p	studies room work reparation
Contents of teaching:			
 Speech production and human hear Physical models of the auditory Syste Dynamic compression Spectral analysis: Spectrum and ceps Spectral perception and masking Vocal tract models Linear prediction Coding in time and frequency doma Speech synthesis Noise reduction and echo compensa Source localization and spatial repro Basics of automatic speech recogniti 	ing em strum ins ition duction ion		
Qualification-goals/Competencies:			
 Students are able to describe the ba They are able to describe the proces auditory perception. They are able to present basic knowl They can describe and use signal processional procession. 	sics of human speech prod s of human auditory perce ledge of statistical speech r ocessing methods for sourc	uction and the correspond otion and the correspondin modeling and automatic sp re separation and room-acc	ing mathematical models. ng signal processing tools for mimicing peech recognition. pustic measurements.
Grading through:			
Written or oral exam as announced b	by the examiner		
Responsible for this module: • Prof. DrIng. Markus Kallinger Teacher: • Institute for Signal Processing • Prof. DrIng. Markus Kallinger			
Literature:			
 L. Rabiner, BH. Juang: Fundamental J. O. Heller, J. L. Hansen, J. G. Proakis 	s of Speech Recognition - Discrete-Time Processing	Jpper Saddle River: Prentic of Speech Signals - IEEE Pre	e Hall 1993 ess
Language: • offered only in German			



Notes:

Prerequisites for attending the module:

- None

Prerequisites for the exam:

- Successful completion of assignments during the semester.

Modul exam:

- CS5260-L1: Speech and Audio Signal Processing, written or oral exam, 100% of modul grade

Mentioned in SGO MML under CS5260 (without SJ14).



RO450	00-KP08 - Advanced C	ontrol and Estimation	n (ACE)
Duration:	Turnus of offer:		Credit points:
2 Semester	each semester		8
Course of study, specific field and term: • Master Robotics and Autonomous Sy	/stems 2019 (optional subje	ct), Elective, 1st and 2nd se	emester
Classes and lectures:		Workload:	
 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) 20 Hour 		 120 Hours in-class 70 Hours private 30 Hours in-class 20 Hours exam private 	sroom work studies room exercises reparation
Contents of teaching: Content of teaching for course Linea Vector spaces, norms, linear operato Eigenvalues, eigenvectors, Jordan no Singular value decomposition and o Linear systems in continuous and dis Modeling of linear systems and linea Fundamental solution to linear system Laplace transform and z-transform Content of teaching for course Grap Introduction to Probability Theory, D Fundamentals on Probabilistic Graph Forney-Style Factor Graphs as a Prob Message Passing via Sum- and Max- Gaussian Message Passing State Estimation (Kalman Filtering an Parameter Estimation via Expectatio Expectation Propagation Control on Factor Graphs	ar Systems Theory: rs prmal form perator norms screte time arization ems state equations hical Models in Systems and Discretely and Continuously hical Models pabilistic Graphical Model Produkt Algorithms and Smoothing including No n Maximization	l Control: Distributed Random Varial nlinear Extensions)	bles
Qualification-goals/Competencies: Educational objectives for course Lir Students are familiar with the impor Students have a solid background in Students are able to model linear sy Students are able to solve the state of Students improve their problem solv Students develop their techniques for Students are enabled to perform res Educational objectives for course Gr Students develop and extend their f continuously distributed random val Students can understand simple line Students can understand, extend an control to relevant problems with the	tear Systems Theory: tant basic concepts of linea the theory of linear system stems in mechanical and ele equations and analyze syste ving and mathematical skills or logical reasoning and and eaerch in the field of system aphical Models in Systems a undamental knowledge on riables. ear algorithms, such as the k probabilistic algorithms to n d apply advanced algorithm ie help of graphical probabi	r algebra. Is in continuous and disrete ectrical domain from first p ems in the time and freque is. It rigorous proofs. Ins and control theory. Ind Control: probability theory and the formation filter, with the help ovel ones with the help of ns in signal processing, par listic models.	e time. principles. ncy domain. e transformation of discretely as well as of graphical probabilistic models. graphical probabilistic models. rameter and state estimation as well as
Grading through: • Written or oral exam as announced b	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

Prof. 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:

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s):

- Successful completion of exercises as specified at the beginning of the semester.

Module Exam(s):

- RO4500-L1: Advanced Control and Estimation, An oral examination on the contents of both submodules, 40min, 100% of the module grade.



R	O5100-KP08 - Medica	al Robotics (MedRob08)			
Duration:	Turnus of offer:	Credit points:			
1 Semester	every summer semester	8			
Course of study, specific field and term: • Master Robotics and Autonomous Sy	 Course of study, specific field and term: Master Robotics and Autonomous Systems 2019 (optional subject), Elective, 2nd semester 				
Classes and lectures:		Workload:			
 Inverse Problems in Image Processin Inverse Problems in Image Processin Medical Robotics (lecture, 2 SWS) Medical Robotics (exercise, 1 SWS) 	g (lecture, 2 SWS) g (exercise, 1 SWS)	 125 Hours private studies 90 Hours in-classroom work 25 Hours exam preparation 			
Contents of teaching:					
 Introduction to inverse and ill-posed conduction, computed tomography, Concept of ill-posedness of the inver Singular value decomposition and ge Regularization methods (eg Tikhonor Deconvolution Image restoration (deblurring, defoct Statistical methods (Bayes, maximum Computed Tomography, Magnetic P 	problems on the basis of s acoustics) rse problem (Hadamard) eneralized inverse v, Phillips, Ivanov) using) n likelihood) article Imaging	elected examples (including seismology, impedance tomography, heat			
Qualification-goals/Competencies:					
 good or bad posedness. They are able to formulate inverse particular inverse particular condition of a particular provide the second state of the se	roblems of mathematical ir roblem and the stability of methods and are able to a suitable regularization. onstruction and restoration cepts of forward and inverse nedical robot systems and t ds of motion learning to sin es for dynamic calculations	naging and solve (approximate) with suitable numerical methods. a method. pply them to practical problems. on real measurement data. se kinematics for the examples of 3-joint and 6-joint robots. so simple practical applications. nple practical problems. s in order to create the calculations for their own constructions.			
Grading through:					
Written or oral exam as announced b	by the examiner				
Responsible for this module: • Prof. DrIng. Achim Schweikard					
 Institute of Medical Engineering Institute for Robotics and Cognitive S 	Systems				
Literature:					
 Kak and Slaney: Principles of Compute Natterer and Wübbeling: Mathematic Bertero and Boccacci: Inverse Problem Andreas Rieder: Keine Probleme mit Buzug: Computed Tomography - Spr JC. Latombe: Robot Motion Plannir J.J. Craig: Introduction to Robotics - F : Vorlesungsskript: Med. Robotics 	terized Tomographic Imag cal Methods in Image Reco ms in Imaging - IoP Press, I inversen Problemen - View ringer, Berlin, 2008 ng - Dordrecht: Kluwer 199 Pearson Prentice Hall 2002	ing - SIAM Series 33, New York, 2001 Instruction - SIAM Monographs, New York 2001 London, 2002 reg, Wiesbaden, 2003 0			



Language:

• offered only in English

Notes:

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s):

- Successful completion of exercise assignments as specified at the beginning of the semester

Module Exam(s):

- RO5100-L1: Medical Robotics, one oral examination on the contents of both submodules, 100% of the module grade



	RO5200-KP08 - Bio-in	spired Robotics (BRS)		
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 S	ystems 2019 (optional subje	ct), Elective, Arbitrary seme	ester	
Classes and lectures:	ectures: Workload:			
 Collective Robotics (lecture, 2 SWS) Collective Robotics (exercise, 1 SWS) Evolutionary Robotics (lecture, 2 SWS) Evolutionary Robotics (exercise, 1 SWS) Evolutionary Robotics (exercise, 1 SWS) 		estudies oom work reparation		
Contents of teaching:				
 Biological basics Self-organization, robustness, scalab Robot swarms by land, by sea, and b Mathematical modeling of swarms a Evolutionary computation Artificial evolution of robot controlle Optimization and learning in robot controlle 	vility, superlinear speedups by air and collective decision-maki ers and robot morphologies experiments	ng		
Qualification-goals/Competencies:				
 Students get a comprehensive over Students are able to assess chances Students are able to implement read Students are able to implement evo mobile robots in. Students are able to name challenge 	view of biologically inspired. and challenges of robust an ctive control for swarm robo lutionary algorithms and art es of evolutionary robotics in	Id scalable robot systems. Its in simulation and on mo ifficial neural networks and n applications and to discu	bile robots. are able to apply them to problems of ss potential solutions.	
Written or oral exam as announced	by the examiner			
Responsible for this module:				
Prof. DrIng. Mladen Berekovic				
Teacher: • Institute of Computer Engineering				
• Dr. rer. nat. Javad Ghofrani				
Literature: • Nolfi, S., Floreano, D.: The Biology, Ir • Hamann, H.: Swarm Robotics: A Forr	ıtelligence, and Technology nal Approach - Springer 201	of Self-Organizing Machine 8	es - MIT Press, 2001	
Language: • offered only in English				
Nataa				
Admission requirements for taking the - None	e module:			
Admission requirements for participat - Successful completion of exercises of	ion in module examination(: f both sub-modules as speci	s): fied at the beginning of the	e respective semester.	
Module Exam(s): - RO5200-L1: Bio-inspired Robotics, ora	al examination on the conte	nts of both submodules, 10	00% of the module grade	



	RO5500-KP08 - Auto	nomous Vehicles (AV)
Duration:	Turnus of offer:		Credit points:
2 Semester	each semester		08
Course of study, specific field and term: • Master Robotics and Autonomous Sy	ystems 2019 (optional subj	ect), Elective, 1st and 2nd s	emester
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) Perception for Autonomous Vehicles (exercise, 2 SWS) 		e studies room work preparation	
Contents of teaching:			
 Content of teaching of the course Vele Review of control methods and rigic Basic terminology of vehicle dynami Vehicle dynamic models (lateral, lon Component models (engine, transm Tire modeling Stability analysis Handling performance Active safety systems Autonomous driving Content of teaching of the course Pee The architecture of autonomous-driv Tracking, detection, classification Models of stochastic signals Transform-based analysis of stochastic System theory Parameter estimation Linear optimal filters and adaptive fi Graphical models and dynamic Baye Neural networks Hidden Markov Models, Kalman Filte Applications in the domain of auton 	ehicle Dynamics and Contr I body dynamics cs gitudinal, vertical) ission, brake, steering) erception for Autonomous ving systems tic signals lters es networks er, Particle Filter, etc. omous driving	ol: Driving:	
Qualification-goals/Competencies: Educational objectives of the course Students master basic terminology a Students obtain a comprehensive ur Students understand the main object Students can derive basic vehicle dy Students are able to apply concepts Students get an insight into the field Students are able to perform indeper Educational objectives of the course Students get an overview on autono Students become thoroughly acqua Students master tools for the analysi Students are able to design tracking Students are able devise algorithmic	Vehicle Dynamics and Cor and concepts of vehicle dyn derstanding of the dynam ctives of vehicle control. namics models for control of basic and advanced cor d of active safety systems, of endent design, research and Perception for Autonomo prous-driving systems. inted with the perception of duction to stochastic signal is of stochastic signals. rious models for stochastic algorithms.	ntrol: namics. nics of a vehicle. design. ntrol and estimation to prac driver assistance, and auton d development work in this us Driving: layer of the architecture of a ls. signals.	ctical problems. nomous driving. s field. an autonomous-driving system. prior knowledge.
Grading through: • Written or oral exam as announced b	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 DrIng. 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:
Admission requirements for taking the module: - None
Admission requirements for participation in module examination(s): - Successful completion of exercises as specified at the beginning of the semester.
Module Examination(s): - RO5500-L1: Vehicle Dynamics and Control, written exam, 60min, 50% of module grade - RO5500-L2: Perception for Autonomous Vehicles, written exam, 60min, 50% of the module grade



F	RO5800-KP04, RO5801-KP04	- Advanced Topics in Robotics (ATiR)	
Duration:	Turnus of offer:	Credit points:	
1 Semester	each winter semeste	r 4	
Course of study, specific fiel	d and term:		
 Master Robotics and A 	utonomous Systems 2019 (optional	subject), Elective, 1st or 2nd semester	
Classes and lectures:		Workload:	
Advanced Topics in RoAdvanced Topics in Ro	anced Topics in Robotics (lecture, 2 SWS)• 55 Hours private studiesanced Topics in Robotics (exercise, 1 SWS)• 45 Hours in-classroom work• 20 Hours exam preparation		
Contents of teaching:			
 Dynamics and Control Motion Planning for Ro Augmented Reality Design of Robot System Intracorporal Robotics 	of Robots obots ms		
 Students understand t processing and analysi Students have an exte They are able to imple 	he connection to underlying mathe is of algorithms. nded overview of application areas ment such methods and derive nev	matical methods, especially in dynamics, optimization, ar for robotics. / applications based on such methods.	nd sensor data
written exam, oral exam	m and/or presentation as announce	d by the examiner	
Requires: • Robotics (CS2500-KP04	ł, CS2500)		
Responsible for this module	:		
Prof. DrIng. Achim Sci	hweikard		
Teacher: Institute for Bobotics a	nd Cognitive Systems		
Prof. DrIng. Achim Sci	hweikard		
Achim Schweikard, Flo	ris Ernst: Medical Robotics - Springe	r, 2015, Jocelyne Troccaz (ed.): Medical Robotics, Wiley, 2	2009
Language: • offered only in English			
Notes: Admission requirements - None (the competencie	for taking the module: so of the modules listed under		



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		8
Course of study, specific field and term: • Master Robotics and Autonomous Sy	rstems 2019 (optional subje	ect), Elective, 1st or 2nd sen	nester
Classes and lectures: • Advanced Topics in Robotics (lecture • Advanced Topics in Robotics (exercis • Rescue Robotics (lecture, 2 SWS) • Rescue Robotics (exercise, 2 SWS)	Workload:obotics (lecture, 2 SWS)• 105 Hours in-classroom workobotics (exercise, 1 SWS)• 95 Hours private studiesure, 2 SWS)• 40 Hours exam preparationrcise, 2 SWS)•		sroom work studies reparation
 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 			
 Qualification-goals/Competencies: Educational objectives of the course Students understand the connection processing and analysis of algorithm. Students have an extended overview They are able to implement such me Educational objectives of the course The students can apply the tools to probotics, localization and path planni The students have knowledge about communcation and interaction of res The students have developed a notic persons, determine vital signs and re Grading through: written exam, oral exam and/or prese 	Advanced Topics in Robot to underlying mathematic s. <i>i</i> of application areas for ro thods and derive new app Rescue Robotics: program and simulate mob ing in difficult scenarios. the work and command si scue robots with the perso on of medical first response alize medical assistance at	ics: cal methods, especially in d botics. lications based on such me ile rescue robots. They hav tructures of rescue persone nnel. by rescue personnel as we the scene of incident.	ynamics, optimization, and sensor data thods. e developed a good overview about mobile ell and the requirements on control, ell as technical solutions to locate missing
Requires: • Robotics (CS2500-KP04, CS2500)			
Responsible for this module: • Prof. DrIng. Achim Schweikard Teacher: • Institute for Robotics and Cognitive S	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:

Admission requirements for taking the module:

- None

Entry requirements for taking module examination(s):

- RO5800: Advanced Topics in Robotics None
- RO5803: Rescue Robotics Successful completion of exercises as specified at the beginning of the semester.

Module Exam(s):

- RO5800-L1: Advanced Topics in Robotics, An oral examination covering the content of both sub-modules, 100% of module grade.



PS	5000-KP06, PS5000 - S	Student Conference	(ST)	
Duration:	Turnus of offer:		Credit points:	
1 Semester	each winter semester		6 (Тур В)	
Course of study, specific field and term: Master Psychology - Cognitive Syste Master Biophysics 2023 (compulsory) Master Auditory Technology 2022 (c Master MES 2020 (compulsory), inter Master Medical Informatics 2019 (co Master Biophysics 2019 (compulsory) Master Auditory Technology 2017 (c Master Interdisciplinary Courses (opi Master Robotics and Autonomous Sy Master Medical Informatics 2014 (co Master MES 2014 (compulsory), inter	ms 2022 (compulsory), psyc), biophysics, 3rd semester ompulsory), Auditory Techn rdisciplinary competence, 3r mpulsory), interdisciplinary), biophysics, 3rd semester ompulsory), Auditory Techn tional subject), Interdisciplin ystems 2019 (compulsory), C mpulsory), interdisciplinary rdisciplinary competence, 3r	hology, 3rd semester ology, 3rd semester d semester competence, 3rd semester ary modules, Arbitrary sen Compulsory courses, 3rd se competence, 3rd semester d semester	r nester emester r	
Classes and lectures: • Student Conference (seminar, 4 SWS	5)	 Workload: 155 Hours work of development) an 25 Hours in-class 	on an individual topic (research and d written elaboration room work	
Contents of teaching:				
 Preparation of a scientific publicatio Preparation of a scientific poster in B Presentation of a scientific poster in Talk in English based on the results Active participation in scientific disc Active participation in a scientific period Qualification-goals/Competencies: Students have experience in a comp They are able to get an extensive ov They have the experience and ability They are able to defend one's work is They have knowledge of the peer-ree They are able to constructively critic 	n in English based on the re English based on the results German or English, based o of at least one of the project ussions eer-review process orehensive review of a scient rerview of a complex scientif y to take an active part in sc successfully in a scientific dis eview process of publication ize in a blind peer-review pr	sults of at least one of the of at least one of the proje n the results of at least on internships ific topic fic area ientific discussions scourse s ocess	project internships ect internships e of the project internships	
Grading through: • continuous, successful participation	in course			
Responsible for this module: • Prof. Dr. rer. nat. habil. Heinz Handel • Prof. Dr. rer. nat. Thorsten Buzug Teacher: • All Institutes and Clinics of the Unive	s ersität zu Lübeck			
Literature: • is selected individually:				
Language: • offered only in English	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 - Auto	onomous Systems (A	(S)
Duration:	Turnus of offer:		Credit points:
2 Semester	each winter semester		12
Course of study, specific field a • Master Robotics and Auto	and term: onomous Systems 2019 (compulsory),	Compulsory courses, 1st	and 2nd semester
Classes and lectures: • Real-Time Systems (lectures) • Real-Time Systems (exerced) • Model Predictive Control • Model Predictive Control	re, 2 SWS) cise, 2 SWS) (lecture, 2 SWS) (exercise, 2 SWS)	Workload:• 140 Hours private studies• 120 Hours in-classroom workS)• 40 Hours exam preparationVS)	
Contents of teaching:			
 Content of teaching of th Real-time processing (de Process automation syste Real-time programming Process connectivity and Modelling of discrete eve Modelling of continuous Application of design too Content of teaching of th LQ optimal control and K Convex optimization Invariant sets Theory of Model Predicti Algorithms for numerical Explicit MPC Practical aspects (Robust MPC applications 	ne course Real-Time Systems: finitions, requirements) ems networking ent systems (automata, state charts) systems (differential equations, Laplac ols (Matlab/Simulink, Stateflow) ne course Model Predictive Control: Calman filter ve Control (MPC) l optimization MPC, Offset-free tracking, etc.)	ce transformation)	
Qualification-goals/Competen Educational objectives of The students are able to They are able to explain They are able to program They are able to elucidat They are able to model, a They are able to model, a They are able to make us Educational objectives of Students get a comprehe Students get an overview Students are able to desi Students get acquainted Students are able to esta Students gain insight inte	cies: If the course Real-Time Systems: describe the fundamental problems o real-time computer systems for proces in real-time systems in the IEC language e process interfaces and real-time bus analyze and implement event discrete analyze and implement continuous syste of design tools for real-time systems if the course Model Predictive Control: ensive introduction to methods of opt v of the fundamentals of numerical op gn model predictive controllers for lin with several tools to implement mode blish system theoretic properties of m o possible applications areas for MPC.	f real-time processing. ss automation, in particul es. system. systems, in particular pro stems, in particular feedb 5. imal control. otimization. lear and nonlinear system el predictive controllers. lodel predictive controlle	ar SPS. ocess control systems. ack control systems. is.
Grading through:			
Written or oral exam as a	nnounced by the examiner		
Requires:			
Control Systems (RO4400)-KP08)		
Responsible for this module:			
 Prof. Dr. Georg Schildbac 	h		



• 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:

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s):

- Successful completion of exercises as specified at the beginning of the semester.

Module Exam(s):

- RO4000-L1: Autonomous Systems, participation in the written examinations of both submodules.
- RO4001-L1: Model Predictive Control, written exam, 90 min, 50% of the module grade
- CS4160-L1: Real-Time Systems, written exam, 90min, 50% of module grade

	RO4100-KP08 - Rob	ot Learning (RobLe)	
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 Sy	/stems 2019 (compulsory), (Compulsory courses, 1st an	id 2nd semester
Classes and lectures:Workload:• CS4575-V: Sequence Learning (lecture, 2 SWS)• 120 Hours wo• CS4575-Ü: Sequence Learning (exercise, 1 SWS)• 120 Hours privile• CS4295-V: Deep Learning (lecture, 2 SWS)• 60 Hours in-cl• CS4295-Ü: Deep Learning (exercise, 1 SWS)• 60 Hours in-cl		Workload: • 120 Hours work o • 120 Hours private • 60 Hours in-classr • 60 Hours in-classr	on project e studies room exercises room work
Contents of teaching:			
 Foundations and Deep Learning Bas Shallow Neural Networks (Basic Neur Approximation Theorem, No-Free Lu Optimization (Stochastic Gradient De Convolutional Neural Networks (1D 0 Techniques, Transposed Convolution Regularization (Early Stopping, L1 an Very Deep Networks (Highway Netw Dimensionality Reduction (PCA, t-SN Generative Neural Networks (Variation Graph Neural Networks (Graph Convel) Fooling Deep Neural Networks (Advel) Physics-Aware Deep Learning (Physic) Introduction to Sequence Learning (Recurrent Neural Networks (Simple F Gated Recurrent Networks (Vanishin) Important Techniques for RNNs (Tea Bidirectional RNNs and related conce Hierarchical RNNs and Learning on N Online Learning and Learning withou Reservoir Computing (Echo State Ne Spiking Neural Networks (Spiking Ne Temporal Convolution Networks (Ca Introduction to Transformers (Seque Large Language Models) State Space Models (Structured State 	ics (Learning Paradigms, Cla ron Model, Multilayer Perce inch Theorems, Inductive B escent, Momentum Variants Convolution, 2D Convolution 1) id L2 Regularization, Label S rorks, Residual Blocks, ResNa IE, UMAP, Autoencoder) onal Autoencoder, Generati rolutional Networks, Graph ersarial Attacks, White Box a cal Knowledge as Inductive Formalisms, Metrics, Recap RNN Models, Backpropagati g Gradient Problem in RNN cher Forcing, Scheduled Sa epts Aultiple Time Scales ut BPTT (Real-Time Recurrent tworks, Deep ESNs) euron Models, Learning in S susal Convolution, Tempora ence-to-Sequence Learning,	assification and Regression, ptions, Backpropagation, C iases) s, Adaptive Optimizer) on, 3D Convolution, ReLUs a Smoothing, Dropout Strate et Variants, DenseNets) ve Adversarial Networks, D Attention Networks) and Black Box Attacks, One- Bias, PINN, PhyDNet, Neur- itulation of Relevant Machi on Through Time) s, Long Short-Term Memor mpling, h-Detach) nt Learning, e-Prop, Forwar NNs, Neuromorphic Compu I Dilation, TCN-ResNets) Basics on Attention, Self-A Mamba)	, Underfitting and Overfitting) Computational Graphs, Universal and Variants, Down and Up Sampling gies, Batch Normalization) iffusion Models) -Pixel Attacks) al ODE, FINN) ne Learning Techniques) ries, Gated Recurrent Units, Stacked RNNs) ries, Gated Recurrent Units, Stacked RNNs) rd Propagation Through Time) uting, Recurrent SNNs) ttention and the Query-Key-Value Principle,
 Qualification-goals/Competencies: Students get a fundamental underst auto-differentiation Students understand the implication Students get a comprehensive unde Students learn to analyze the challer Students know how to analyze the n their relevance Students get a comprehensive unde Students get a comprehensive unde Students know how to analyze the n their relevance Students learn to analyze the challer Students can implement common au Students know how to analyze the n their relevance 	anding deep learning basic is of inductive biases rstanding of most relevant iges in deep learning tasks ind cons of various deep lear nodels and results, to impro- rstanding of most relevant inges in sequence learning t ind cons of various sequence nd custom sequence learnin nodels and results, to impro-	s such as backpropagation deep learning approaches and to identify well-suited rning models ove the model parameters, sequence learning approac asks and to identify well-su e learning models ng models for time series a ove the model parameters,	, computational graphs, and approaches to solve them and to interpret the model predictions and ches lited approaches to solve them nalysis, classification, and forecasting and to interpret the model predictions and
Grading through:			



Written or oral exam as announced by the examiner
Responsible for this module:
Prof. Dr. Sebastian Otte
Teacher:
Institute for Robotics and Cognitive Systems
 MitarbeiterInnen des Instituts Prof. Dr. Sebastian Otte
Literature:
 Goodfellow, I., Bengio, Y., & Courville, A.: Deep Learning - MIT Press (2016), ISBN 978-0262035613 Nakajima, K., & Fischer, I.: Reservoir Computing: Theory, Physical Implementations, and Applications - Springer Nature Singapore (2021) ISBN 978-9811316869 Sun, R., & Giles, C.: Sequence Learning: Paradigms, Algorithms, and Applications - Springer Berlin Heidelberg (2001), ISBN 978-3540415978 Bishop, C. M.: Pattern Recognition and Machine Learning - Springer (2006), ISBN 978-0387310732 Sutton, R., & Barto, A.: Reinforcement Learning: An Introduction - The MIT Press (2018), ISBN 978-0262039246
 François-Lavet, V., Henderson, P., Islam, R., Bellemare, M., & Pineau, J.: An Introduction to Deep Reinforcement Learning - Now Publishers Inc (2018), ISBN 978-1680835380 Recent publications on the related topics:
Language:
offered only in English
Notes:
Admission requirements for taking the module: - None
Admission requirements for participation in module examination(s): - Successful completion of exercise assignments as specified at the beginning of the semester
Module Exam(s):
- CS4295-L1: Deep Learning, exam, 90 min, 50% of the module grade - CS4575-L1: Sequence Learning, exam, 90 min, 50% of the module grade



RO4	300-KP08 - Machine Learnin	ng 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 • Master Robotics and Autone	1 term: omous Systems 2019 (compulsory),	Compulsory courses, 1	st and 2nd semester	
Classes and lectures: Machine Learning (lecture, 2) Machine Learning (exercise, Computer Vision (lecture, 2) Computer Vision (exercise, 2)	Workload:e, 2 SWS)• 110 Hours private studiesse, 1 SWS)• 90 Hours in-classroom work2 SWS)• 40 Hours exam preparatione, 1 SWS)			
Contents of teaching: Representation learning, ind Statistical learning theory VC dimension and support Boosting Deep Learning Limits of induction and imp Introduction to human and Sensors, cameras, optics and Image features: edges, intri Range imaging and 3-D can Motion and optical flow Object recognition Example applications Qualification-goals/Competencie Students can understand ar They can explain and apply They can chose and then eve	cluding manifold learning vector machines ortance of data ponderation computer vision d projections nsic dimension, Hough transform, F neras s: nd explain various machine-learning different machine learning method valuate an appropriate method for a splain the limits of automatic data a	ourier descriptors, snak g problems. Is and algorithms. a particular learning pro	es ıblem.	
 Students can understand the Students can understand the They can explain and perfor They can explain and apply They can indicate appropriation 	e basics of computer vision. m camera choice and calibration. the basic methods for feature extra ite methods for different kinds of co	action, motion estimation pomputer-vision application	on, and object recognition. ions.	
Grading through: • Oral examination				
Responsible for this module: • Prof. DrIng. Erhardt Barth Teacher: • Institute for Neuro- and Bioi • Prof. DrIng. Erhardt Barth • Prof. Dr. rer. nat. Thomas Ma	nformatics artinetz			
Literature: Chris Bishop: Pattern Recog Vladimir Vapnik: Statistical L Richard Szeliski: Computer V	nition and Machine Learning - Sprir Learning Theory - Wiley-Interscience /ision: Algorithms and Applications	nger ISBN 0-387-31073- e, ISBN 0471030031 - Springer, Boston, 201	8	



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

Language: • English, except in case of only German-speaking participants Notes: Admission requirements for taking the module: - None Admission requirements for participation in module examination(s): - Successful completion of exercises of both sub-modules as specified at the beginning of the respective semester. Module Exam(s):

- RO4300-L1: Machine Learning and Computer Vision, oral examination on the contents of both submodules, 100% of the module grade



RO5000-	KP12 - Internship Robotics	s and Autonomous Syst	ems 1 (ProPraRAS1)
Duration:	Turnus of offer:		Credit points:
1 Semester	each winter semester	r	12
Course of study, specific field a • Master Robotics and Auto	nd term: nomous Systems 2019 (compulse	ory), Compulsory courses, 3rd	semester
Classes and lectures: Workload: • Internship 1 (block practical course, 12 SWS) • 320 Hours work on project • 40 Hours written report		k on project en report	
Contents of teaching: • project task in a specific a • documentation, presenta • the project task is embed	pplication scenario tion, motivation in a heterogeneo ded in a heterogeneous and vivic	ous environment d environment with substantia	al communication and integration demands
Qualification-goals/Competence The students have a deep They are able to impleme They are able to documer They are capacble of pres They have project experie They have basic skills in the	ies: o understanding of selected aspect nt selected aspects of robotics ar nt and present project results. enting to particular audiences or ence in concrete application scena the field of project management.	cts of robotics and autonomo nd autonomous systems. under time restrictions (eg el arios.	us systems. evator pitch etc.).
Grading through: • documentation			
Responsible for this module: • Prof. Dr. Philipp Rostalski Teacher: • Institute of Computer Eng • Institute for Robotics and • Institute for Electrical Eng	ineering Cognitive Systems ineering in Medicine		
Language: • English, except in case of	only German-speaking participan	nts	
Notes: Admission requirements for - Registration of the internsl be found in the download a Admission requirements for - Regular and successful par Module Exam(s): - RO5000-L1: Internship Rob The internships can be com the field of robotics and aut Both project internships car	taking the module: hips with the chair of the examina- rea of the study program homep taking module examination(s): ticipation in the internship potics and Autonomous Systems f pleted at the University of Lübech onomous systems in Germany an	ation board is mandatory for l age. 1, block practical with final rep k as well as at external univers nd abroad. ernship.	later recognition. The corresponding forms can port, 100% of module grade. sities, research institutions and companies in
(Proportion of LE Computer	(Proportion of LE Computer Science/Engineering in BP is 100%).		



RO5001-KP	12 - Internship Robotics a	and Autonomous Syst	ems 2 (ProPraRAS2)	
Duration:	Turnus of offer:		Credit points:	
1 Semester	each winter semester		12	
Course of study, specific field and • • Master Robotics and Autonor	t erm: nous Systems 2019 (compulsor	y), Compulsory courses, 3rd	semester	
Classes and lectures: Workload: • Internship 2 (block practical course, 12 SWS) • 320 Hours work on project • 40 Hours written report		< on project en report		
Contents of teaching: • project task in a specific appl • documentation, presentation • the project task is embedded	cation scenario , motivation in a heterogeneou in a heterogeneous and vivid e	s environment environment with substantia	al communication and integration demands	
Qualification-goals/Competencies: • The students have a deep un • They are able to implement s • They are able to document and • They are capacble of presentit • They have project experience • They have basic skills in the figure	derstanding of selected aspects elected aspects of robotics and nd present project results. ing to particular audiences or u in concrete application scenari ield of project management.	s of medical engineering. autonomous systems. nder time restrictions (eg ele ios.	evator pitch etc.).	
Grading through: • documentation				
Responsible for this module: • Prof. Dr. Philipp Rostalski Teacher: • Institute of Computer Engine • Institute for Robotics and Cog • Institute for Electrical Engine • Alle prüfungsberechtigten D	ering Initive Systems Pring in Medicine Pozentinnen/Dozenten des Stuc	lienganges		
Language: • English, except in case of only	/ German-speaking participants	;		
Notes: Admission requirements for tak - Registration of the internships be found in the download area Admission requirements for tak - Regular and successful particip Module Exam(s): - RO5001-L1: Internship Robotic The internships can be complet the field of robotics and autono	ing the module: with the chair of the examinati of the study program homepag ing module examination(s): pation in the internship ation in the internship and Autonomous Systems 2, 1 ed at the University of Lübeck a mous systems in Germany and	ion board is mandatory for l ge. block practical with final rep as well as at external univers abroad.	ater recognition. The corresponding forms can port, 100% of module grade. sities, research institutions and companies in	
Both project internships can be	complined into one large interr	nsnip.		

(Proportion of LE Computer Science/Engineering in BP is 100%).



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RO5990	0-KP30 - Master Thesis Robo	otics and Autonomous S	Systems (MScRAS)	
Duration:	Turnus of offer:	Turnus of offer: Credit poin		
1 Semester	each semester		30	
Course of study, specific field a • Master Robotics and Auto	and term: onomous Systems 2019 (compulso	ry), Compulsory courses, 4th s	emester	
Classes and lectures:Workload:• Master's Thesis (supervised self studies, 1 SWS)• 870• Colloquium (presentation (incl. preparation), 1 SWS)• 30 Hpreparationpreparation		Workload: • 870 Hours resear • 30 Hours oral preparation)	oad: 870 Hours research for and write up of a thesis 30 Hours oral presentation and discussion (including preparation)	
Contents of teaching: • individual studies under	supervision			
Qualification-goals/Competen Students are able to solv They have the expertise They can present comple They are experts for a root 	cies: e a complex scientific problem by to plan, organize and carry out a p ex information in written and oral f ughly defined topic.	the means of their discipline. roject work. orm.		
Grading through: • Written report				
Responsible for this module: • Studiengangsleitung Ro Teacher: • Institutes of the Departm • Alle prüfungsberechtigt	botik und Autonome Systeme ent of Computer Science/ Enginee en Dozentinnen/Dozenten des Stu	ring dienganges		
Literature: • links will be given by the	supervisor:			
Language: • offered only in English				
Notes: Admission requirements fo - See study program regula Admission requirements fo - see study program regula Module Exam(s): - RO5990-L1: Masterarbeit I	r taking the module: itions (e.g. certain minimum CP ach r participation in module examinat tions Robotics and Autonomous Systems	nieved). :ion(s): s, final paper, 100% of module	grade.	



CS4660-KP04, CS4660 - Process Control Systems (ProzFueSys)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each winter semester		4	
Course of study, specific field and Master Robotics and Autono Master Psychology 2016 (op Master psychology 2013 (op Master Media Informatics 2 Master Computer Science 2 Master Computer Science 2 Master Entrepreneurship in	d term: mous Systems 2019 (optional subjectional subject), interdisciplinary contronal subject), interdisciplinary contronal subject), interdisciplinary contronal subject), computer science 014 (compulsory), computer science 012 (optional subject), specialization field for the compulsory), specialization field for the compulsory), specialization field for the compulsory), specialization field for the computer science 012 (compulsory), specialization field for the compulsory), specialization field for the computer science 012 (compulsory), specialization field for the computer science 012 (computer science 012 (ct), Module part Current Iss ompetence, 3rd semester ompetence, 3rd semester ce, 3rd semester on field robotics and auton eld media informatics, 2nd al subject), specific, Arbitra	sues Robotics and Automation, Arbitrary semester nation, 2nd or 3rd semester semester ary semester	
Classes and lectures:		Workload:		
 Process Control Systems (le Process Control Systems (ex 	 Process Control Systems (lecture, 2 SWS) Process Control Systems (exercise, 1 SWS) You State State		te studies ssroom work preparation	
 Introduction and Overview Incidents and Accidents Error, Failure and Responsite Human Factors Mental, conceptual and tecc Task Analysis and Task Moce Event Analysis and Event M Task Allocation Situation Awareness Diagnoses und Contingence Interaction in real-time: Continue Risk and Safety Operations and Safety 	bility hnical Models lelling odelling y nception and Design			
 Qualification-goals/Competencie The students know the most They know the definitions of They can assess what needs proceed methodically. 	es: st important theories, methods and of the terms risk and security and w s to be considered in the developn	d systems for monitoring a vhy they are applied in diff nent of mission- and safety	nd controlling processes. ferent ways. /-critical human-machine systems and how to	
Grading through: • written exam				
Responsible for this module: • Prof. Dr. phil. André Calero Teacher: • Institute for Multimedia and • Prof. Dr. phil. André Calero Literature:	Valdez I Interactive Systems Valdez			
 M. Herczeg: Prozessführung Steuerung von Prozessen ir M. Herczeg: Software-Ergor und aktualisierte Auflage. D M. Herczeg: Interaktionsdes J. Reason: Human Error - Bo J. Rasmussen, L. P. Goodste 	ssysteme Sicherheitskritische Me n Echtzeit - München: de Gruyter - (nomie: Theorien, Modelle und Krite De Gruyter Studium, 2018 sign - München: Oldenbourg-Verlag ston: Cambridge University Press, in, A. M. Peijtersen: Cognitive Syste	ensch-Maschine-Systeme u Oldenbourg-Verlag, 2014 rien für gebrauchstauglich g, 2006 1990 ems Engineering - New Yor	und Interaktive Medien zur Überwachung und ne interaktive Computersysteme - 4. erweiterte rk: Wiley, 1994	

- J. Hushingssen, E. F. Goodstein, A. W. Feljtersen, Cognitive Systems Engineering Trew Tork, Wiley, 1994



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Language:

• offered only in German

Notes:

Prerequisites for attending the module: - None

Prerequisites for the exam:

- Successful completion of homework assignments during the semester.



Duration:	Furnus of offer:		Credit points:
l Semester e	each summer semester		4
 Course of study, specific field and term: Master Robotics and Autonomous Syster Master Biophysics 2023 (module part), Master Computer Science 2019 (module Master MES 2020 (module part), compi Master Entrepreneurship in Digital Tecc Master Biophysics 2019 (module part), Master IT-Security 2019 (module part), Master Entrepreneurship in Digital Tecc Master Computer Science 2014 (module part), compi 	ns 2019 (module part), Mo advanced curriculum, 2nd le part), Module part, Arbi uter science / electrical en hnologies 2020 (module p advanced curriculum, 2nd Module part, 1st or 2nd s hnologies 2014 (module p uter science / electrical er le part), Module part, Arbi	dule part Current Issues I d semester trary semester ogineering, Arbitrary ser part), Module part, Arbit d semester emester part), Module part, Arbit ogineering, 1st or 2nd se trary semester	Robotics and Automation, 1st and/or 2nd semest nester rrary semester errary semester emester
Classes and lectures:		Workload:	
 Selected Topics of Signal Analysis and SWS) Selected Topics of Signal Analysis and 1 SWS) 	 Selected Topics of Signal Analysis and Enhancement (lecture, 2 SWS) Selected Topics of Signal Analysis and Enhancement (exercise, 1 SWS) Selected Topics of Signal Analysis and Enhancement (exercise, 1 SWS) 		te studies assroom work a preparation
Contents of teaching:	i		
 Adaptive filters Multichannel signal processing, beamf Compressed sensing Basic concepts of multirate signal processing algorithms Nonlinear signal processing algorithms Application scenarios in auditory technimeasurement, noise reduction, decommended 	orming, and source separ essing s nology, enhancement, and volution (listening-room c	ation d restauration of one- a ompensation), inpaintir	nd higher-dimensional signals, Sound-field ng
Qualification-goals/Competencies:			
 Students are able to explain the basic They are able to describe and apply lin Students are able to describe the conc They are able to describe and apply th They are able to describe the concept They are able to analyze and design m Students are able to explain various ap They are able to create and implement 	elements of stochastic sig lear estimation theory. epts of adaptive signal pr e concepts of multichann of compressed sensing. lultirate systems. oplications of nonlinear ar t linear optimum filters an	nal processing and opti ocessing. el signal processing. nd adaptive signal proce nd nonlinear signal enha	mum filtering. essing. ancement techniques on their own.
Grading through:			
 exam type depends on main module 			
 exam type depends on main module Responsible for this module: Siehe Hauptmodul Teacher: Institute for Signal Processing Prof. DrIng. Markus Kallinger 			
 exam type depends on main module Responsible for this module: Siehe Hauptmodul Teacher: Institute for Signal Processing Prof. DrIng. Markus Kallinger 			



Signalschätzung - Springer-Vieweg, 3. Auflage, 2013 • S. Haykin: Adaptive Filter Theory - Prentice Hall, 1995
Language:
offered only in German
Notes:
(Part of modules CS4290, CS4510, CS5400, RO4290-KP04, CS5274-KP08) (Is equal to CS5275)
For Details see main module.
Prerequisites for attending the module: - None
Prerequisites for the exam: - Successful completion of homework assignments during the semester (at least 50%).
Modul exam in Main module: - CS5275-L1: Selected Topics of Signal Analysis and Enhancement, written or oral exam, 100% of modul grade



CS5280 T - Module Part: Seminar Robotics and Automation (SemRobAuta)			
Duration: Turnus of offer: Credit points:		Credit points:	
1 Semester	each semester	4	
Course of study, specific field a • Master Robotics and Auto • Master Computer Science	and term: nomous Systems 2019 (optional subject) e 2014 (Module part of a compulsory m), Module part Current Issues Robotics and Automation, Arbitrary semester odule), specialization field robotics and automation, Arbitrary semester	
Classes and lectures: Workload: • Advanced Seminar Robotics and Automation (seminar, 2 SWS) • 90 Hours work on an individual topic with written and oral presentation • 30 Hours in-classroom work			
Contents of teaching: • Different topics from the • The students learn the conself-contained writing an	fields of robotics and artificial intellige prrect reading of scientific papers, resea d presentation of their own scientific e	nce for term papers are offered. Irch and investigation, correct quotation and structuring, and laboration as a preparation for their final examination.	
Qualification-goals/Competent • The participants are able • The students are able to • The participants can anal present their own scienti	cies: to do research on scientific publication investigate self-dependently scientific p yze and reproduce the tenor with rega fic work.	ns, to analyze the contents and to understand them. Dublications, to analyze and understand their contents. rd to their scope of work. The students are competent to write and	
Grading through: • exam type depends on m	nain module		
Responsible for this module: • Siehe Hauptmodul Teacher: • Institute for Electrical Eng • Institute for Robotics and • Institute of Computer Eng • Prof. DrIng. Mladen Bere • Prof. DrIng. Achim Schw • Prof. Dr. Philipp Rostalski	gineering in Medicine I Cognitive Systems gineering ekovic reikard		
Language: • English, except in case of	only German-speaking participants		
Notes: Prerequisites for attending - None	the module:		



RO42	210-KP04 - Path Planning and C	Control of Wheeled Robots (PPaCWR)
Duration:	Turnus of offer:	Credit points:
1 Semester	each winter semester	4
Course of study, specific field • Master Robotics and Au	and term: tonomous Systems 2019 (module part),	Module part Current Issues Robotics and Automation, Arbitrary semeste
Classes and lectures:		Workload:
 RO4200-V: Path Planning and Control of Wheeled Robots (lecture, 2 SWS) RO4200-Ü: Path Planning and Control of Wheeled Robots (exercise, 1 SWS) 		 75 Hours private studies 45 Hours in-classroom work
Contents of teaching:		
 Students are familiarwit Students are familiar wi Students are familiar wi Students are able to im 	h kinematic and dynamic modeling of the path planning methods for wheeled th trajectory tracking control of wheele plement the methods mentioned above	wheeled mobile robots robots and important issues d mobile robots e using Matlab
Oualification-goals/Competer	ncies:	
 Classification of wheele Types of wheels and wh Difference between mo Kinematic nonholonom Degrees of mobility, stee Forward kinematics (un Inverse kinematics Lagrange dynamic approach Path planning vs traject Trajectory planning Path planning using art Planning via retraction Planning via cell decom Probabilistic planning Application of MPC Con Trajectory tracking Leader-Follower trajecte Control of multi-robot s 	d mobile robots ieel configurations bile robots and robot arms ic constraints on wheels ierability, and maneuverability icycle, differential-drive robot, car-like ro roach isory planning ificial potential fields iposition itroller on wheeled robots ory tracking control systems	obot, n-trailer systems)
Grading through:		
portfolio exam		
Responsible for this module: • Prof. Dr. Georg Schildba Teacher: • Institute for Electrical Er • Prof. Dr. Behnam Mirip	ich ngineering in Medicine pour Fard	
l iterature:		
 M.W. Spong, S. Hutchin R. Siegwart, I.R. Nourbal B. Siciliano, L. Sciavicco, H. Choset, K. Lynch, S. H Implementation - MIT P 	son, and M. Vidyasagar: Robot Modeling khsh, D. Scaramuzza: Introduction to Au L. Villani, G. Oriolo: Robotics - Modellin lutchinson, G. Kantor, W. Burgard, L. Kav Press, 2005	g and Control - 2nd ed. John Wiley & Sons, 2020 Itonomous Mobile Robots - MIT Press, 2011 g, Planning and Control - 3rd Edition, Springer, 2009 vraki, and S. Thrun: Principles of Robot Motion - Theory, Algorithms, and



Language:

• offered only in English

Notes:

This module can only be taken as one module from the Current Issues Robotics and Automation (CS4290-KP04, CS4290) catalog.

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s):

- Successful completion of exercise slips as specified at the beginning of the semester.

Module Exam(s):

RO4210-L1: Portfolio Examination Path Planning and Control of Wheeled Robots with a total of 100 points, divided as follows:

- 60 points for submission of homework
- 40 points for an e-test



CS3110-KP04, CS3110 - Computer-Aided Design of Digital Circuits (SchaltEntw)				
Duration:	Turnus of offer:		Credit points:	
l Semester	each winter semester		4	
Course of study, specific field ar Master Robotics and Autor Master MES 2020 (optiona Bachelor Computer Science Bachelor Robotics and Aut Bachelor IT-Security 2016 (Bachelor MES 2014 (optior Bachelor Computer Science Bachelor MES 2011 (optior Bachelor CLS 2010 (option Bachelor Computer Science	nd term: nomous Systems 2019 (optional subjel subject), computer science / electric e 2016 (optional subject), major subj onomous Systems 2016 (optional sul optional subject), computer science, nal subject), computer science / elect e 2014 (optional subject), central top nal subject), Applied computer science al subject), computer science, 5th or e 2012 (optional subject), central top	ect), Additionally recognized cal engineering, Arbitrary sen ect informatics, Arbitrary sen bject), computer science, 5th Arbitrary semester rical engineering, 5th or 6th s ics of computer science, 5th ce, 3rd, 5th, or 6th semester 6th semester ics of computer science, 5th	elective module, Arbitrary semester nester or 6th semester or 6th semester or 6th semester	
Classos and locturos:		Workload		
Computer-Aided Design o Computer-Aided Design o	Iasses and lectures: Workload: • Computer-Aided Design of Digital Circuits (lecture, 2 SWS) • 55 Hours private studies • Computer-Aided Design of Digital Circuits (exercise, 1 SWS) • 45 Hours in-classroom work • 20 Hours exam preparation			
 Design of standard composed Circuit design at different Circuit design for synthesise VHDL simulation cycle VHDL circuit design for FP Designing Testbenches High-Level-Synthesis 	inents in VHDL abstraction levels s GAs			
Qualification-goals/Competenci	es:			
 Based on a non-formal des They are able to simulate a They are able to explain the They are able to determine They are able to explain the They are able to explain the They are able to write syntaxic 	scription of a digital system, students and test VHDL descriptions re internal structures of FPGAs e which VHDL construct will result in re VHDL simulation cycle thesizable VHDL code	are able to design digital cir which circuit structure	cuits using VHDL	
Grading through: • written exam				
Responsible for this module: • Prof. DrIng. Mladen Berek Teacher: • Institute of Computer Engl • Prof. DrIng. Mladen Berek Literature: • F. Kesel, R. Bartholomä: En	ovic neering ovic twurf von digitalen Schaltungen unc	Systemen mit HDLs und FPC	5As - Oldenbour Verlag 2009	
C.Maxfield: The Design Wa	rrior's Guide to FPGAs - Newnes 200	4		
Language:				



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

Notes:

Admission requirements for taking the module: - None





CS	4452-KP06 - Reliabilit	y Engineering (TechZ	′uv)
Duration:	Duration: Turnus of offer:		Credit points:
1 Semester	normally each year in the	winter semester	6
Course of study, specific field and term: • Master Robotics and Autonomous Sy • Master Computer Science 2019 (opti • Master IT-Security 2019 (optional sul	ystems 2019 (optional subje ional subject), Elective, Arbi bject), IT Safety and Reliabil	ect), Additionally recognize trary semester ity, 1st, 2nd, or 3rd semeste	d elective module, Arbitrary semester er
Classes and lectures:Workload:• Reliability Engineering (lecture, 2 SWS)• 100 Hours private studies• Reliability Engineering (exercise, 2 SWS)• 60 Hours in-classroom work• 20 Hours exam preparation		e studies room work reparation	
Contents of teaching: Basic concepts Reliability analysis Qualification tests Maintainability analysis Design guidelines for reliability, mai	ntainability and software qu	Jality	
Qualification-goals/Competencies: • Students are able to discuss the basi • They are able to analyze the reliabili • They are able to select and apply qu • They are able to perform a maintain • They are able to follow design guide	ic concepts of Reliabilty Eng ty of technical systems by n alification tests ability analysis elines for reliable and maint	jineering nathematical models ainable systems.	
Grading through: • Viva Voce or test			
Responsible for this module: • Prof. DrIng. Mladen Berekovic Teacher: • Institute of Computer Engineering • DrIng. Saleh Mulhem			
Literature: • A. Birolini: Reliability Engineering: Th • M. Rausand: Reliability of Safety-Crit	neory and Practice - Springe ical Systems - Wiley 2014	ır 2013	
Language: • English, except in case of only Germ	an-speaking participants		
Notes: Admission requirements for taking the - None Admission requirements for participati - Successful completion of exercises as Module Exam(s):	e module: ion in module examination(s specified at the beginning	s): of the semester.	
- CS4452-L1: Technical Reliability, written exam, 90min, 100% of the module grade. According to the decision of the examination board of computer science of 15.1.2020 this module can be chosen by students Master			

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Computer Science SGO from 2019 in the area of 5th elective.







	CS4480-KP04 - System Identification (Sysiden)				
Duration:	Turnus of offer:		Credit points:		
1 Semester	irregularly in the summe	r semester	4		
Course of study, specific field and term • Master MES 2020 (optional subjec • Master MES 2014 (optional subjec • Master Robotics and Autonomous	: t), computer science / electri t), computer science / electri Systems 2019 (optional sub	cal engineering, Arbitr cal engineering, Arbitr ject), Additionally reco	ary semester ary semester gnized elective module, 1st or 2nd semester		
Classes and lectures:Workload:• System Identification (lecture, 2 SWS)• 65 Hours private studies and exercises• System Identification (exercise, 1 SWS)• 45 Hours in-classroom work• 10 Hours exam preparation			ivate studies and exercises -classroom work sam preparation		
Contents of teaching: Introductory topics: Discretization and Discrete-time (DT) models Least-square estimation Main topics: Parametric model identification: Prediction error method, Subspace identification Non-parametric model identification Data-driven models 					
 Qualification-goals/Competencies: The students can explain the gene method, the prediction error meth Students can formulate and imple students are able to estimate mat presented in this course. They can evaluate the quality of th They can use Matlab System Ident 	eral framework and basic pro nod, the subspace method, s ment algorithms for system hematical models of a dynar ne identified models. ification Toolbox to identify	operties of different ide tandard non-parametr identification. nical system from inpu linear dynamical mode	entification methods including least-squares ic methods and the data-driven method. It-output data using the different methods els using different identification methods.		
Grading through:Written or oral exam as announced by the examiner					
Responsible for this module: • Prof. Dr. Philipp Rostalski Teacher: • Institute for Electrical Engineering in Medicine • DrIng. Hossameldin Abbas					
 Literature: Karel J. Keesman: System Identification: An Introduction - Springer-Verlag London Limited 2011 Lennart Ljung and Torkel Glad: Modeling of Dynamic Systems - Prentice Hall 1994 Lennart Ljung: System Identification - Theory for the User - Prentice Hall 1999 					
Language: • offered only in English					
Notes:					



Admission requirements for taking the module: - None

Admission requirements for participation in module examination(s): - none

Module Exam(s):

- CS4480-L1: System Identification, Oral Examination, 100% of module grade


CS4504-KP08 - Cyber Physical Systems (CPS8)				
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), Additionally recognized elective module, Arbitrary semester 				
Classes and lectures:Workload:• CS5150 T: Organic Computing (lecture with exercises, 3 SWS)• 130 Hours private studies• CS5153 T: Wireless Sensor Networks (lecture with exercises, 3 SWS)• 90 Hours in-classroom work• 20 Hours exam preparation				
 Contents of teaching: basic principles of organic computing / self-x system properties from motion to intelligent behavior and system/machine behavior design for self-organization, robustness, adaptivity, flexibility, trust analyzing, reverse-engineering, debugging machine behavior designing experiments and measuring behavior designing experiments and measuring behavior modeling system/machine behavior complexity, opacity, obscurity, trust of (AI) systems and explainable AI architecture of organic computing systems applications of self-x systems basics of wireless sensor networks hardware aspects of sensor nodes physics and protocols of wireless communication routing in wireless networks time synchronization and localization in wireless networks data management and data processing in wireless sensor networks 				
 Qualification-goals/Competencies: Students are able to utilize the principles of organic computing/self-x systems on exemplary designs. They are able to explain principles of organic computing/self-x systems. They are able to analyze system/machine behaviors in a structured, sound approach. Students are able to present the pros and cons of sensor networks. They are able to cope with analysis, design, and evaluation of protocols in sensor networks. They are able to interpret and pursue current research activities for sensor networks. 				
Grading through: • Oral examination				
Responsible for this module: Prof. DrIng. Mladen Berekovic Teacher: Institute of Computer Engineering Dr. rer. nat. Javad Ghofrani 				
 Literature: C. Müller-Schloer, S. Tomforde: Organic Computing Technical Systems for Survival in the Real World - Birkhäuser, 2017 H. Karl, A. Willig: Protocols and Architectures of Wireless Sensor Networks - Wiley, 2005 				
Language: • offered only in English				
Notes:				



Admission requirements for taking the module: - None

Admission requirements for participation in module examination(s): - Successful completion of exercises as specified at the beginning of the semester.

Module Exam(s):

- CS4504-L1: Cyber Physical Systems, oral exam, 100% of module grade.



CS4514-KP12 - Intelligent Agents (IntAgents)			
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 (optional subject), Additionally recognized elective module, 1st to 3th semester Certificate in Artificial Intelligence (compulsory), Artificial Intelligence, 1st semester Master Entrepreneurship in Digital Technologies 2020 (advanced module), specific, Arbitrary semester Master Computer Science 2019 (optional subject), Canonical Specialization Data Science and AI, 1st or 2nd semester Master IT-Security 2019 (advanced module), Elective Computer Science, 1st or 2nd semester Master Computer Science 2019 (optional subject), advanced module. Arbitrary semester 			
Classes and lectures:		Workload:	
 CS4514-P: Lab course Intelligent Ag SWS) CS4514-V: Intelligent Agents (lecture) 	ents (practical course, 2 e with exercises, 6 SWS)	 195 Hours private 120 Hours in-clas 45 Hours exam p 	e studies sroom work reparation
 Agents, Mechanisms, and Collaboration: Intelligent agents and artificial intelligence / Game theory and social choice / Mechanism design, algorithmic mechanism design / Agent collaboration, rules of encounter / Continuous Space / Epistemic logic / Knowledge and seeing / Knowledge and time / Dynamic epistemic logic / Knowledge-based programs Perception (Language and Vision): Information retrieval and web-mining agents / Probabilistic dimension reduction, latent content descriptions, topic models, LDA, LDA-HMM / Representation learning for sequential structures, embedding spaces, word2vec, CBOW, skip-gram, hierarchical softmax, negative sampling / Language models (1d-CNNs. RNNs, LSTMs, ELMo, Transformers, BERT, GPT-3/OPT, and beyond), Natural language inference and query answering / Computer Vision (2D-CNNs, Deep Architectures: AlexNet, ResNet) //Combining language and vision (CLIP (OpenAI) / LIT (Google) / data2vec (Facebook) / Flamingo (DeepMind), DALL-E and beyond) //Knowledge graph embedding with GNNs, combining embedding-based KG completion with probabilistic graphical models(ExpressGNN, pLogicNet), MLN inference and learning based on embedded knowledge graphs, GMNNs) Planning, Causality, and Reinforcement Learning: Planning and acting with deterministic models, temporal models, nondeterministic models, probabilistic models / Standard decision making / Advanced decision making and reinforcement learning / Causal dependencies / Intervention / Instrumental variables / Counterfactuals / Causal planning / Causal reinforcement learning In the project lab students use the usual (open source) data science related programming languages and tools in order to transfer the 			
 Qualification-goals/Competencies: The students can enumerate central ideas, define the relevant concepts and explain the functioning of algorithms with help of application scenarios for all the items listed in contents of teaching. 			
Grading through: • Oral examination			
Responsible for this module: • Prof. DrIng. Nele Rußwinkel Teacher: • Institute of Information Systems • Prof. DrIng. Nele Rußwinkel			
 Literature: J. Pearl, C. Glymour, and N.P. Jewell: Causal Inference in Statistics - A Primer - Wiley, 2016 Y. Shoham, K. Leyton-Brown: Multiagent-Systems: Algorithmic, Game-Theoretic, and Logical Foundations - Cambridge University Press, 2009 S.J. Russell, P. Norvig: Artificial Intelligence: A Modern Approach - Pearson, 2020 M. Ghallab, D. Nau, P. Traverso: Automated Planning and Acting - Cambridge University Press, 2016 			
offered only in English			



Notes:

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s):

- successful completion of the Lab Course Intelligent Agents CS4514-P

Module examination(s):

- CS4514-L1: Intelligent Agents, oral examination, 100% of module grade.

(Replaces CS4513-KP12).





	CS4521-KP12 - Construct	tive Cognitive Scien	ice (CCS)	
Duration:	Turnus of offer:		Credit points:	
2 Semester	each semester		12	
Course of study, specific field	and term:			
Master Computer ScienceMaster Robotics and Automatics	e 2019 (optional subject), advanced r conomous Systems 2019 (optional sub	nodule, Arbitrary semeste oject), Additionally recogr	er nized elective module, 1st to 3th semester	
Classes and lectures:		Workload:		
 Human-Aware AI (lectur Models for human intell Human-Aware AI (Excer 	man-Aware Al (lecture, 3 SWS)• 135 Hours in-classroom workodels for human intelligent Assistance (lecture, 3 SWS)• 105 Hours private studiesman-Aware Al (Excercises with project, 3 SWS)• 90 Hours work on project• 30 Hours exam preparation		classroom work vate studies k on project m preparation	
Contents of teaching:				
 Constructive Cognitive Science, Situation understanding and mental models Explainable Human-AI Interaction Cognitive Modelling especially cognitive architectures Human-Robot Collaboration Digital cognitive Twins and Physical Human Models Intention recognition and Theory of Mind Interactive task learning Situated cognitive agents Tracing the cognitive state of the human-in-the-loop 				
 Qualification-goals/Competer The students can enume application scenarios as 	ncies: erate central ideas, define the relevant well as apply the algorithms for all th	t concepts and explain th e items listed in contents	e functioning of algorithms with help of s of teaching.	
Grading through:				
 exercises and project as: Oral examination	signments			
Responsible for this module:				
Prof. DrIng. Nele Rußw	inkel			
Institute of Information	Systems			
Prof. DrIng. Nele Rußw	Prof. DrIng. Nele Bußwinkel			
 S.J. Russell: Human Compatible: Artificial Intelligence and the Problem of Control - Penguin Books, 2020 C.S. Nam, JY. Jung, S. Lee (Eds.): Human-Centered Artificial Intelligence: Research and Applications - Elsevier, 2022 J.R. Anderson: How Can the Human Mind Occur in the Physical Universe? - Oxford University Press, 2007 B. Sneiderman: Human-Centered AI - Oxford University Press, 2022 				
Language:				
offered only in English				
Notes:		· · · · · · · · · · · · · · · · · · ·		



Admission requirements for taking the module: - None

Admission requirements for participation in module examination(s): - Successful completion of exercises and project tasks as specified at the beginning of the semester.

Module Exam(s):

- CS4505-L1: Constructive Cognitive Science, oral exam, 100% of the module grade.



CS4702-KP06 - Computer Security (CoSec)				
Duration:	Turnus of offer:		Fredit points:	
1 Semester	normally each year in the sur	nmer semester 6	5	
 Course of study, specific field and term: Master Robotics and Autonomous Systems 2019 (optional subject), Additionally recognized elective module, Arbitrary semester Master Entrepreneurship in Digital Technologies 2020 (advanced module), specific, Arbitrary semester Master Media Informatics 2020 (optional subject), computer science, Arbitrary semester Master Medical Informatics 2019 (optional subject), ehealth / infomatics, 1st or 2nd semester Master IT-Security 2019 (optional subject), IT Security and Privacy, 1st, 2nd, or 3rd semester 				
Classes and lectures:		Workload:		
 Computer Security (lecture, 2 SWS) Computer Security (practical course 	, 3 SWS)	 85 Hours private stu 75 Hours in-classroot 20 Hours exam prepared 	udies om work paration	
Contents of teaching:				
 Applied cryptography in systems and protocols: Overview of common methods and their applications Efficient and secure implementation of common crypto procedures: multiple-precision arithmetic, efficient exponentiation, constant time algorithms etc. Physical implementation attacks and countermeasures: Error injection attacks, passive physical attacks such as SPA/DPA and timing attacks, modern inference methods and associated cryptanalysis methods, classes of protective measures Virtualization security and microarchitecture attacks: security concepts in the operating system and hypervisor, microarchitecture attacks such as cache attacks, spectre, etc., measures to restore system security Trusted computing and hardware-assisted system security: How TPMs, Secure Elements and Trusted Execution work environments, basics and cryptographic techniques, design basics for secure systems 				
 The students can demonstrate a deep understanding of cryptographic methods and their applications in communication systems. They can construct secure and efficient cryptographic primitives and implement them securely in computer systems. They can explain methods and algorithms for efficient multiple-precision arithmetic. They can perform basic side-channel attacks on systems with physical access or shared systems with code execution rights. They can implement protection against specific physical attacks for cryptographic primitives. They can evaluate the security of existing primitives. 				
Grading through: Viva Voce or test written homework 				
Requires: • Cybersecurity (CS2250-KP04)				
Responsible for this module: Prof. DrIng. Thomas Eisenbarth Teacher: Institute for IT Security Prof. DrIng. Thomas Eisenbarth 				
 Literature: S. Mangard, E. Oswald & T. Popp: Power analysis attacks: Revealing the secrets of smart cards - Vol. 31, Springer Science & Business Media, 2008 D. Stinson: Cryptography: Theory and Practice - 4th ed., CRC Press, 2018 : Recent literature 				
Language: • English, except in case of only Germ	an-speaking participants			



Notes:

Admission requirements for taking the module: - None (the competencies under



CS4703-KP06 - Advanced Cryptology (AdvCrypto)					
Duration:	Turnus of offer:		Credit points:		
1 Semester	every summer semester		6		
Course of study, specific field and term: • Master Computer Science 2019 (option • Master Robotics and Autonomous Sy • Master CLS 2016 (optional subject), of • Master IT-Security 2019 (optional subject)	 Course of study, specific field and term: Master Computer Science 2019 (optional subject), Elective, Arbitrary semester Master Robotics and Autonomous Systems 2019 (optional subject), Additionally recognized elective module, Arbitrary semester Master CLS 2016 (optional subject), computer science, 3rd semester Master IT-Security 2019 (optional subject). IT Security and Privacy. Arbitrary semester 				
 Classes and lectures: Lecture Advanced Cryptoplogy (lecture) Exercise Advanced Cryptoplogy (seme exercises, 1 SWS) 	Classes and lectures:Workload:• Lecture Advanced Cryptoplogy (lecture, 3 SWS)• 100 Hours private studies• Exercise Advanced Cryptoplogy (seminar-style lectures with exercises, 1 SWS)• 60 Hours in-classroom work• 20 Hours exam preparation				
 Contents of teaching: Concrete security and asymptotic see Block-Ciphers: Feistel Networks, Subsee Authenticated Encryption Secure multi-party calculations: prepresent evidence) Obfuscation: Nicht-Machbarkeit (Black 	curity: comparison of both stitution-Permutation Netw rocessing model, protectio ckBox), Machbarkeit (indisti	approaches in relation to n rorks, Design Principles, Lin n of algorithms against sid nguishable Obfuscation)	nodes of operations lear Cryptanalysis, Differential cryptanalysis e-channel attacks, MPC-in-the-Head (for ZK		
 Qualification-goals/Competencies: The participants can explain and use basic theoretic cryptographic objects They are able to understand current concepts of cryptography They show a deep understanding of cryptographic methods They understand the basic connection between theoretical and practical aspects of cryptography They are able to understand current scientific works about cryptography and explain them 					
 Grading through: Written or oral exam as announced by the examiner written homework 					
Requires: • Cryptology (CS3420-KP04, CS3420)					
Responsible for this module: • Prof. DrIng. Thomas Eisenbarth Teacher: • Institute for IT Security • Dr Sebastian Berndt					
 Literature: Katz, Lindell: Introduction to Modern Cryptography - 2nd ed., CRC Press, 2014 Cramer, Damgård, Nielsen: Secure Multiparty Computation and Secret Sharing - 1st ed., Cambridge University Press, 2015 Barak: An Intensive Introduction to Cryptography - Lecture Notes 					
Language:English, except in case of only German-speaking participants					
Notes: Admission requirements for taking the module: - None (the competencies under					



CS4705-KP06 - Cryptographic Engineering (CryEng)				
Duration:	Turnus of offer:	Credit p	points:	
1 Semester	every summer semester	6		
 Course of study, specific field and term: Master Entrepreneurship in Digital Technologies 2020 (advanced module), specific, Arbitrary semester Master Robotics and Autonomous Systems 2019 (optional subject), Additionally recognized elective module, Arbitrary semester Master Computer Science 2019 (optional subject), Elective, Arbitrary semester Master IT-Security 2019 (optional subject), IT Security and Privacy, 1st, 2nd, or 3rd semester 				
Classes and lectures:		Workload:		
 Cryptographic Engineering (lect) Cryptographic Engineering (exer) 	ıre, 2 SWS) cise, 2 SWS)	 100 Hours private studies 60 Hours in-classroom wor 20 Hours exam preparation 	rk n	
 Contents of teaching: Efficient Implementation of Finite Field Arithmetic for cryptographic Applications. Stream Ciphers: Design and hardware Implementation. Block Ciphers: Design, hardware Implementation, and Lightweight Encryption Algorithms. Hash Functions: Design and hardware Implementation. Public-Key Cryptography over GF(2m): Design and Implementation. True and Pseudo Random Number Generators (TRNG): Design, test, and hardware Implementation. Physical Unclonable Functions (PUFs): Design Challenges and Hardware- Architectures. 				
 Qualification-goals/Competencies: Students will become familiar with the concept of cryptographic engineering and the associated topics with it. They can expand and enhance their knowledge about a cryptography and applied cryptography. They can become more familiar with the concepts of hardware-security. They can learn efficient implementation of Finite Field Arithmetic in hardware and its applications in cryptography. They can learn the techniques for hardware-implementation of cryptographic algorithms They can demonstrate a deep understanding of several structures and designs of stream and block ciphers They can take an advanced step towards hardware and physical security such as TRNG, PUFs. 				
Grading through: written exam 				
Requires: • Cryptology (CS3420-KP04, CS3420)				
Responsible for this module: • Prof. DrIng. Mladen Berekovic Teacher: • Institute of Computer Engineering • DrIng. Saleh Mulhem				
 Literature: Ferguson, Niels, Bruce Schneier, and Tadayoshi Kohno: Cryptography Engineering: Design Principles and Practical Applications - 2012 Koç Ç.K.: Cryptographic Engineering - Springer, Boston, MA, (2009) Wachsmann, Christian, and Ahmad-Reza Sadeghi: Physically unclonable functions (PUFs): Applications, models, and future directions - Morgan & Claypool Publishers, 2014 Johnston, David: Random Number Generators Principles and Practices: A Guide for Engineers and Programmers - Walter de Gruyter GmbH & Co KG, 2018 Language: offered only in English 				



Notes:

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s): - Successful completion of exercises as specified at the beginning of the semester.

Module examination(s):

- CS4705-L1: Cryptographic Technology, written exam, 90min, 100% of module grade.





CS4720-KP06 - Energy Efficiency in Emebedded Systems (EEE)			
Duration:	Turnus of offer:		Credit points:
1 Semester	every summer semester		6
Course of study, specific field and term:			
 Master Robotics and Autonomous Sy Master Computer Science 2019 (opti 	/stems 2019 (module part), onal subject), Elective, Arbi	Additionally recognized el trary semester	ective module, Arbitrary semester
Classes and lectures:		Workload:	
 Energy Efficiency in Emebedded Sys Energy Efficiency in Emebedded Sys 	tems (lecture, 2 SWS) tems (exercise, 2 SWS)	 85 Hours private 70 Hours in-class 25 Hours exam p 	studies and exercises room work reparation
Contents of teaching:			
 Motivation and power dissipation or Power dissipation of digital circuits, Power Management in Hard- and So Energy efficient system design (appl) Energy Harvesting and Transiently P 	n semiconductor level inparticular CMOS ftware (Sleep Modes, DVS, l ications) owered Computing (TPC)	FS, Undervolting)	
Qualification-goals/Competencies:			
 students will have a deeper understate embedded systems They have a deeper understanding of They can analyze the power dissipate They can use a variety of standard tee They can model and evaluate energy 	anding of nardware and sof of the electrotechnical basic ion of systems at any level a echniques to achieve y-autonomous systems	tware mechanisms for eva s of power dissipation in d and apply appropriate met	ligital systems hods to increase efficiency
 Grading through: Written or oral exam as announced by the examiner 			
Responsible for this module:			
Prof. DrIng. Mladen Berekovic			
Teacher:			
Institute of Computer Engineering			
• Dr. Ulf Kulau			
 Literature: Ulf Kulau: Course: Energy Efficiency in Embedded Systems A System-Level Perspective for Computer Scientists - EWME, 2018 David Harris and N. Weste: CMOS VLSI Design ed Pearson Education, 2010 Jan Rabaey: Low Power Design Essentials (Integrated Circuits and Systems) - Springer, 2009 			
Language:			
English, except in case of only Germa	an-speaking participants		
Notes: Prerequisites for attending the module: - None			
Prerequisites for the exam: - Successful completion of practice and project assignments during the semester.			





CS5195-KP04 - Current Topics in IT Security (AktTheITS)				
Duration:	Turnus of offer: Credit points:		Credit points:	
1 Semester	each semester		4	
 Course of study, specific field and term: Master Computer Science 2019 (optional subject), Elective, Arbitrary semester Master IT-Security 2019 (compulsory), IT-Security, 3rd semester Master Robotics and Autonomous Systems 2019 (optional subject), Additionally recognized elective module, Arbitrary semester 				
Classes and lectures:		Workload:		
 Current Topics IT Security and Reliab lectures, 2 SWS) Current Topics IT Security and Reliab 	ility (seminar-style ility (project work, 1 SWS)	 45 Hours work of 45 Hours in-class 30 Hours private 	 45 Hours work on project 45 Hours in-classroom work 30 Hours private studies and exercises 	
Contents of teaching:				
 new results in cyber security design and implementation of a security 	ure system for a complex ap	oplication and its security a	analysis	
Qualification-goals/Competencies:				
 deeper knowledge of current develo professional experience of construction 	pments in IT security ing and analyzing compute	r systems and networks w	ith respect to security issues	
Grading through:				
Responsible for this module:				
Prof. DrIng. Thomas Eisenbarth Teacher:				
 Institute for IT Security Institute for Theoretical Computer Sc 	ience			
Prof. Dr. Maciej Liskiewicz				
 Prof. Dr. Rüdiger Reischuk Prof. DrIng. Thomas Eisenbarth 				
Prof. Dr. Esfandiar Mohammadi				
Literature:				
 papers to be discussed depend on sp 	pecific topics: -			
Language:				
 English, except in case of only German-speaking participants 				
Notes:				
Admission requirements for taking the module: - None				
Admission requirements for participation in module examination(s): - alternates, will be announced at the beginning of the semester				
Module Exam(s): - CS5195-L1: Current Topics in IT Security, oral exam, 100% of module grade.				

In the winter semester, the organization and teaching are carried out by ITS, with Professor Thomas Eisenbarth in charge.

In the summer semester, the organization and teaching are carried out by TCS, with Professor Rüdiger Reischuk holding the responsibility.





CS5560-KP05 - Design and Control of UAVs (DCUAV)				
Duration:	Turnus of offer:	Credit points:		
1 Semester	every summer semester	5		
Course of study, specific field and term:				
Master Robotics and Autonomous	Systems 2019 (optional subj	ect), Additionally recognized elective module, Arbitrary semester		
Classes and lectures:		Workload:		
 Design and Control of Unmanned A SWS) Design and Control of Unmanned A SWS) 	Aerial Vehicles (lecture, 2 Aerial Vehicles (exercise, 2	 60 Hours in-classroom work 40 Hours work on project 30 Hours private studies 20 Hours exam preparation 		
Contents of teaching:				
 Overview of UAV systems and components UAV safety and regulations Introduction to autopilot systems Fundamentals of multicopter dynamics Assembly of a multicopter Onboard sensors and data fusion Introduction to multicopter control Motion planning and autonomous flight 				
 Students know about basic types of UAV systems and their components Students are familiar with basic UAV safety procedures and regulations Students understand the fundamentals of UAV dynamics and control Students are able to assemble and program a simple multicopter Students have gained hands-on experience on an individual drone project Students are acquainted with algorithms for motion planning and autonomous flight Students know about current trends in UAVs 				
Grading through: portfolio exam 				
Responsible for this module: • Prof. Dr. Georg Schildbach Teacher: • Institute for Electrical Engineering in Medicine • Prof. Dr. Georg Schildbach • Carlos Castelar, M.Sc.				
 Literature: Quan, Quan: Introduction to Multicopter Design and Control - 1st Edition, Springer Singapore, 2017. Quan, Quan; Dai, Xunhua, Dai; Wang, Shuai: Multicopter Design and Control Practice - 1st Edition, Springer Singapore, 2021 				
Language:offered only in English				
Notes:				



Admission requirements for taking the module: - None

Admission requirements for participation in module examination(s): - Writing a project paper according to the specifications at the beginning of the semester

Module Examination(s):

- CS5560-L1: Design and Control of UAVs, Portfolio examination consisting of: 1/3 project work and 2/3 examination

The type of examination (written or oral) is determined at the beginning of the semester.



MA4030-KP08, MA4030 - Optimization (Opti)			
Duration:	Turnus of offer:		Credit points:
1 Semester	each summer semester		8
 Course of study, specific field and term: Minor in Teaching Mathematics, Bachelor of Arts 2023 (compulsory), mathematics, 8th semester Bachelor CLS 2023 (compulsory), mathematics, 4th semester Master Auditory Technology 2022 (optional subject), mathematics, 2nd semester Master MES 2020 (optional subject), mathematics, 4natural sciences, Arbitrary semester Bachelor Computer Science 2019 (optional subject), Extended optional subjects, Arbitrary semester Master Robotics and Autonomous Systems 2019 (optional subject), Additionally recognized elective module, Arbitrary semester Master Robotics and Autonomous Systems 2017 (compulsory), mathematics, 8th semester Master Auditory Technology 2017 (optional subject), mathematics, 1st or 2nd semester Bachelor Computer Science 2016 (optional subject), advanced curriculum, Arbitrary semester Bachelor CLS 2016 (compulsory), mathematics, 4th semester Master MES 2014 (optional subject), mathematics, 2nd semester Master MES 2011 (optional subject), mathematics, 2nd semester Master Computer Science 2012 (optional subject), advanced curriculum numerical image processing, 2nd or 3rd semester Bachelor MES 2011 (optional subject), medical engineering science, 6th semester Master Computer Science 2012 (optional subject), advanced curriculum analysis, 2nd or 3rd semester 			nester semester d elective module, Arbitrary semester nester ter processing, 2nd or 3rd semester d semester
Classes and lectures:		Workload:	
 Optimization (lecture, 4 SWS) Optimization (exercise, 2 SWS) 	ercise, 2 SWS) • 130 Hours private • 90 Hours in-classr • 20 Hours exam pr		e studies and exercises room work reparation
 Linear optimization (simplex method Unconstrained nonlinear optimizatio Equality- and inquality-constrained r Stochastic methods for machine lear 	d) on (gradient descent, conjug nonlinear optimization (Lag rning	gate gradients, Newton me range multipliers, active se	ethod, Quasi-Newton methods, globalization) et methods)
Qualification-goals/Competencies: • Students can model real-life problems as optimization problems. • They understand central optimization techniques. • They can explain central optimization techniques. • They can compare and assess central optimization techniques. • They can implement central optimization techniques. • They can assess numerical results. • They can select suitable optimization techniques for practical problems. • Interdisciplinary qualifications: • Students can transfer theoretical concepts into practical solutions. • They are experienced in implementation. • They can think abstractly about practical problems.			
Grading through: • Written or oral exam as announced by the examiner			
Is requisite for: • Non-smooth Optimization and Analy	ysis (MA5035-KP05)		
Requires: • Linear Algebra and Discrete Structur • Analysis 2 (MA2500-KP09) • Analysis 2 (MA2500-KP04, MA2500)	es 2 (MA1500-KP08, MA150	10)	



Responsible for this module:
Prof. Dr. rer. nat. Jan Modersitzki
Teacher:
Institute of Mathematics and Image Computing
 Prof. Dr. rer. nat. Jan Modersitzki Prof. Dr. rer. nat. Jan Lellmann
Literature:
 J. Nocedal, S. Wright: Numerical Optimization - Springer F. Jarre: Optimierung - Springer C. Geiger: Theorie und Numerik restringierter Optimierungsaufgaben - Springer
Language: • offered only in German
Notes:
Prerequisites for attending the module: - None (Familiarity with the topics of the required modules is assumed, but the modules are not a formal prerequisite for attending the course).
Prerequisites for the exam: - Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.
Examination: - MA4030-L1: Optimization, written examination (90 min) or oral examination (30 min) as decided by examiner, 100 % of final mark



RO5803-KP04 - Rescue Robotics (RR)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each summer semester		4	
Course of study, specific field and term: • Master Robotics and Autonomous Sy:	• Master Robotics and Autonomous Systems 2019 (optional subject). Additionally recognized elective module. Arbitrary semester			
Classes and lectures:		Workload:		
 RO5803-V: Rescue Robotics (lecture, 2 RO5803-Ü: Rescue Robotics (exercise) 	2 SWS) 2 SWS)	60 Hours in-class60 Hours private	room work studies	
Contents of teaching:				
 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 			ices on rescue robot design. eterogeneous teams.	
 Qualification-goals/Competencies: The students can apply 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: • Oral examination				
Teacher: Institute for Robotics and Cognitive Systems Prof. Dr. rer. nat. Floris Ernst 				
Language:offered only in English				
Notes: Admission requirements for taking the module: - None Entry requirements for taking module examination(s): - RO5803: Rescue Robotics - Successful completion of exercises as specified at the beginning of the semester. Module Exam(s): RO5803-L1: Rescue Robotics, oral examination, 100% of module grade				