

UNIVERSITÄT ZU LÜBECK

Module Guide for the Study Path

Master Robotics and Autonomous Systems

Version from 8. May 2019



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Robotics and Autonomous Systems

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Elective

Medical Robotics (RO5100-KP08, MedRob08)



RO4001 T - Model Predictive Control (MPC)				
Duration:	Turnus of offer:	Credit points:		
1 Semester each winter semester		4		
Course of study, specific field and	term:			
Master Robotics and Autono	mous Systems (module part), spe	cialization field robotics and automation, 1st or 2nd semester		
Classes and lectures:		Workload:		
 Model Predictive Control (lecture, 2 SWS) Model Predictive Control (exercise, 2 SWS) 		 60 Hours in-classroom work 40 Hours private studies 20 Hours exam preparation 		
Contents of teaching:		· · ·		
 LQ optimal control and Kalm Convex optimization Invariant sets Theory of Model Predictive C Algorithms for numerical opt Explicit MPC Practical aspects (Robust MP MPC applications 	an filter control (MPC) timization C, Offset-free tracking, etc.)			
 Students get a comprehensive Students get an overview of Students are able to design r Students get acquainted with Students are able to establish Students gain insight into population 	, ve introduction to methods of op the fundamentals of numerical op nodel predictive controllers for lir h several tools to implement mod n system theoretic properties of n pssible applications areas for MPC	imal control. otimization. near and nonlinear systems. lel predictive controllers. nodel predictive controllers.		
Grading through:				
Written or oral exam as anno	unced by the examiner			
Requires: • Control Systems (RO4400-KP	12)			
Responsible for this module:				
Prof. Dr. Georg Schildbach				
Teacher:				
Prof. Dr. Georg Schildbach				
litoraturo				
 F. Borrelli, A. Bemporad, M. M 978-1107016880) 	lorari: Predictive Control for Linea	r and Hybrid Systems - Cambridge University Press, 2017 (ISBN:		
Language: • offered only in English				
Notes:				
Will be conducted as a two we	ek block course.			



CS5820-KP04, CS5820 - Legal foundations for IT (ITRecht)			
Duration: Turnus of offer:		Credit points:	
1 Semester irregularly		4 (Тур В)	
Course of study, specific field Master Interdisciplinary Master Robotics and Au Master Medical Informat Master MES since 2014 Bachelor MES since 2014 Master Computer Science	and term: Courses (optional subject), Interdisc tonomous Systems (optional subject tics (optional subject), interdisciplina optional subject), no specific field, 1 4 (optional subject), no specific field ce before 2014 (optional subject), in	iplinary modules, arbitrary semester .t), interdisciplinary competence, 1st or 2nd semester ary competence, 1st or 2nd semester st or 2nd semester , arbitrary semester terdisciplinary competence, 3rd semester	
Classes and lectures:		Workload:	
 Legal Foundations for IT (lecture, 1 SWS) Legal Foundations for IT (seminar, 1 SWS) 		 55 Hours private studies 45 Hours in-classroom work 20 Hours exam preparation 	
Contents of teaching: Introduction and Overview Personality rights, freedom of the press and the media, and freedom of speech Regulatory objectives: information and law Youth protection and self-regulation Privacy and Data Protection Press and advertising law Copyright, trademark, patent law German Data Protection Act (TDG) and Teleservice Data Protection Act(TDDSG), Signature Act (SigG), German Interstate Media Services Agreement(MDStV) Contract law and e- contracting International aspects Case Studies Summary and Outlook 			
Qualification-goals/Competer • The students know the • The students know the	n cies: legal basis for the production and u legal basis for the operation of IT an	se of software and digital media. d communications systems.	
Grading through: • Written or oral exam as	announced by the examiner		
Responsible for this module: • Studiengangsleitung lr Teacher: • external institution • externe Lehrbeauftrage Literature: • : • : • :	nformatik te		
 Language: English, except in case of only German-speaking participants 			



CS5840-KP04, CS5840 - Seminar in Englisch (SemiEngl)			
Duration:	Turnus of offer:	Credit points:	
1 Semester	each semester	4 (Тур В)	
Course of study, specific fie Master Computer Scie Master Robotics and Master Computer Scie Master Computer Scie	eld and term: ence since 2019 (optional subject), inte Autonomous Systems (advanced curri ence 2014 till 2018 (optional subject), i ence before 2014 (optional suject), inte	rdisciplinary competence, arbitrary semester culum), interdisciplinary competence, 1st or 2nd semester nterdisciplinary competence, arbitrary semester erdisciplinary competence, arbitrary semester	
Classes and lectures: Workload: • Seminar in Englisch (seminar, 2 SWS) • 90 Hours work on an individual topic with wripresentation • 30 Hours in-classroom work		 Workload: 90 Hours work on an individual topic with written and oral presentation 30 Hours in-classroom work 	
Contents of teaching: • Familiarization in a de • Working on a scientif • Presentation and disc	emanding scientific topic ic topic and its answers for problems o cussion of the topic in English	n their own	
Qualification-goals/Compe • The students can obt • They can review a sci • They are able to prese • The can present and • They can follow a scie	tencies: ain a solid grounding a demanding sci entific work. ent the results in a written documenta discuss a scientific topic in English. entific presentation and assess critically	entific topic. tion and in a talk in an understandable way. y in an open discussion.	
Grading through: • Oral presentation and	l written report		
Responsible for this modul • Studiengangsleitung Teacher: • Institutes of the Depa • Alle prüfungsberech	e: g Informatik Irtment of Computer Science/ Engineer Itigten Dozentinnen/Dozenten des Stu	ring dienganges	
Literature: • :			
Language: • offered only in Englisl	h		



EC5010-KP04, EC5010 - Entrepreneurship in the digital economy (EEntre)			
Duration:	uration: Turnus of offer:		Credit points:
1 Semester	each winter semester		4
Course of study, specific field and term: • Master Media Informatics (optional • Master Interdisciplinary Courses (op • Master Robotics and Autonomous • Master Entrepreneurship in Digital • Master Entrepreneurship in Digital	subject), Interdisciplinary m otional subject), Interdiscipli Systems (optional subject), Technologies (compulsory), Technologies since 2020 (cc	odules, arbitrary semester nary modules, arbitrary sen interdisciplinary competenc entrepreneurship, 3rd seme mpulsory), entrepreneurshi	nester ce, 1st or 2nd semester ester ip, 3rd semester
Classes and lectures:		Workload:	
 Entrepreneurship in the digital economy (lecture, 2 SWS) Entrepreneurship in the digital economy (exercise, 1 SWS) 		 60 Hours private studies 45 Hours in-classroom work 15 Hours exam preparation 	
 In this class students obtain a key is shaping and changing of young co time, this class will include strategy entrepreneurship in the context of Special emphasize will be on start- 	nsight into the entrepreneu mpanies. In addition, studer development, fundamenta established enterprises and ups in the digital economy.	rial processes, the identifica nts are able to understand b l aspects of corporate mark social entrepreneurship.	ition of business opportunities as well as the pusiness models on a basic level. At the same eting, growth forms and strategies,
 Qualification-goals/Competencies: Students are able to identify the central issues in the process of founding a new company and have a broad Knowledge including the scientific basis as well as the practical application of the importance of entrepreneurship in economic and in a business context. Students are able to apply this knowledge to their own examples and in a changing context. Students are able to develop features and factors of successful start-upsand 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: attendance at exercises portfolio exam written exam, oral exam and/or presentation as announced by the examiner 			
Responsible for this module: • Prof. Dr. Christian Scheiner Teacher: • Institute for Entrepreneurship and Business Development • Prof. Dr. Christian Scheiner Literature: • Bygrave & Zacharakis: The Portable MBA in Entrepreneurship - Wiley-Verlag: 2010 • Bygrave & Zacharakis: Entrepreneurship - Wiley-Verlag: 3. Auflage 2013 • Hisrich, Peters & Shepherd: Entrepreneurship - McGraw-Hill: International Edition 2010 Language: • English, except in case of only German-speaking participants			



Notes:

(Formerly EC5010)





PS4620-KP04, PS4620SJ14 - Ethics of Sciences (EthikKP04)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each summer semester		4 (Тур В)	
Course of study, specific field and term: Bachelor MES since 2014 (optional sub Master MES since 2014 (optional sub Master Medical Informatics (optional Master Interdisciplinary Courses (optional Bachelor Interdisciplinary Courses (optional Master Robotics and Autonomous Sy Bachelor Biophysics (optional subjection) Master Medical Informatics since 201	ubject), no specific field, arb oject), no specific field, 1st o I subject), interdisciplinary c cional subject), Interdisciplir ptional subject), Interdiscipl ystems (optional subject), in t), no specific field, 6th sem I9 (optional subject), interd	itrary semester r 2nd semester competence, 1st or 2nd ser hary modules, arbitrary sen linary modules, arbitrary se nterdisciplinary competence ester isciplinary competence, 1s	mester nester emester ce, 1st or 2nd semester t or 2nd semester	
Classes and lectures:		Workload:		
• Ethics in Sciences (lecture, 2 SWS)	 Ethics in Sciences (lecture, 2 SWS) 65 Hours private studies 30 Hours in-classroom work 25 Hours work on an individual topic with written and ora presentation 			
Contents of teaching:				
 Basics of philosophy and sociology of science Good scientific practice Basics of bioethics: duties of investigators, obligations to colleagues, Ethics of human subjects research and animal experim. Environmental ethicsentation. Control and governance of technology. Risk assessement Use and implications of images in science 				
 Students can explain the methodolo They can recognize ethical dimensio They can recognize and evaluate eth They can understand relevant laws in They can participate in current discu They can reflect on ethical dimensio 	ogy of the physical sciences ons of practice and deciding nical dimensions of practice n Germany ussions in bioethics and rese ns of biomedical sciences	and technology and their and deciding in biotechno earch ethics	philosophical basis olgoy	
Grading through: • Oral presentation and written report	:			
Responsible for this module:				
Prof. Dr. phil. Christoph Rehmann-Sutter Teacher: Institute for the History of Medicine and Science Studies				
 Prof. Dr. med. Cornelius Borck Prof. Dr. phil. Christoph Rehmann-Sutter Prof. Dr. rer. nat. Burghard Weiss 				
Literature:				
 Daniel A. Vallero: Biomedical Ethics for Engineers. Ethics and Decision Making in Biomedical and Biosystem Engineering - Amsterdam: Elsevier 2007 Ben Mepham: Bioethics. An Introduction for the Biosciences - Oxford: Oxford University Press 2008 Sergio Sismondo: An introduction to science and technology studies - Chichester: Wiley-Blackwell 2010 				
Language: offered only in English				





PS5430-k	(P04 - Ethical Design Considerat	ions in Medical Technology (EthMedTech))
Duration:	Turnus of offer:	Credit points:	
1 Semester	each summer semester	4	
Course of study, specific fiel Master MES since 2020 Medicine clinical part (Master MES since 2014 Master Robotics and A	d and term: (optional subject), interdisciplinary, arbi optional subject), Elective, arbitrary seme (optional subject), no specific field utonomous Systems (optional subject), i	trary semester ester nterdisciplinary competence, 2nd or 4th semester	
Classes and lectures: Workload: • Ethical Design Considerations in Medical Technology (lecture with project, 3 SWS) • 50 Hours private studies • 45 Hours work on project • 25 Hours in-classroom work			
Contents of teaching: Basic concepts and me Ethical decision model Case studies and proje Innovation methods b Innovation games, bus Qualification-goals/Competer	ethods in ethics. s. .cts in ethical decision-making in medical ased on the adapted BIODESIGN principl .iness-, value proposition- and ethics-can encies:	technology. e. vas	
Grading through:			
 Written or oral exam a: Marked presentation w 	s announced by the examiner vith written report		
Responsible for this module • DrIng. Christian Herzo Teacher: • Institute for Electrical E • DrIng. Christian Herzo • Prof. Dr. Michael Friebe	: og, geb. Hoffmann ingineering in Medicine og, geb. Hoffmann		
Language: • English, except in case	of only German-speaking participants		



PS5810-KP04,	, PS5810 - Scientific	Teaching and Tutoring	g (WLehrKP04)
Duration:	Turnus of offer:		Credit points:
1 Semester	each semester		4 (Тур В)
Course of study, specific field and term: Master Computer Science since 2019 Master Entrepreneurship in Digital Te Master Interdisciplinary Courses (opt Bachelor Interdisciplinary Courses (opt Master CLS starting 2016 (optional su Master Robotics and Autonomous Sy Master Entrepreneurship in Digital Te Master Media Informatics (optional su Master MES since 2014 (optional su Bachelor MES since 2014 (optional su Master Computer Science 2014 till 20 Master CLS (optional suject), interdise Master Computer Science before 201	(optional subject), interd echnologies since 2020 (o ional subject), Interdiscipl ptional subject), Interdisci ubject), Interdisciplinary m rstems (optional subject), echnologies (optional subject), ubject), interdisciplinary c ject), no specific field, 1st ubject), no specific field, 1st ubject), no specific field, 1st ubject), no specific field, 3 18 (optional subject), inter ciplinary competence, 3rd 4 (optional subject), inter	isciplinary competence, arbi ptional subject), interdiscipl inary modules, arbitrary sen plinary modules, arbitrary sen odules, 3rd semester interdisciplinary competence ject), interdisciplinary comp ompetence, arbitrary semes or 2nd semester rbitrary semester erdisciplinary competence, a l semester disciplinary competence, ar	itrary semester inary competence, arbitrary semester nester emester ce, 1st or 2nd semester etence, arbitrary semester iter arbitrary semester bitrary semester
Classes and lectures: • Theory and Practice of Good Teachin • Work as a tutor in a lecture (practical	of Good Teaching (seminar, 1 SWS) lecture (practical course, 2 SWS) • 45 Hours oral presentation (including preparation) • 15 Hours in-classroom work		studies and exercises sentation (including preparation) room work
Contents of teaching: • Organizing and running a scientific le • Basic didactics of scientific teaching • Practical work in tutorials	ecture		
Qualification-goals/Competencies: Ability to run a tutorial and to explain Basic pedagogical and didactical skill 	n topics of the relevant su Is	bfield of informatics.	
Grading through: • continuous participation in all course	es of the module		
Responsible for this module: • Prof. Dr. rer. nat. Jürgen Prestin Teacher: • Institute for Mathematics • Dr. Jörn Schnieder Language: • depends on the chosen courses			



Г

	PY1200-KP04 - Basic I	Psychology 1 (APKP04	4)		
Duration:	Turnus of offer:		Credit points:		
1 Semester	1 Semester each winter semester		4		
Course of study, specific field and term: • Bachelor MES since 2020 (optional s • Master Robotics and Autonomous S • Bachelor Biophysics (optional subjec • Master MES since 2020 (optional sub	subject), interdisciplinary, ar systems (optional suject), in ct), no specific field, 5th sen bject), interdisciplinary, arbi	bitrary semester terdisciplinary competence nester trary semester	e, 1st or 2nd semester		
Classes and lectures: Workload: • Basic Psychologie 1 (lecture, 2 SWS) • 90 Hours private studies and exercises • 30 Hours in-classroom work		studies and exercises room work			
Contents of teaching: • Acquisition of basic knowledge in th • Teaching of basic ideas, concepts an • Learning basic principles of experim • Understanding and judgment of ba	he topics perception, action nd theories of perception ar nental psychology work for sic ideas, theories and meth	, cognition and language nd cognitive psychology planning and conducting e nods of perception, cognitio	xperiments on and language		
 Qualification-goals/Competencies: Understanding and ability to apply psychological concepts Basic understanding of translating psychological research questions into empirical questions Developing scientific reasoning, thinking and discussing based on basic psychological research Social competency in discussing and application of knowledge Self competency in terms of critical reflection and work with scientific literature Ability to structure newly acquired knowledge 					
Grading through: written exam 					
Responsible for this module: • Prof. Dr. rer. nat. Ulrike Krämer Teacher: • Department of Neurology • Prof. Dr. rer. nat. Ulrike Krämer • Dr. rer. nat. Ulrike Krämer • Dr. rer. nat. DiplPsych. Frederike Beyer					
 Müsseler (Hrsg.): Allgemeine Psychologie - Spektrum, 2007 Anderson: Kognitive Psychologie (7. Auflage) - Springer, 2013 					
Anguage: offered only in German					



PY4210-KP04, PY4210 - Engineering Psychology (IngPsy)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each winter semester		4	
Course of study, specific field and terms Master Robotics and Autonomous Master MES since 2014 (optional sub- Bachelor MES since 2014 (optional Master Media Informatics (compul Bachelor Psychology since 2016 (or Master Psychology (optional subject)	Systems (optional subject), ubject), no specific field, 1st subject), no specific field, ar sory), psychology, 1st semes ptional subject), psychology ct), psychology, arbitrary ser	interdisciplinary competen or 2nd semester rbitrary semester ster r, arbitrary semester mester	nce, 1st or 2nd semester	
Classes and lectures:		Workload:		
 Engineering Psychology (lecture, 2 Engineering Psychology (seminar, 	2 SWS) 1 SWS)	75 Hours in-class45 Hours private	sroom work e studies and exercises	
Contents of teaching:				
 Overview over the lecture: Special features, psychological basics Introduction and overview: definition, brief introduction to philosophy of technics, technology use in everyday life, brief history of engineering psychology Man-machine-systems: definition, application, design and evaluation of MMS, age-differentiated design Usability: User Experience, Accessibility, Inclusive Design Assistance and automation: strategies, consequences, taxonomies Human information processing in interaction with technical systems: structure and process, Mental Models and cognitive modelling, strengths and weaknesses, limits, task dependency, complex problem solving, typical errors, heuristics Summary 				
Qualification-goals/Competencies: Students understand psychologica Students can integrate their own w They can can plan, coordinate and psychologists, ergonomics and use 	al fundamentals for the desig work on MMS in a historical a I conduct usability studies ar ability specialists and design	gn and evaluation of man-n and sociological perspectiv nd work effectively in interc ers.	nachine-systems (MMS). e. disciplinary teams with engineering	
Grading through:				
Written or oral exam as announced	d by the examiner			
Responsible for this module: Prof. Dr. rer. nat. Thomas Franke Teacher: Institute for Multimedia and Interactive Systems Prof. Dr. rer. nat. Thomas Franke 				
 Literature: B. Zimolong & U. Konradt: Ingenieurpsychologie, Enzyklopädie der Psychologie, Wirtschafts-, Organisations- und Arbeitspsychologie - Serie 3 / Bd. 2 Ingenieurpsychologie, Hogrefe-Verlag: Göttingen, 1990 / 2006 W. Hacker: Allegmeine Arbeitspsychologie - Hogrefe Verlag, 2014 				
 P. Badke-Schaub, G. Hofinger & K. Lauche: Human Factors, Psychologie des sicheren Handelns - Springer, 2008 				
Language: • offered only in German				





PY4210-KP05 - Engineering Psychology (IngPsy5)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each winter semester		5	
Course of study, specific field • Master MES since 2020 • Bachelor MES since 2022 • Master Media Informati • Master Robotics and Au	l and term: (optional subject), interdisciplinary, ark 0 (optional subject), interdisciplinary cs since 2020 in planing (compulsory), Itonomous Systems (optional subject)	oitrary semester psychology, 1st to 3th seme , interdisciplinary competend	ster .e, 1st or 2nd semester	
Classes and lectures:		Workload:		
Engineering PsychologyEngineering Psychology	y (lecture, 2 SWS) y (seminar, 1 SWS)	 105 Hours private 45 Hours private	e studies and exercises studies	
Contents of teaching:				
Grading through: • Written or oral exam as	announced by the examiner			
Responsible for this module: • Prof. Dr. rer. nat. Thoma Teacher: • Institute for Multimedia • Prof. Dr. rer. nat. Thoma	is Franke and Interactive Systems is Franke			
Literature: • : • : Language: • offered only in German				



CS4	130-KP06, CS4130 - In	formation Systems (InfoSys)
Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	6
Course of study, specific field and terms	:	
 Master Computer Science since 20 Master Entrepreneurship in Digital Master Media Informatics since 20 Master Computer Science since 20 Master Medical Informatics since 2 Master Robotics and Autonomous Master IT-Security (basic module), Master Medical Informatics (basic of Master Medical Informatics (basic of Master Medical Informatics (basic of Master Media Informatics (optional Master Entrepreneurship in Digital Master Computer Science 2014 till Master Computer Science 2014 till 	19 (compulsory), Canonical 1 Technologies since 2020 (b 20 in planing (optional subje 19 (basic module), systems i 019 (basic module), systems Systems (optional subject), systems informatics, 1st or 2 module), ehealth / infomatic I subject), computer science Technologies (basic module 2018 (optional subject), spe 2018 (basic module), system	Specialization Data Science and Al, arbitrary semester asic module), technology field computer science, 1st or 2nd semester ect), computer science, arbitrary semester informatics, 1st or 2nd semester s informatics, 1st or 2nd semester computer science, 1st or 2nd semester 2nd semester es, 1st or 2nd semester e, arbitrary semester e), technology field computer science, 1st or 2nd semester ecialization field software systems engineering, 2nd or 3rd semester ms informatics, 1st or 2nd semester
Classes and lectures:		Workload:
Information Systems (lecture, 2 SV	/S)	100 Hours private studies
 Information Systems (exercise, 2 S 	WS)	 60 Hours in-classroom work 20 Hours exam preparation
Contents of teaching:		
 ontological constraints as well as v Data stream processing (e.g., for se Non-symbolic data and their symbolic data and their symbolic the symbolic data and their symbolic the symbolic data and the symb	with incomplete data) ensor networks, robotics, we polic annotations (e.g., for ap hybrid decision and comput ess analysis (e.g., for biologic	ette detection, inconsistency nanaling, integration than relational and eb agents) with OBDA and complex event processing (CEP) oplications in bioinformatics/computational biology and for media tation problems and their complexity, (analysis of) algorithms cal pathways) and process design (e.g., for non-trivial business processes)
Qualification-goals/Competencies:		
 Knowledge: The module aims at in overview of concepts, methods, at such as the web. Skills: The students get a basic und limitations of information systems and completeness (Does the syste possible to formulate all required it take the system to come up with logical modeling skills using real a time-based and event data), and r acquires the ability to assess which logical models where necessary. Social Competence und Independ solutions in short presentations. In 	ntroducing the students to the nd theories for understanding derstanding of logical and for , be it concrete ones or thos m produce what is expected queries? What are equivalen n an answer? How much spa pplication scenarios from in- nedicine (sensor networks, g n logical model is suitable for ent Work: Students work in a udependent work is promote	he formal basics of databases and ontologies, so that they get an ig, analyzing, and designing information systems in open large contexts, ormal methods, which allows them to assess the possibilities and the that still have to be designed. Assessment parameters are correctness d? If so, does it produce all results?) as well as expressiveness (Is it it query languages?) and, last but not least, performance (How long does ince does it need?). In addition to these analysis skills, students receive dustry (business processing, integration of data resources, processing of genomic ontologies, annotation). Based on these, the student not only or which application scenario, but also the ability to construct their own groups to solve small exercises and project problems and sketch their ed by exercises with practical ontology and database systems.
Grading through:		
 exercises and project assignments Written or oral exam as announced 	d by the examiner	
Responsible for this module:		
 Prof. Dr. rer. nat. habil. Ralf Möller PD Dr. Sven Groppe 		



Teacher:

- Institute of Information Systems
- PD Dr. Sven Groppe
- Prof. Dr. rer. nat. habil. Ralf Möller
- PD Dr. Özgür Özçep

Literature:

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

Language:

• German and English skills required

Notes:

Previous name: Web Based Information Systems

Prerequisites for this module are:

- Algorithm and Data Structures (CS1001)
- Linear Algebra and Discrete Structures I+II (MA1000, MA1500)
- Databases (CS2700)

Recommended additional modules:

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



Ouration:	Turnus of offer:	Credit po	ints:
Semester	each winter semester	6	
Course of study, specific field a Master Computer Science Master Entrepreneurship Master Media Informatics Master Computer Science Master Medical Informatic Master Robotics and Auto Master IT-Security (basic fi Master Medical Informatic Master Medical Informatics Master Entrepreneurship Master Computer Science Master Computer Science	and term: e since 2019 (compulsory), Canonical Sp in Digital Technologies since 2020 (bas since 2020 in planing (optional subject e since 2019 (basic module), systems inf cs since 2019 (basic module), systems inf onomous Systems (optional subject), co module), systems informatics, 1st or 2nd cs (basic module), ehealth / infomatics, (optional subject), computer science, a in Digital Technologies (basic module), e 2014 till 2018 (optional subject), systems e 2014 till 2018 (basic module), systems	ecialization SSE, arbitrary semester c module), technology field computer c computer science, arbitrary semest ormatics, 1st or 2nd semester formatics, 1st or 2nd semester mputer science, 1st or 2nd semester semester st or 2nd semester bitrary semester technology field computer science, 1 lization field software systems engin nformatics, 1st or 2nd semester	er science, 1st or 2nd semester ter Ist or 2nd semester heering, 2nd or 3rd semester
Classes and lectures:		Workload:	
 Distributed Systems (lect Distributed Systems (exercised) 	 Distributed Systems (lecture, 2 SWS) Distributed Systems (exercise, 2 SWS) Obstributed Systems (exercise, 2 SWS)		
 Protocols and layered model Message representations Realization of network see Communication mechanic Addresses, names and dia Synchronisation Replication and consister Fault tolerance Distributed transactions Security 	odels rvices isms rectory services ncy		
 Qualification-goals/Competent The participants will according, naming etc. They know the most imp They are able to program They know the most imp mutual exclsuion. They have a good feeling They have a good feeling 	cies: uire a deep understanding for problem ortant services in distributed systems so simple distributed applications and sy ortant algorithms in distributed system for when it makes sense to use distribu- for what kind of solutions could best b	s to be solved in distributed systems ch as name service, distributed file s tems themselves. , for instance for time synchronizatio ted instead of centralized systems. e used for what kind of problems in a	, such as synchronization, error ystems etc. on, for leader election, or for distributed Internet applications.
Grading through: • Written or oral exam as a	nnounced by the examiner		
Responsible for this module: • Prof. Dr. Stefan Fischer Feacher: • Institute of Telematics			



have to be positively attested.

Module Guide

 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: Preliminary examination results can be provided at the beginning of each Semester. If preliminary examination results are required, they

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		and compater syste	
Duration:	Turnus of offer:		Credit points:
Semester	each summer semeste	۲	6
Course of study, specific field and	term:		
 Master Entrepreneurship in D Master Computer Science sin Master Medical Informatics si Master Robotics and Autonor Master IT-Security (basic mod Master Medical Informatics (b Master Entrepreneurship in D Master Computer Science 20 	igital Technologies since 2020 ce 2019 (basic module), technic nce 2019 (optional subject), tec nous Systems (optional subjec ule), technical computer science asic module), computer science igital Technologies (basic module), technologies (basic mo	(advanced module), techn cal computer science, 1st o chnical computer science, t), computer science, 1st o ce, 1st or 2nd semester e, 1st or 2nd semester ule), technology field com nnical computer science, 1	nology field computer science, arbitrary semester or 2nd semester 1st or 2nd semester or 2nd semester puter science, 1st or 2nd semester st or 2nd semester
Classes and lectures:		Workload:	
 Parallel Computer Systems (le Parallel Computer Systems (e 	ems (lecture, 2 SWS) ems (exercise, 2 SWS)		
Contents of teaching:			
 Parallel computing models Taxonomy of parallel computing Multi/manycore-systems Graphic Processing Units (GP) OpenCL Specification languages Hardware architectures System management of man 	ers Us) y-core systems		
 Qualification-goals/Competencies: Students are able to characted They are able to explain mode They are able to make use of They are able to judge which used. They are able to evaluate the They are able to write progration of the programe able to compare meters 	rize different parallel computin els of parallel computing. common programming interfa kind of parallel computing sys pros and cons of different harc ms for parallel computing syste thods for dynamic voltage and	ig architectures. Ices for parallel computing tem is best suited for a de dware architectures. ems under considerations I frequency scaling (DVFS)	g systems. dicated problem and how many cores should b of the underlying hardware architecture. for manycore systems.
Grading through:			
ExercisesWritten or oral exam as anno	unced by the examiner		
Responsible for this module:			
Prof. DrIng. Mladen Berekov	ic		
Teacher:			
Institute of Computer Engine	ering		
Prof. DrIng. Mladen Berekov	ic		
Literature:			
 G. Bengel, C. Baun, M. Kunze, M. Dubois, M. Annavaram, P. B. R. Gaster, L. Howes, D. R. K. D. Wilkinger, M. Aller, Derula 	K. U. Stucky: Masterkurs Paralle Stenström: Parallel Computer C aeli, P. Mistry, D. Schaa: Heterog	ele und Verteilte Systeme - Drganization and Design - geneous Computing with (- Vieweg + Teubner, 2008 University Press 2012 OpenCL - Elsevier/Morgan Kaufman 2013

• 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





CS42	20-KP04, CS4220 - Pa	ttern Recognition (M	uster)		
Duration:	Turnus of offer:		Credit points:		
1 Semester	every second semester 4		4		
 Course of study, specific field and term: Master Media Informatics since 2020 in planing (optional subject), computer science, arbitrary semester Master MES since 2014 (optional subject), medical engineering science, arbitrary semester Master Robotics and Autonomous Systems (optional subject), computer science, 1st or 2nd semester Master CLS starting 2016 (compulsory), mathematics, 2nd semester Master Medical Informatics since 2019 (optional subject), Medical Data Science / Artificial Intelligence, 1st or 2nd semester Master Medical Informatics (optional subject), medical image processing, 1st or 2nd semester Master Medical Informatics (optional subject), medical image processing, 1st or 2nd semester 					
Classes and lectures:		Workload:			
 Pattern Recognition (lecture, 2 SWS) Pattern Recognition (exercise, 1 SWS) 	 Pattern Recognition (lecture, 2 SWS) Pattern Recognition (exercise, 1 SWS) Pattern Recognition (exercise, 1 SWS) 20 Hours exam preparation 				
Contents of teaching: Introduction to probability theory Principles of feature extraction and pattern recognition Bayes decision theory Discriminance functions Neyman-Pearson test Receiver Operating Characteristic Parametric and nonparametric density estimation KNN classifiers Linear classifiers Linear classifiers Support vector machines and kernel trick Random Forest Neural Nets Feature reduction and feature transforms Validation of classifiers Selected application scenarios: acoustic scene classification for the selection of hearing-aid algorithms, acoustic event recognition,					
 Qualification-goals/Competencies: Students are able to describe the main elements of feature extraction and pattern recognition. They are able to explain the basic elements of statistical modeling. They are able to use feature extraction, feature reduction and pattern classification techniques in practice. 					
 Grading through: Exercises Written or oral exam as announced by the examiner 					
Responsible for this module: Prof. DrIng. Alfred Mertins Teacher: Institute for Signal Processing Prof. DrIng. Alfred Mertins 					
Literature: • R. O. Duda, P. E. Hart, D. G. Storck: Pattern Classification - New York: Wiley					
offered only in German					





CS4405-KP04, CS4405 - Neuroinformatics (NeuroInf)					
Duration:	Turnus of offer:		Credit points:		
1 Semester	each summer semester		4		
Course of study, specific field and term:					
 Course of study, specific field and term: Master CLS starting 2016 (compulsory), computer science, 2nd semester Master Robotics and Autonomous Systems (optional subject), computer science, 1st or 2nd semester Master MES since 2014 (optional subject), computer science / electrical engineering, arbitrary semester Master MES before 2014 (optional subject), mathematics, 2nd semester Bachelor MES before 2014 (optional subject), optional subject medical engineering science, 6th semester Master Computer Science before 2014 (optional subject), advanced curriculum organic computing, 2nd or 3rd semester Master MES before 2014 (advanced curriculum), imaging systems, signal and image processing, 2nd semester Master Computer Science before 2014 (optional subject), advanced curriculum intelligent embedded systems, 2nd or 3rd semester Master Computer Science before 2014 (compulsory), specialization field robotics and automation, 2nd semester Master CLS (compulsory), computer science, 2nd semester Master CLS (compulsory), computer science, 2nd semester Master MES since 2020 (optional subject), computer science / electrical engineering, arbitrary semester 					
Classes and lectures:		Workload:			
 Neuroinformatics (lecture, 2 SWS) Neuroinformatics (exercise, 1 SWS) 		55 Hours private45 Hours in-class20 Hours exam private	studies room work reparation		
Contents of teaching: • The human brain and abstract neuro • Learning with a single neuron:* Pero • Network architectures:* Hopfield-Ne • Unxupervised Learning:* k-means, N Qualification-goals/Competencies: • The students are able to understand • They know abstract neuronal model	 Contents of teaching: The human brain and abstract neuron models Learning with a single neuron:* Perceptrons* Max-Margin Classification* LDA and logistic Regression Network architectures:* Hopfield-Networks* Multilayer-Perceptrons* Deep Learning Unxupervised Learning:* k-means, Neural Gas and SOMs* PCA & ICA* Sparse Coding Qualification-goals/Competencies: The students are able to understand the principle function of a single neuron and the brain as a whole. 				
 They are able to derive a learning ru They are able to apply (and implementation) 	le from a given error functi ent) the proposed learning	on. rules and approaches to so	lve unknown practical problems.		
Grading through: • Exercises • Written or oral exam as announced b	by the examiner				
Responsible for this module:					
Prof. Dr. rer. nat. Thomas Martinetz					
Institute for Neuro- and Bioinformati	cs				
 Prof. Dr. rer. nat. Thomas Martinetz Prof. Dr. rer. nat. Amir Madany Mamlouk 					
 Literature: S. Haykin: Neural Networks - London: Prentice Hall, 1999 J. Hertz, A. Krogh, R. Palmer: Introduction to the Theory of Neural Computation - Addison Wesley, 1991 T. Kohonen: Self-Organizing Maps - Berlin: Springer, 1995 H. Ritter, T. Martinetz, K. Schulten: Neuronale Netze: Eine Einführung in die Neuroinformatik selbstorganisierender Netzwerke - Bonn: Addison Wesley, 1991 Language: 					
offered only in German					





CS4503-KP12, CS4503 - Ambient Computing (AmbCompA)			
Duration:	Turnus of offer:		Credit points:
2 Semester	normally each year in the	summer semester	12
Course of study, specific field and term: • Master Entrepreneurship in Digital • Master Computer Science since 20 • Master Robotics and Autonomous • Master IT-Security (advanced mode • Master Entrepreneurship in Digital • Master Computer Science 2014 till	Technologies since 2020 (ad 19 (optional subject), advenc Systems (advanced module) ule), Elective Computer Scien Technologies (advanced mo 2018 (advanced module), ad	lvanced module), techno ce module, arbitrary semo), computer science, 1st c nce, 1st or 2nd semester odule), technology field c lvanced curriculum, 2nd	logy field computer science, arbitrary semester ester or 2nd semester omputer science, 2nd and/or 3rd semester and/or 3rd semester
Classes and lectures:		Workload:	
 CS4670 T: Ambient Computing (lecture, 3 SWS) Seminar Ambient Computing (seminar, 2 SWS) Lab Course Ambient Computing (project work, 3 SWS) 		 120 Hours in-classroom work 120 Hours group work 70 Hours private studies 30 Hours oral presentation (including preparation) 20 Hours exam preparation 	
Contents of teaching: • see module parts			
Qualification-goals/Competencies: • see module parts			
Grading through: • Oral examination			
Responsible for this module: • Prof. DrIng. Andreas Schrader Teacher: • Institute of Telematics • Prof. DrIng. Andreas Schrader			
Literature: • : see module parts			
Language: • English, except in case of only Gerr	nan-speaking participants		



CS4504-KP12, CS4504 - Cyber Physical Systems (CPS)				
Duration:	Turnus of offer:	Credit points:		
2 Semester	irregularly	12		
Course of study, specific fiel Master Entrepreneursh Master Computer Scier Master Robotics and A Master IT-Security (adv Master Entrepreneursh Master Computer Scier	d and term: ip in Digital Technologies since 2020 (ad nce since 2019 (optional subject), advence utonomous Systems (advanced module) ranced module), Elective Computer Scien ip in Digital Technologies (advanced mo nce 2014 till 2018 (advanced module), ad	vanced module), technology field computer science, arbitrary semester e module, arbitrary semester , computer science, 1st or 2nd semester ce, 1st or 2nd semester dule), technology field computer science, 2nd and/or 3rd semester vanced curriculum, 2nd and/or 3rd semester		
Classes and lectures:		Workload:		
 CS5150 T: Organic Computing (lecture with exercises, 3 SWS) CS5153 T: Wireless Sensor Networks (lecture with exercises, 3 SWS) Cyber Physical Systems (seminar, 2 SWS) 		 220 Hours private studies 120 Hours in-classroom work 20 Hours exam preparation 		
Contents of teaching: • see module parts				
Qualification-goals/Competencies: • see module parts				
Grading through: • exercises and project a • presentation • Oral examination	ssignments			
Responsible for this module Prof. DrIng. Heiko Har Teacher: Institute of Computer I Prof. DrIng. Heiko Har 	: nann Engineering mann			
Literature: • :				
Language: • German and English sk	ills required			



	CS4660 T - Module Part: Proce	ess Control Systems	(ProzFueSya)
Duration:	Turnus of offer:		Credit points:
1 Semester	each winter semester		4
Course of study, specific field • Master Robotics and Au • Master Computer Scien	l and term: Itonomous Systems (module part), co ce 2014 till 2018 (module part), modu	mputer science, arbitrary le part, arbitrary semester	semester
Classes and lectures:		Workload:	
Process Control Systems (lecture with exercises, 3 SWS)		 55 Hours private studies 45 Hours in-classroom work 20 Hours exam preparation 	
Contents of teaching:			
 Introduction and Overv Risk and Safety Incidents and Accidents Error, Failure and Response Human Factors Mental, conceptual and Task Analysis and Task Event Analysis and Evense Task Allocation Situation Awareness Diagnoses und Conting Interaction in real-times Risk and Safety Operations and Safety 	iew 5 insibility technical Models Modelling nt Modelling ency Conception and Design		
Oualification-goals/Compete	ncies:		
 The students know the They know the definition They can assess what n methodically. 	most important theories, methods an ons of the terms risk and security and v eeds to be considered in the developr	d systems for monitoring why they are applied in di nent of safety-critical hun	and controlling processes. ifferent ways. nan-machine systems and how to proceed
Grading through:			
 exercises and project as exam type depends on Written or oral exam as 	signments main module announced by the examiner		
Requires:			
Human-Computer-Inter	action (CS4230)		
Responsible for this module:			
Siehe Hauptmodul			
Teacher:			
Institute for Multimedia	and Interactive Systems		
Prof. Dr. rer. nat. MichaeProf. DrIng. Nicole Joc	ا! Herczeg hems		
Literature:			
 M. Herczeg: Software-E und aktualisierte Auflag M. Herczeg: Interaktion J. Reason: Human Error 	rgonomie: Theorien, Modelle und Krite je. De Gruyter Studium, 2018 sdesign - München: Oldenbourg, 2006 - Boston: Cambridge University Press,	erien für gebrauchstauglic ; 1990	che interaktive Computersysteme - 4. erweiterte

• J. Rasmussen, L. P. Goodstein, A. M. Peijtersen: Cogntive Systems Engineering - New York: Wiley, 1994



• M. Herczeg: Prozessführungssysteme Sicherheitskritische Mensch-Maschine-Systeme und Interaktive Medien zur Überwachung und Steuerung von Prozessen in Echtzeit - München: de Gruyter - Oldenbourg-Verlag, 2014

.

Language:

• offered only in German



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 since 2019 (optional subject), Elective, arbitrary semester Master Media Informatics since 2020 in planing (optional subject), computer science, arbitrary semester Master Robotics and Autonomous Systems (optional subject), computer science, 1st or 2nd semester Master Computer Science 2014 till 2018 (compulsory), specialization field software systems engineering, 1st or 2nd semester Master MES before 2014 (advanced curriculum), imaging systems, signal and image processing, 1st or 3rd semester Master Media Informatics (optional subject), computer science, arbitrary semester Master Computer Science before 2014 (optional subject), specialization field robotics and automation, 2nd or 3rd semester Master Computer Science before 2014 (optional subject), advanced curriculum parallel and distributed system architecutres, 2nd or 3rd semester Master Computer Science before 2014 (optional subject), advanced curriculum intelligent embedded systems, 2nd or 3rd semester Master Computer Science before 2014 (compulsory), specialization field software systems engineering, 2nd semester Master Computer Science before 2014 (optional subject), advanced curriculum intelligent embedded systems, 2nd or 3rd semester Master Computer Science before 2014 (compulsory), specialization field software systems engineering, 2nd semester 				
Classes and lectures:		Workload:		
 Hardware/Software Co-Design (lectu Hardware/Software Co-Design (exer 	ıre, 2 SWS) cise, 1 SWS)	 55 Hours private 45 Hours in-classi 20 Hours exam place 	studies room work reparation	
Contents of teaching: System design flow Basic architectures for HW/SW systems System design and modelling System synthesis Algorithms for scheduling System partitioning Algorithms for system partitioning Design systems Performance analysis System design and specification with SystemC Application examples Qualification-goals/Competencies: Students are able to determine a suitable hardware/software architecture for a given system description 				
 They are able to determine and describe the pros and cons of implementation alternatives They are able to apply methods for system partitioning They are able to translate non-formal system descriptions into formal models They are able to explain the different steps in system synthesis They are able to estimate the quality of system designs They are able to create system descriptions in SystemC 				
 Grading through: Exercises Written or oral exam as announced by the examiner 				
Responsible for this module: • Prof. DrIng. Mladen Berekovic Teacher: • Institute of Computer Engineering • Prof. DrIng. Mladen Berekovic Literature:				
F. Kesel: Modellierung von digitalen	Systemen mit SystemC - O	denbourg Verlag 2012		



• Teich, J., Haubelt, C.: Digital Hardware/Software-Systeme. Synthese und Optimierung - Berlin: Springer 2007

Language:

offered only in German



CS5204-KP04, CS5204 - Artificial Intelligence 2 (KI2)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each winter semester		4	
Course of study, specif • Master Robotics a • Master Biophysic	ic field and term: and Autonomous Systems (optional subject), s (optional subject), Elective, 1st semester	computer science, 1st or 2r	nd semester	
 Master MES since Master Biomedica Master CLS startin Master Computer Master Computer Master MES since 	2014 (optional subject), computer science / al Engineering (optional subject), Interdiscipli ng 2016 (optional subject), computer science r Science before 2014 (optional subject), adva r Science before 2014 (optional subject), spec 2020 (optional subject), computer science /	electrical engineering, arbiti nary modules, 2nd semeste , 3rd semester anced curriculum intelligent ialization field robotics and electrical engineering, arbiti	rary semester r embedded systems, 2nd or 3rd semester automation, 3rd semester rary semester	
Classes and lectures:		Workload:		
Artificial Intellige Artificial Intellige	nce 2 (lecture, 2 SWS)	 55 Hours private 45 Hours in class 	studies	
Artificial Intellige	nce 2 (exercise, 1 SWS)	43 Hours In-class20 Hours exam p	reparation	
Contents of teaching: Support Vector M Classification Regression Time-Series Pred Lagrange Multipl Sequential Minim Geometric Reaso Qualification-goals/Con The students are The chosen meth search of parame learning, designed	Machines and Dualization liction liers nal Optimization ning mpetencies: able to choose a method for machine learnir nod can be customized to the needs of the ap eters and involves adjustments to the basic m ed and implemented by the students.The star	ng for a given application an oplication. The process of cu athematical techniques.This ting point are support vecto	nongst a variety of such methods. stomization goes well beyond straightforward s leads to innovative applications for machine or machines.	
Oral examination				
Responsible for this mo Prof. DrIng. Ach Teacher: Institute for Robo Prof. DrIng. Ach	odule: im Schweikard otics and Cognitive Systems im Schweikard			
Literature: • P. Norvig, S. Russ	ell: Künstliche Intelligenz - München: Pearsor	0 2004		
offered only in Er	nglish			



CS4374-KP06 - Medical Deep Learning (MDL)				
Duration: Turnus of offer:	Credi	it points:		
1 Semester each summer semester	6			
Course of study, specific field and term:				
 Master MES since 2020 (optional subject), computer science / electrical engineering, arbitrary semester Master Robotics and Autonomous Systems (optional subject), medical computer science, 1st or 2nd semester Master Medical Informatics (optional subject), medical computer science, 1st or 2nd semester Master MES since 2014 (optional subject), computer science / electrical engineering, 1st or 2nd semester Master Medical Informatics since 2019 (advanced module), medical computer science, 1st or 2nd semester 				
Classes and lectures: Workload:				
 Medical Deep Learning (lecture, 2 SWS) Medical Deep Learning (exercise, 2 SWS) 	 Medical Deep Learning (lecture, 2 SWS) Medical Deep Learning (exercise, 2 SWS) 			
Contents of teaching:				
 Cardiac Healthcare: ECG signal analysis for arrhythmia detection or sleep apnea and for mobile low-cost devices MRI sequence analysis for anatomical segmentation and temporal modelling Multimodal Clinical Case Retrieval / Prediction: Pathology and Semantic Image Retrieval and Localisation Analysis of text / natural language (radiology reports/study articles) for multimodal data mining in Electronic Health Records (EHR) Computer Aided Detection and Disease Classification: CT Lung nodule detection for cancer screening with data augmentation and transfer learning Weakly-supervised abnormality detection and biomarker discovery Interpretable and reliable deep learning systems Human interaction and correction within deep learning models Visualisation of uncertainty and internally learned representations Deep Learning Concepts, Architectures and Hardware Convolutional Neural Networks, Layers, Deep Residual Learning Losses, Derivatives, Large-scale Stochastic Optimisation Directed Acyclic Graph Networks, Generative Adversarial Networks Cloud Computing, GPUs, Low Precision Computing, DL Frameworks 				
 Qualification-goals/Competencies: Students know the importance of data security, patient anonymisation and ethics for clinical studies involving sensitive data They know methods and tools to collect, preprocess, store and annotate large datasets for deep learning from medical data They have an in-depth understanding of deep / convolutional neural networks for general data (signals / text / images) processing, their learning process and evaluation of their performance on unseen data They understand the principles of weakly-supervised learning, transfer learning, concept discovery and generative adversarial networks They know how to explore learned feature representations for retrieval and visualisation of high-dimensional abstract data They can implement modern network architectures in DL frameworks and are able to adapt and extend them to given problems in medicine They have a broad overview of current applications of deep learning in medicine in both research and clinical practice and can transfer their knowledge to newly emerging domains 				
Grading through: Exercises Written or oral exam as announced by the examiner 				
Responsible for this module:	Responsible for this module:			
Prof. Dr. Mattias Heinrich				
Institute of Medical Informatics				
Prof. Dr. Mattias Heinrich				



Language:

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

Notes:

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



RO5100-KP12 - Medical Robotics (MedRob12)				
Duration:	Turnus of offer:	Credit points:		
2 Semester	each summer semester	12		
Course of study, specific field and • Master Robotics and Autonc	l term: pmous Systems (advanced module),	advanced curriculum, 1st or 2nd semester		
Classes and lectures:Workload:• ME4030 T: Inverse Probleme bei der Bildgebung (lecture with exercises, 3 SWS)• 190 Hours private studie • 150 Hours in-classroom • 20 Hours exam preparat • 20 Hours exam preparat • 20 Hours exam preparat • 20 Hours exam preparat 		Workload: • 190 Hours private studies • 150 Hours in-classroom work • 20 Hours exam preparation		
Contents of teaching: • see module parts				
Qualification-goals/Competencies see module parts 	5:			
Grading through: • Exercises • presentation • Written or oral exam as anno	ounced by the examiner			
Responsible for this module: • Prof. DrIng. Achim Schweik Teacher: • Institute of Computer Engine • Institute for Electrical Engine • Institute of Medical Engine • Institute of Medical Informat • Institute for Robotics and Co	ard eering eering in Medicine ring tics ognitive Systems			
Language: • offered only in English				
Notes: Choose 3 courses from ME403	0 T, CS4371 T, RO5100 A, CS5280 T			



	CS4160 TSJ14 - Module part:	Real-Time Systems	(Echtzei14a)	
Duration:	Turnus of offer:		Credit points:	
1 Semester	each winter semester		6	
Course of study, specific	field and term:			
Master Robotics andMaster Computer S	d Autonomous Systems (module part), mo cience 2014 till 2018 (module part), special	dule part, 1st or 2nd sen ization field robotics and	nester I automation, arbitrary semester	
Classes and lectures:		Workload:		
 Real-Time Systems Real-Time Systems	(lecture, 2 SWS) (exercise, 2 SWS)	 100 Hours private studies 60 Hours in-classroom work 20 Hours exam preparation 		
Contents of teaching:				
 Real-time processin Process automation Real-time programm Process connectivit Modelling of discretion Modelling of contin Application of design 	ng (definitions, requirements) In systems In systems In and networking Te event systems (automata, state charts) In uous systems (differential equations, Lapla In tools (Matlab/Simulink, Stateflow)	ace transformation)		
 The students are at They are able to exponent to the students are able to provide the students are able to provide the students are able to movide the students are able to	plain real-time computer systems for proceed ogram real-time systems in the IEC languag icidate process interfaces and real-time bus odel, analyze and implement event discrete odel, analyze and implement continuous sy ake use of design tools for real-time system	ess automation, in particu Jess s system. e systems, in particular p rstems, in particular feed is.	ular SPS. rocess control systems. back control systems.	
Grading through:				
Exercisescontinuous, successexam type depends	sful participation in practical course s on main module			
Responsible for this mod	ule:			
• Prof. DrIng. Mlade	n Berekovic			
Teacher:				
 Institute of Comput 	er Engineering			
Prof. DrIng. Mlade	n Berekovic			
Literature:				
 R. C. Dorf, R. H. Bish L. Litz: Grundlagen M. Seitz: Speicherpi H. Wörn, U. Brinkscl S. Zacher, M. Beutei 	op: Modern Control Systems - Prentice Hal der Automatisierungstechnik - Oldenbourg rogrammierbare Steuerungen - Fachbuchv hulte: Echtzeitsysteme - Berlin: Springer 200 r: Begelungstechnik für Ingenieure - Spring	l 2010 3 2012 erlag Leipzig 2012 05 ier-Vieweg 2014		
• offered only in Gerr	nan			



CS4270 T - Module part: Medical Robotics (MedRoba)				
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 Medical Informatics (module • Master Computer Science 2014 till 20 • Master Medical Informatics since 201	/stems (module part), mod part), module part, arbitrar 018 (module part), module 19 (module part), module p	lule part, 1st or 2nd semest y semester part, arbitrary semester art, arbitrary semester	ter	
 Classes and lectures: Medical Robotics (lecture, 2 SWS) Medical Robotics Exercise (exercise, 1 SWS) 		 Workload: 55 Hours private studies 45 Hours in-classroom work 20 Hours exam preparation 		
Contents of teaching: • Kinematics, path planning of robot systems • Robot Programming • Medical Navigation • Sensors in medical applications • Surgery planning • Velocity kinematics after motion prediction • Motion planning				
 Qualification-goals/Competencies: The participants are able to derive th implant it in an application. Design goals for a robotic applicatio Mathematical methods for machine The dynamics of motion in space car 	ne inverse kinematic equati n can be formulated and re learning can be applied to n be mapped to learning te	on for a given robot const educed to a practical syster motion learning, consideri echniques.	ruction with 6 degrees of freedom, and n. ing the dynamics of motion.	
Grading through: • Exercises • exam type depends on main module	2			
Responsible for this module: Siehe Hauptmodul Teacher: Institute for Robotics and Cognitive S Prof. DrIng. Achim Schweikard 	Systems			
Literature: JC. Latombe: Robot Motion Plannii J.J. Craig: Introduction to Robotics - I : lecture notes (400 pages full text)	ng - Dordrecht: Kluwer 1990 Pearson Prentice Hall 2002	0		
Language: • offered only in English				


	CS4670 T - Module part: Am	bient Computing (AmbCompa)	
Duration:	Turnus of offer:	Credit points:	
1 Semester	each summer semester 4		
Course of study, specific fiel Master Computer Scie Master Entrepreneursh Master IT-Security (mo Master Robotics and A Master Entrepreneursh Master Computer Scie	ld and term: nce since 2019 (module part), module pa hip in Digital Technologies since 2020 (m dule part), module part, 1st or 2nd seme autonomous Systems (module part), mo hip in Digital Technologies (module part), nce 2014 till 2018 (module part), module	art, arbitrary semester iodule part), module part, arbitrary semester ester dule part, 1st or 2nd semester), module part, arbitrary semester e part, arbitrary semester	
Classes and lectures:		Workload:	
Ambient Computing (Ambient Computing (lecture, 3 SWS) 55 Hours private studies 45 Hours in-classroom work 20 Hours exam preparation 		
Contents of teaching: • Technical Component • Software Architecture • Context Awareness • Ambient Spaces • Ambient Intelligence • Ambient Interaction • Ambient Multimedia • Ambient Computing A • Security / Privacy / Data	s of Ambient Systems s for Ambient Systems Applications ta Protection in Ambient Systems		
Qualification-goals/Compet • The students are able • They have an overview • They are able to follow	encies: to evaluate possibilities, concepts and cl v about current technologies and systen v and judge state-of-the-art research in t	nallenges of Ambient Systems 1s for developing Ambient Systems the area of Ambient Computing	
Grading through: • exam type depends or	n main module		
Responsible for this module Siehe Hauptmodul Teacher: Institute of Telematics Prof. DrIng. Andreas 	:: Schrader		
Literature: • John Krumm: Ubiquito • Stefan Poslad: Ubiquit • Uwe Hansman et al: Po	ous Computing Fundamentals - CRC Pres ous Computing: Smart Devices, Environr ervasive Computing - Springer, 2003	is, 2009 nents and Interactions - Wiley, 2009	
Language: • English, except in case	of only German-speaking participants		





CS5150 T - Module part: Organic Computing (OrganicCoa)			
Duration:	Turnus of offer: Credit		Credit points:
1 Semester	normally each year in the winter semester		4
Course of study, specific field and term: • Master Computer Science since 201 • Master Entrepreneurship in Digital T • Master IT-Security (module part), mo • Master Robotics and Autonomous S • Master Entrepreneurship in Digital T • Master Computer Science 2014 till 2	9 (module part), module pa echnologies since 2020 (m odule part, 1st or 2nd seme ystems (module part), mod echnologies (module part) 018 (module part), module	art, arbitrary semester odule part), module part, a ister dule part, 1st or 2nd semes , module part, arbitrary sen e part, arbitrary semester	rbitrary semester ter nester
Classes and lectures:		Workload:	
 Organic Computing (lecture, 2 SWS) Organic Computing (exercise, 1 SWS) 	5)	 60 Hours private 45 Hours in-class 15 Hours exam p 	studies sroom work preparation
Contents of teaching:			
 Basic principles of Organic Computi Self-organization and emergence Architecture and design of Organic Organic Computing for distributed a Organic Computing in Neuro- and E Organic Grid Autonomous Systems 	ng Computing systems systems bionformatics		
Qualification-goals/Competencies: Students are able to utilize the prime They are able to explain the princip They are able to analyze emergence 	ciples of organic computing les of Organic Computing. behavior in Organic Comp	g on exemplary designs. Duting systems.	
Grading through: • exam type depends on main modul	e		
Responsible for this module:			
Siehe Hauptmodul			
Teacher:			
Institute of Computer Engineering			
Prof. DrIng. Heiko Hamann			
Literature: • C. Müller-Schloer, H. Schmeck, T. Un • R. P. Würtz: Organic Computing - Sp • C. Klüver, J. Kluever, J. Schmidt: Moo	gerer: Organic Computing ringer, 2008 Iellierung komplexer Proze	A Paradigm Shift for Com sse durch naturanaloge Ve	nplex Systems - Birkhäuser, 2011 rfahren - Springer Vieweg 2012
Language: • offered only in German			



C	S5153 T - Module part: Wirel	ess Sensor Networl	ks (DISensorNa)
Duration:	Turnus of offer:		Credit points:
1 Semester	normally each year in the winter semester 4		
Course of study, specific field Master Computer Science Master Entrepreneurship Master IT-Security (mode Master Robotics and Aut Master Computer Science Master Entrepreneurship Master Computer Science	and term: :e since 2019 (module part), module p o in Digital Technologies since 2020 (r ule part), module part, 1st or 2nd sem tonomous Systems (module part), mo :e 2014 till 2018 (module part), specia o in Digital Technologies (module part) ce 2014 till 2018 (module part), advan	part, arbitrary semester module part), module pa nester odule part, 1st or 2nd se lization field robotics ar t), module part, arbitrary ced curriculum, arbitrary	art, arbitrary semester emester 1d automation, arbitrary semester y semester y semester
Classes and lectures:		Workload:	
Wireless Sensor Networks (lecture, 2 SWS) Wireless Sensor Networks (exercise, 1 SWS)		 60 Hours pri 45 Hours in- 15 Hours ex	ivate studies -classroom work am preparation
Contents of teaching: Basics of Sensor Networ Architecture of Sensor N Identities and addressin Wireless communication Data management and Localization Energy harvesting Applications	ks lodes and Sensor Networks g າ topology control		
Qualification-goals/Competer • The students are able to • They are able to cope w • They are able to interpre-	ncies: • present the potential, benefits and li ith analysis, design, and evaluation of et and pursue current research activit	mitations of sensor netw f protocols in sensor net ies for sensor networks.	works. works.
Grading through: • exam type depends on r	main module		
Responsible for this module: • Siehe Hauptmodul Teacher: • Institute of Computer Er • Prof. DrIng. Heiko Ham • Prof. DrIng. Mladen Ber	ngineering ann rekovic		
Literature: • H. Karl, A. Willig: Protoco • F. Zhao, L. Guibas: Wirel • BC. Renner: Sustained (ols and Architectures of Wireless Sens ess Sensor Networks - Morgan Kaufm Operation of Sensor Nodes with Ener	or Networks, - Wiley, 20 ann, 2004 gy Harvesters and Super	05 rcapacitors - Books on Demand 2013
Language: • German and English skil	ls required		



Duration:		
	Turnus of offer:	Credit points:
Semester	each summer semester	4
Course of study, specific field a Master Computer Science Master MES since 2020 (n Master Entrepreneurship Master Biophysics (modu Master Auditory Technole Master IT-Security (modu Master Robotics and Auto Master Entrepreneurship Master MES since 2014 (r Master Computer Science	and term: e since 2019 (module part), module par nodule part), computer science / electri in Digital Technologies since 2020 (mo ile part), advanced curriculum, 2nd sem ogy (module part), Auditory Technology ile part), module part, 1st or 2nd semes onomous Systems (module part), modu in Digital Technologies (module part), r nodule part), computer science / electri e 2014 till 2018 (module part), module p	t, arbitrary semester cal engineering, arbitrary semester dule part), module part, arbitrary semester ester /, 2nd semester er ule part, 1st or 2nd semester module part, arbitrary semester cal engineering, 1st or 2nd semester part, arbitrary semester
Classes and loctures:		Workload
 Selected Topics of Signal SWS) Selected Topics of Signal 1 SWS) 	Analysis and Enhancement (lecture, 2 Analysis and Enhancement (exercise,	 55 Hours private studies 45 Hours in-classroom work 20 Hours exam preparation
 Linear estimators Linear optimal filters Adaptive filters Multichannel signal proc Compressed sensing Basic concepts of multiral 	essing, beamforming, and source separ	ation
 Nonlinear signal process Application scenarios in a measurement, noise redu 	ing algorithms auditory technology, enhancement, and uction, deconvolution (listening-room c	l restauration of one- and higher-dimensional signals, Sound-field ompensation), inpainting
 Nonlinear signal process Application scenarios in a measurement, noise redu 	ing algorithms auditory technology, enhancement, and uction, deconvolution (listening-room c	l restauration of one- and higher-dimensional signals, Sound-field ompensation), inpainting
 Nonlinear signal process Application scenarios in measurement, noise reduces Qualification-goals/Competen Students are able to explete They are able to describe Students are able to describe They are able to analyze Students are able to explete They are able to explete 	ing algorithms auditory technology, enhancement, and uction, deconvolution (listening-room c cies: lain the basic elements of stochastic sig e and apply linear estimation theory. cribe the concepts of adaptive signal pr e and apply the concepts of multichann e the concept of compressed sensing. and design multirate systems. lain various applications of nonlinear ar nd implement linear optimum filters an	d restauration of one- and higher-dimensional signals, Sound-field ompensation), inpainting nal processing and optimum filtering. ocessing. el signal processing. d adaptive signal processing. d nonlinear signal enhancement techniques on their own.
 Nonlinear signal process Application scenarios in measurement, noise reduces Qualification-goals/Competen Students are able to explete to describe Students are able to describe Students are able to describe They are able to analyze Students are able to create a 	ing algorithms auditory technology, enhancement, and uction, deconvolution (listening-room c cies: lain the basic elements of stochastic sig e and apply linear estimation theory. cribe the concepts of adaptive signal pr e and apply the concepts of multichann e the concept of compressed sensing. and design multirate systems. lain various applications of nonlinear ar nd implement linear optimum filters an	d restauration of one- and higher-dimensional signals, Sound-field ompensation), inpainting nal processing and optimum filtering. ocessing. el signal processing. d adaptive signal processing. d nonlinear signal enhancement techniques on their own.
 Nonlinear signal process Application scenarios in measurement, noise reduces Qualification-goals/Competen Students are able to explete to describe Students are able to describe Students are able to describe They are able to analyze Students are able to exple They are able to create a Grading through: exam type depends on m Responsible for this module: Siehe Hauptmodul Teacher: Institute for Signal Proces 	ing algorithms auditory technology, enhancement, and uction, deconvolution (listening-room c cies: lain the basic elements of stochastic sig e and apply linear estimation theory. cribe the concepts of adaptive signal pr e and apply the concepts of multichann e the concept of compressed sensing. and design multirate systems. lain various applications of nonlinear ar nd implement linear optimum filters an hain module	d restauration of one- and higher-dimensional signals, Sound-field ompensation), inpainting nal processing and optimum filtering. ocessing. el signal processing. d adaptive signal processing. d nonlinear signal enhancement techniques on their own.



Signalschätzung - Springer-Vieweg, 3. Auflage, 2013 S. Haykin: Adaptive Filter Theory - Prentice Hall, 1995
Language:
German and English skills required
Notes:
According to the PVO the only exam in this module is a written test. Prerequisites are exercises. These must have been done and graded positively before the first exam.
(Is part of module CS4290, 4510, 5400, RO4290-KP04, CS5274-KP08) (Is the same as CS5275)



CS52	80 T - Module Part: Seminar Rob	otics and Automatio	n (SemRobAuta)
Duration:	Turnus of offer:	Turnus of offer:	
1 Semester	each semester		4
Course of study, specific field • Master Robotics and Au • Master Computer Scier	d and term: utonomous Systems (module part), modu nce 2014 till 2018 (module part), specializa	ule part, 1st or 2nd semest ation field robotics and au	er tomation, arbitrary semester
Classes and lectures: Advanced Seminar Robotics and Automation (seminar, 2 SWS) 		 Workload: 90 Hours work on an individual topic with written and oral presentation 30 Hours in-classroom work 	
Contents of teaching: • Different topics from th • The students learn the self-contained writing	ne fields of robotics and artificial intellige correct reading of scientific papers, resea and presentation of their own scientific e	nce for term papers are of irch and investigation, corr laboration as a preparation	fered. rect quotation and structuring, and n for their final examination.
Qualification-goals/Compete • The participants are ab • The students are able t • The participants can ar present their own scien	encies: le to do research on scientific publicatior to investigate self-dependently scientific p nalyze and reproduce the tenor with rega ntific work.	ns, to analyze the contents oublications, to analyze an rd to their scope of work.	and to understand them. d understand their contents. The students are competent to write and
Grading through: • term paper • presentation • exam type depends on	main module		
Responsible for this modules Siehe Hauptmodul Teacher: Institute for Electrical E Institute for Robotics and Institute of Computer E Prof. DrIng. Mladen Be Prof. DrIng. Achim Sch Prof. Dr. Philipp Rostals	ngineering in Medicine nd Cognitive Systems Engineering erekovic hweikard ski		
Language: • English, except in case	of only German-speaking participants		



CS5410 T - Module part: Artificial Life (ArtiLifea)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	irregularly		4	
Course of study, specific field and terr • Master Robotics and Autonomou • Master Computer Science 2014 t • Master Computer Science since 2	n: Is Systems (module part), m ill 2018 (module part), modu 2019 (module part), module	odule part, 1st or 2nd seme le part, arbitrary semester part, arbitrary semester	ester	
Classes and lectures: V • Artificial Life (lecture, 2 SWS) • Artificial Life (exercise, 1 SWS)		Workload: • 60 Hours priva • 45 Hours in-cla • 15 Hours exam	 Workload: 60 Hours private studies 45 Hours in-classroom work 15 Hours exam preparation 	
Contents of teaching: Properties, flavors and kinds of (Artificial chemistry and self-repli Introduction to information theo Introduction to statistical mecha Complex networks and NK mode Evolutionary algorithms Emergence Cellular automata Game of life Tierra Ant algorithms	artificial) life cating code rry nics and thermodynamics els			
Qualification-goals/Competencies: Understanding criteria and defin Understanding of Understanding (and ability to ap Understanding the principles of Knowledge of the main models of 	itions of ply) evolutionary algorithms complex networks of artificial life			
Grading through: • Exercises • exam type depends on main mo	dule			
Responsible for this module: Siehe Hauptmodul Teacher: Institute for Neuro- and Bioinform Prof. Dr. rer. nat. Thomas Martine PD Dr. rer. nat. Jens Christian Cla Literature: Christoph Adami: Introduction to 	natics etz ussen o Artificial Life - Springer Verl	ag, 1998		



CS5450 T - Module part: Machine Learning (MaschLerna)			
Duration:	Turnus of offer:		Credit points:
Semester each winter semester		4	
Course of study, specific field and term: Master Computer Science since 2019 Master MES since 2020 (module part Master Entrepreneurship in Digital T Master Biophysics (module part), adv Master IT-Security (module part), mo Master Robotics and Autonomous Sy Master Entrepreneurship in Digital T Master MES since 2014 (module part Master Computer Science 2014 till 20) (module part), module pa), computer science / elect echnologies since 2020 (m vanced curriculum, 1st sem odule part, 1st or 2nd seme vstems (module part), mod echnologies (module part)), computer science / elect 018 (module part), module	nt, arbitrary semester rical engineering, arbitrary odule part), module part, a tester ster dule part, 1st or 2nd semest , module part, arbitrary sen rical engineering, 1st or 2n part, arbitrary semester	semester rbitrary semester ter nester d semester
Classes and lectures:		Workload:	
 Machine Learning (lecture, 2 SWS) Machine Learning (exercise, 1 SWS) 		55 Hours private45 Hours in-class20 Hours exam p	studies room work reparation
Contents of teaching: • Representation learning, including m • Statistical learning theory • VC dimension and support vector m • Boosting • Deep learning • Limits of induction and importance	nanifold learning achines of data ponderation		
Qualification-goals/Competencies: Students can understand and explai They can explain and apply different They can chose and then evaluate an They can understand and explain the 	n various machine-learning t machine learning methoo n appropriate method for a e limits of automatic data a	g problems. Is and algorithms. a particular learning proble analysis.	m.
Grading through: • exam type depends on main module	2		
Responsible for this module: • Siehe Hauptmodul Teacher: • Institute for Neuro- and Bioinformati • Prof. DrIng. Erhardt Barth • Prof. Dr. rer. nat. Thomas Martinetz	cs		
Literature: • Chris Bishop: Pattern Recognition an • Vladimir Vapnik: Statistical Learning • Tom Mitchell: Machine Learning - Machine Learning	d Machine Learning - Sprii Theory - Wiley-Interscience cGraw Hill. ISBN 0-07-0428	nger ISBN 0-387-31073-8 e, ISBN 0471030031 07-7	
• English, except in case of only Germa	an-speaking participants		





ME4030 T - Module Part: Inverse Problems in Image Processing (InversProa)			
Duration:	Turnus of offer: Cred		Credit points:
1 Semester	each summer semester 4		4
Course of study, specific field and • Master Robotics and Autonor • Master Computer Science 20	term: nous Systems (module part), mo 14 till 2018 (module part), modul	dule part, 1st or 2nd sem e part, arbitrary semester	nester
Classes and lectures:		Workload:	
 Tomographische Verfahren II: Inverse Probleme bei der Bildgebung (lecture, 2 SWS) Tomographische Verfahren II: Inverse Probleme bei der Bildgebung (exercise, 1 SWS) 		 55 Hours private studies 45 Hours in-classroom work 20 Hours exam preparation 	
Contents of teaching:			
 Introduction to inverse and il conduction, computed tomo Concept of ill-posedness of tl Singular value decomposition Regularization methods (eg 1 Deconvolution Image restoration (deblurring Statistical methods (Bayes, m Computed Tomography, Mag 	I-posed problems on the basis of graphy, acoustics) ne inverse problem (Hadamard) n and generalized inverse "ikhonov, Phillips, Ivanov) g, defocusing) aximum likelihood) gnetic Particle Imaging	selected examples (inclu	ıding seismology, impedance tomography, heat
 Students are able to explain a good or bad posedness. They are able to formulate in They can assess the condition They master different regular They know methods to deter They can use methods of image 	the concept of ill-posedness of the verse problems of mathematical of a problem and the stability of ization methods and are able to mine a suitable regularization. Ige reconstruction and restoratio	ie inverse problem and d imaging and solve (appro f a method. apply them to practical p n on real measurement c	istinguish given inverse problems regarding oximate) with suitable numerical methods. problems. data.
Grading through:			
 exam type depends on mainWritten or oral exam as anno	module unced by the examiner		
Responsible for this module:			
Siehe Hauptmodul			
Teacher:			
 Institute of Medical Engineeri 	ng		
Prof. Dr. rer. nat. Thorsten Bu:	zug		
Literature: • Kak and Slaney: Principles of • Natterer and Wübbeling: Mat • Bertero and Boccacci: Inverse • Andreas Rieder: Keine Proble • Buzug: Computed Tomograp	Computerized Tomographic Ima hematical Methods in Image Rec Problems in Imaging - IoP Press me mit inversen Problemen - Vie hy - Springer, Berlin, 2008	ging - SIAM Series 33, Ne construction - SIAM Monc London, 2002 weg, Wiesbaden, 2003	w York, 2001 ographs, New York 2001
Language: • offered only in German			



CS4371-KP08, CS4371 - Advanced Techniques of Medical Image Processing (FVMB)			
Duration:	Turnus of offer:	Credit point	s:
1 Semester	each winter semester	8	
Course of study, specific field and to Master Medical Informatics sin Master Robotics and Autonom Master MES since 2014 (option Master Medical Informatics (op Master MES since 2020 (option	erm: ice 2019 (advanced module), medi ious Systems (optional subject), m nal subject), medical engineering s otional subject), medical image pro nal subject), medical engineering s	cal computer science, 1st or 2nd semest nedical image processing, 1st or 2nd sen cience, 1st or 2nd semester pcessing, 1st or 2nd semester cience, arbitrary semester	ter nester
 Classes and lectures: Advanced Techniques of Med SWS) Advanced Techniques of Med SWS) Advanced Techniques of Med course, 1 SWS) 	ical Image Processing (lecture, 3 ical Image Processing (exercise, 2 ical Image Processing (practical	 Workload: 90 Hours in-classroom work 60 Hours private studies and ex 60 Hours private studies 30 Hours exam preparation 	xercises
Contents of teaching: Applications of medical image Image superresolution Denoising and inhomogeneity Linear and non-linear dimensi Patch-based image processing Fusion of (probabilistic) segme Random-walk algorithm for in Non-linear registration and me Similarity metrics for multi-me Introduction into graphical me Viterbi algorithm and message Graph cut segmentation and f Extraction image features and Matching of corresponding lage	e processing techniques / correction onality reduction g and non-local means entations (NLM and STAPLE) teractive segmentation otion estimation (optical flow) odal fusion odels and discrete optimisation e passing (stereo depth estimation further applications descriptors ndmarks)	
Qualification-goals/Competencies: • Students know a wide range of • They can describe these meth • They can transfer image proce • They can solve minimisation p • They understand methodolog • They understand the transfer • They understand solvers for d • They can transfer mathematic • They can proficiently impleme • They can compare different al • They have an extended overvious	of methods for segmentation, regised ods with correct technical termino essing techniques into energy mini- problems using sparse linear syster ical relations between different ap of continuous problems into the d iscrete optimisation problems. al concepts into practical algorithment these concepts in C++. gorithms to another and make sui- iew of application areas for medical	stration and processing of medical imag ology. imisation problems. ns. oplications and techniques. iscrete domain. ns for medical image processing. table problem-related choices of metho al image analysis.	es. ds.
Grading through: • Exercises • continuous, successful particip • Written or oral exam as annou Requires: • Medical Image Computing (CS • Medical Image Computing (CS	bation in practical course nced by the examiner 53310-KP04) 53310-KP08, CS3310SJ14)		



Responsible for this module:
Prof. Dr. rer. nat. habil. Heinz Handels
Teacher:
Institute of Medical Informatics
Prof. Dr. Mattias Heinrich
 Literature: M. Sonka, V. Hlavac, R. Boyle: Image Processing, Analysis and Machine Vision - 2nd edition. Pacific Grove: PWS Publishing 1998
Language:
offered only in German
Notes:
Examination prerequisites can be determined at the beginning of the semester. If pre-exam prerequisites have been defined, they must have been completed before the initial examination and evaluated positively.



Duration		
Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	4
Course of study, specific fie	eld and term:	
 Master Robotics and A Master Medical Inform Master Computer Scie Master Medical Inform 	Autonomous Systems (module part), Rob natics (module part), module part, arbitrar ence 2014 till 2018 (module part), module natics since 2019 (module part), module p	otics and Autonomous Systems, 1st or 2nd semester y semester part, arbitrary semester art, arbitrary semester
Classes and lectures:		Workload:
 Computer Vision (lect Computer Vision (exe 	 Computer Vision (lecture, 2 SWS) Computer Vision (exercise, 1 SWS) Some the studies Some the studies	
 Introduction to huma Sensors, cameras, opt Image features: edge Range imaging and 3 Motion and optical fle Object recognition Example applications 	in and computer vision tics and imaging s, intrinsic dimension, SIFT, Hough transfo -D cameras ow	rm, Fourier descriptors, and snakes
Qualification-goals/Compe • Students can underst • They can explain and • They can explain and • They can indicate app	tencies: and the basics of computer vision. perform camera choice and calibration. apply the basic methods for feature extra propriate methods for different kinds of co	ction, motion estimation, and object recognition. mputer-vision applications.
Grading through:		
Exercisesexam type depends of	on main module	
Responsible for this modul	e:	
Prof. DrIng. Erhardt I	Barth	
Teacher:		
 Institute for Neuro- ar 	nd Bioinformatics	
Prof. DrIng. Erhardt I	Barth	
Literature:		
Richard Szeliski: ComDavid Forsyth and Jea	puter Vision: Algorithms and Applications an Ponce: Computer Vision: A Modern App	- Springer, Boston, 2011 proach - Prentice Hall, 2003
Language: • English, except in case	e of only German-speaking participants	



CS4251-KP0	8, CS4251 - Machine	Learning and Comp	iter Vision (MLaCV)	
Duration:	Turnus of offer:		Credit points:	
2 Semester	normally each year in	the winter semester	8	
Course of study, specific field and tern • Master Robotics and Autonomou	1: s Systems (compulsory), F	obotics and Autonomous	Systems, 1st and 2nd semester	
Classes and lectures: Work		• 240 Hours (s	ee module parts)	
Computer Vision (lecture with ex-	ercises, 3 SWS)	210110415 (5		
Contents of teaching: • see module parts.				
Qualification-goals/Competencies: see module parts. 				
Grading through: • Written or oral exam as announce	ed by the examiner			
Responsible for this module: • Prof. DrIng. Erhardt Barth				
Teacher: • Institute for Electrical Engineering	g in Medicine			
• Prof. DrIng. Erhardt Barth				
Language: • English, except in case of only Ge	rman-speaking participan	ts		



CS4290-KP04, CS4290 - Current Issues Robotics and Automation (RobAktuell)				
Duration:	Turnus of offer:		Credit points:	
Semester	each semester		4	
Course of study, specific field and • Master Robotics and Autono • Master Computer Science 2	l term: omous Systems (optional subject), Ro 014 till 2018 (compulsory), specializat	obotics and Autonomo tion field robotics and a	us Systems, 1st and/or 2nd semester automation, 2nd or 3rd semester	
Classes and lectures:		Workload:		
 Classes and lectures: CS4160 TSJ14: Real-Time Systems (lecture with exercises, 4 SWS) CS4170 TSJ14: Parallel Computer Systems (lecture with exercises, 4 SWS) CS4220 T: Pattern Recognition (lecture with exercises, 3 SWS) CS466 T: Process Control Systems (lecture with exercises, 3 SWS) CS5150 T: Organic Computing (lecture with exercises, 3 SWS) CS5153 T: Wireless Sensor Networks (lecture with exercises, 3 SWS) CS5170 T: Hardware/Software Co-Design (lecture with exercises, 3 SWS) CS5275 T: Selected Topics of Signal Analysis and Enhancement (lecture with exercises, 3 SWS) CS5280 T: Seminar Robotics and Automation (seminar, 2 SWS) CS5410 T: Artificial Life (lecture with exercises, 3 SWS) CS5450 T: Machine Learning (lecture with exercises, 3 SWS) ME4030 T: Inverse Probleme bei der Bildgebung (lecture with exercises, 3 SWS) ME4500: Advanced Methods in Control (lecture with exercises, 3 SWS) RO5700 T: Evolutionary Robotics (lecture with exercises, 3 SWS) RO5600 T: Social Robotics (lecture and exercise, 4 SWS) RO5402 T: Seminar Machine Learning for Medicine (seminar, 2 SWS) RO5202 T: Collective Robotics (lecture with exercises, 3 SWS) 		 Workload: 60 Hours private studies 45 Hours in-classroom work 15 Hours exam preparation 		
• Qualification-goals/Competencie	s:			
Grading through: • Written or oral evam as ann	ounced by the examiner			
Responsible for this module: • Prof. DrIng. Mladen Bereko Teacher: • Institute for Electrical Engin • Institute for Multimedia and • Institute for Signal Processir • Institute for Neuro- and Bioi • Institute for Robotics and Co • Institute of Computer Engin	eering in Medicine I Interactive Systems ng nformatics ognitive Systems eering			
Language:				



• German and English skills required

Notes:

One of the modules parts.



PS	PS5000-KP06, PS5000 - 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 Medical Informatics since 2019 (compulsory), interdisciplinary competence, 3rd semester Master Biophysics (compulsory), biophysics, 3rd semester Master Auditory Technology (compulsory), Auditory Technology, 3rd semester Master Interdisciplinary Courses (optional subject), Interdisciplinary modules, arbitrary semester Master Robotics and Autonomous Systems (compulsory), Robotics and Autonomous Systems, 3rd semester Master Medical Informatics (compulsory), interdisciplinary competence, 3rd semester Master MES since 2014 (compulsory), interdisciplinary competence, 3rd semester 			nester nester ems, 3rd semester	
Classes and lectures:		Workload:		
Student Conference (seminar, 4 SWS	j)	 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 publication in English based on the results of at least one of the project internships Preparation of a scientific poster in English based on the results of at least one of the project internships Presentation of a scientific poster in German or English, based on the results of at least one of the project internships Talk in English based on the results of at least one of the project internships Active participation in scientific discussions Active participation in a scientific peer-review process Oualification-goals/Competencies: Students have experience in a comprehensive review of a scientific discussions They have the experience and ability to take an active part in scientific discussions They are able to defend one's work successfully in a scientific discusse They have knowledge of the peer-review process of publications They are able to constructively criticize in a blind peer-review process 			project internships ect internships e of the project internships	
 scientific paper oral presentation continuous participation in all courses of the module Poster B-Certificate (not graded) 				
Responsible for this module: Prof. Dr. rer. nat. habil. Heinz Handels Prof. Dr. rer. nat. Thorsten Buzug Teacher: All Institutes and Clinics of the Universität zu Lübeck 				
Literature: is selected individually: 				
Language: • offered only in English	• offered only in English			
Notes:				



Because 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.



	RO4000-KP12 - Auto	nomous Systems (AS)
Duration:	Turnus of offer:		Credit points:
2 Semester	each winter semester		12
Course of study, specific field a • Master Robotics and Auto	and term: pnomous Systems (compulsory), Robo	otics and Autonomous Syst	ems, 1st and 2nd semester
Classes and lectures: • Real-Time Systems (lectu • Real-Time Systems (exerc • Model Predictive Control • Model Predictive Control	re, 2 SWS) ise, 2 SWS) (lecture, 2 SWS) (exercise, 2 SWS)	Workload: • 140 Hours privat • 120 Hours in-cla • 40 Hours exam p	e studies ssroom work preparation
Contents of teaching:			
 Content of teaching of th Real-time processing (dei 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 Predictivities Algorithms for numerical Explicit MPC Practical aspects (Robust MPC applications 	e 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: alman filter ve Control (MPC) optimization MPC, Offset-free tracking, etc.)	ce transformation)	
 Education-goals/Competent Educational objectives of The students are able to They are able to explain in They are able to program They are able to elucidate They are able to model, a Students get a comprehe Students get an overview Students get acquainted Students gain insight interview 	the course Real-Time Systems: describe the fundamental problems of real-time computer systems for process 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 the course Model Predictive Control: ensive introduction to methods of option of the fundamentals of numerical op gn model predictive controllers for lin- with several tools to implement mode blish system theoretic properties of m to possible applications areas for MPC.	f real-time processing. ss automation, in particular es. system. systems, in particular proc stems, in particular feedbac s. imal control. timization. ear and nonlinear systems. el predictive controllers. odel predictive controllers	SPS. ess control systems. ck control systems.
Grading through:			
Written or oral exam as a	nnounced by the examiner		
Requires:			
Control Systems (RO4400	-KP12)		
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



RO4100-KP08 - Robot Learning (RobLe)			
Duration:	Turnus of offer:	Credit points:	
2 Semester	each winter semester	8	
Course of study, specific field and ter • Master Robotics and Autonomo	n: ıs Systems (compulsory), Robo	otics and Autonomous Systems, 1st and 2nd semester	
Classes and lectures:		Workload:	
 Probabilistic Machine Learning (Probabilistic Machine Learning (Reinforcement Learning (lecture Reinforcement Learning (exercise) 	lecture, 2 SWS) exercise, 2 SWS) , 2 SWS) e, 2 SWS)	 120 Hours work on project 120 Hours private studies 60 Hours in-classroom exercises 60 Hours in-classroom work 	
 Contents of teaching: Introduction to Probability Theo Linear Probabilistic Regression (I Nonlinear Probabilistic Regression Primitives, Hierarchical Bayesian Probabilistic Inference for Filteri Sampling, Recent research result Probabilistic Optimization (Stock Strategies, Bayesian Optimization Introduction to Robotics and Restrategies). Foundations of Decision Making Process, Poicy Iteration, Bellman Principles of Reinforcement Lear policy learning, Algorithmic print Advanced Policy Gradient Mether Natural Policy Gradient, Step Siz Deep Reinforcement Learning (I in Stochastic Deep Neural Network) 	ry (Statistics refresher, Bayes Th inear models, Maximum Likeli on (Radial basis function netwo & Mixture Models). ng, Smoothing and Planning (C ts in Neural Planning). nastic black-box Optimizer Cov n). inforcement Learning (Refreshe (Reward Hypothesis, Markov F Equation, Link to Optimal Con ning (Exploration and Exploita ciples: Q-Learning, SARSA, TD- ods (Introduction to Gradient D e Adaptation Mechanisms, Rec ntroduction to Deep Networks, orks).	neorem, Common Probability distributions, Gaussian Calculus). hood, Bayes & Logistic Regression). rks, Gaussian Processes, Recent research results in Robotic Movement flassic, Extended & Unscented Kalman Filters, Particle Filters, Gibbs ariance Matrix Analyses-Evolutionary Strategies & Natural Evolutionary er on Robotics, kinematics, model learning and learning feedback control 'roperty, Markov Reward Process, Value Iteration, Markov Decision trol). tion strategies, On & Off-policy learning, model-free and model-based Learning, Function Approximation, Fitted Q-Iteration). bescent, Finite Differences, Likelihood Ratio Trick & Policy Gradient, ent research results in Relative Entropy Policy Search). , Stochastic Gradient Descent, Deep Q-Learning, Recent research results	
 Qualification-goals/Competencies: Students get a comprehensive u Students learn to analyze the ch Students will understand the difand requirements. Students understand and can ap Students know how to analyze the relevance. Students understand how the baneural planning. Students learn to analyze the ch Students will understand the difarequirements for learning them. Students know how to analyze t Students understand and can ap 	Inderstanding of basic probabi allenges in a task and to identi ference between deterministic oply advanced regression, infer he models results, improve th asic concepts are used in curren inderstanding of basic decision allenges in a reinforcement lea ference between deterministic oply advanced policy gradient r he learning results and improv asic concepts are used in curren	ity theory concepts and methods. fy promising machine learning approaches. and probabilistic algorithms and can define underlying assumptions ence and optimization techniques to real world problems. e model parameters and can interpret the model predictions and their nt state of the art research in robot movement primitive learning and in making theories, assumptions and methods. rning application and to identify promising learning approaches. and probabilistic policies and can define underlying assumptions and methods to real world problems. e the policy learner parameters. nt state of the art research in robot reinforcement learning and in deep	
Grading through: • Written or oral exam as annound	ed by the examiner		
Responsible for this module: • Prof. Dr. Elmar Rückert			



Teacher:

- Institute for Robotics and Cognitive Systems
- Prof. Dr. Elmar Rückert
 - MitarbeiterInnen des Instituts

Literature:

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

Language:

offered only in English

Notes:

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

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



RO4	4300-KP08 - Machine Learning	and Computer	/ision (MLRAS)	
Duration:	Turnus of offer:	Turnus of offer:		
2 Semester	normally each year in the w	normally each year in the winter semester		
Course of study, specific field an • Master Robotics and Auton	d term: omous Systems (compulsory), Roboti	cs and Autonomous	Systems, 1st and 2nd semester	
Classes and lectures:		Workload:		
 Machine Learning (lecture, Machine Learning (exercise Computer Vision (lecture, 2 Computer Vision (exercise, 	2 SWS)• 110 Hours private studies, 1 SWS)• 90 Hours in-classroom workSWS)• 40 Hours exam preparation1 SWS)			
Contents of teaching: • • • Representation learning, in • Statistical learning theory • VC dimension and support • Boosting • Deep Learning • Limits of induction and imp • • Introduction to human and • Sensors, cameras, optics an • Image features: edges, intri • Range imaging and 3-D can • Motion and optical flow • Object recognition • Example applications	cluding manifold learning vector machines portance of data ponderation l computer vision ad projections insic dimension, Hough transform, Fou meras	urier descriptors, snał	es	
Qualification-goals/Competencie Students can understand a They can explain and apply They can chose and then e They can understand and e Students can understand th They can explain and perfo They can explain and apply They can indicate appropri	es: nd explain various machine-learning p v different machine learning methods valuate an appropriate method for a p explain the limits of automatic data an ne basics of computer vision. rm camera choice and calibration. v the basic methods for feature extract ate methods for different kinds of con	problems. and algorithms. particular learning pro alysis. tion, motion estimation puter-vision application	blem. on, and object recognition. ions.	
Grading through:				
ExercisesOral examination				
Responsible for this module: • Prof. DrIng. Erhardt Barth Teacher: • Institute for Neuro- and Bio • Prof. DrIng. Erhardt Barth • Prof. Dr. rer. nat. Thomas M	informatics artinetz			
Literature:				
Chris Bishop: Pattern Recog	nition and Machine Learning - Spring	er ISBN 0-387-31073-	8	



- Richard Szeliski: Computer Vision: Algorithms and Applications Springer, Boston, 2011
- David Forsyth and Jean Ponce: Computer Vision: A Modern Approach Prentice Hall, 2003

Language:

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

Notes:

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

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



	RO4500-KP08 - Advanced	Control and Estimation (ACE)
Duration:	Turnus of offer:	Credit points:
2 Semester	each semester	8
Course of study, specific field an • Master Robotics and Auton Classes and lectures: • Linear Systems and Contro • Linear Systems and Contro • Graphical Models in System • Graphical Models in System project, 1 SWS)	d term: omous Systems (optional subject), (lecture, 2 SWS) (exercise, 2 SWS) as and Control (lecture, 2 SWS) as and Control (Excercises with	Robotics and Autonomous Systems, 1st and 2nd semester Workload: • 120 Hours in-classroom work • 70 Hours private studies • 30 Hours in-classroom exercises • 20 Hours exam preparation
Contents of teaching: Content of teaching for cou Vector spaces, norms, linea Eigenvalues, eigenvectors, Singular value decomposit Linear systems in continuo Modeling of linear systems Fundamental solution to lin Laplace transform and z-tra Content of teaching for cou Introduction to Probability Fundamentals on Probabilit Forney-Style Factor Graphs Message Passing via Sum- Gaussian Message Passing State Estimation (Kalman F Parameter Estimation via E Expectation Propagation Control on Factor Graphs	urse Linear Systems and Control: r operators Jordan normal form on and operator norms us and discrete time and linearization hear systems state equations unsform urse Graphical Models in Systems ar Theory, Discretely and Continuousl stic Graphical Models as a Probabilistic Graphical Model and Max-Produkt Algorithms Itering and Smoothing including N spectation Maximization	nd Control: y Distributed Random Variables onlinear Extensions)
Qualification-goals/Competencie Educational objectives for of Students are familiar with t Students have a solid back Students are able to model Students are able to solve t Students improve their pro Students develop their tech Students are enabled to per Educational objectives for of Students develop and exter continuously distributed ra Students can understand s Students can understand, econtrol to relevant problem	es: course Linear Systems and Control: he important basic concepts of line ground in the theory of linear system linear systems in mechanical and e he state equations and analyze syst blem solving and mathematical skil aniques for logical reasoning and ar rform reseaerch in the field of system course Graphical Models in Systems and their fundamental knowledge of ndom variables. mple linear algorithms, such as the ments of probabilistic algorithms to extend and apply advanced algorith as with the help of graphical probabilistic	ar algebra. ns in continuous and disrete time. lectrical domain from first principles. rems in the time and frequency domain. ls. nd rigorous proofs. ms and control theory. and Control: n probability theory and the transformation of discretely as well as Kalman filter, with the help of graphical probabilistic models. novel ones with the help of graphical probabilistic models. ms in signal processing, parameter and state estimation as well as bilistic models.
Grading through: • Written or oral exam as anr Responsible for this module: • Prof. Dr. Goorg Schildbach	ounced by the examiner	
Prof. Dr. Philipp Rostalski		



Teacher:

- Institute for Electrical Engineering in Medicine
- Prof. Dr. Georg Schildbach
- Dr.-Ing. Christian Herzog, geb. Hoffmann

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



RO450	0-KP12 - Advanced	Control and Estimation	n (ACES)
Duration:	Turnus of offer:		Credit points:
2 Semester	each semester		12
Course of study, specific field and term: • Master Robotics and Autonomous Sy	ystems (advanced modul	e), Robotics and Autonomo	us Systems, 1st and 2nd semester
 Master Robotics and Autonomous Systems (advanced module), Robotics and Autonomous Systems, 1st and 2nd semester Classes and lectures: Linear Systems and Control (lecture, 2 SWS) Linear Systems and Control (exercise, 2 SWS) Graphical Models in Systems and Control (lecture, 2 SWS) Graphical Models in Systems and Control (lectercises with project, 1 SWS) Advanced Control and Estimation (seminar, 2 SWS) Contents of teaching: Content of teaching for course Linear Systems and Control: Vector spaces, norms, linear operators Eigenvalues, eigenvectors, Jordan normal form Singular value decomposition and operator norms Linear systems in continuous and discrete time Modeling of linear systems state equations Laplace transform Content of teaching for course Graphical Models in Systems and Control: Introduction to Probabilistic Graphical Models Forney-Style Factor Graphs as a Probabilistic Graphical Model Message Passing via Sum- and Max-Produkt Algorithms Gaussian Message Passing State Estimation via Expectation Maximization Expectation Propagation Controt of Factor Graphs 		te studies ssroom work sroom exercises preparation	
Qualification-goals/Competencies: Educational objectives for course Lin Students are familiar with the impor Students have a solid background ir Students are able to model linear sy Students are able to solve the state Students are able to solve the state Students develop their techniques f Students are enabled to perform res Educational objectives for course Gr Students develop and extend their f continuously distributed random va Students can understand simple line Students can understand, extend ar control to relevant problems with th Educational objectives of the semina Students are able to research and un Students are able to reproduce and Students are able reproduce, extend	hear Systems and Control tant basic concepts of lin in the theory of linear syste stems in mechanical and equations and analyze sy- ving and mathematical sk or logical reasoning and a seaerch in the field of syst aphical Models in System fundamental knowledge of riables. ear algorithms, such as the probabilistic algorithms to d apply advanced algorit he help of graphical proba ar Advanced Control and inderstand current literatu evaluate current algorithm d and present results from	: ear algebra. ems in continuous and disret electrical domain from first p stems in the time and freque ills. and rigorous proofs. ems and control theory. s and Control: on probability theory and the p novel ones with the help o hms in signal processing, pa abilistic models. Estimation: re. ms based on research literature.	te time. principles. ency domain. e transformation of discretely as well as p of graphical probabilistic models. if graphical probabilistic models. arameter and state estimation as well as



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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 DrIng. Christian Herzog, geb. Hoffmann
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



RO5000-KP12 - Internship Robotics and Autonomous Systems 1 (ProPraRAS1)			
Duration:	Turnus of offer:	Turnus of offer: Credit points:	
1 Semester	each winter semester		12
Course of study, specific field • Master Robotics and Au	1 and term: utonomous Systems (compulsory), Rob	potics and Autonomous Sys	stems, 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 specifi • documentation, preser • the project task is emb	c application scenario Itation, motivation in a heterogeneous edded in a heterogeneous and vivid er	environment nvironment with substantia	al communication and integration demands
Qualification-goals/Compete • deep understanding ar • ability to document an • ability to tailor a preser • project experience in s • development of project	encies: nd realization of selected topics in robo d present the project results ntation to a specific audience in a limite pecific application scenarios t management skills	otics and autonomous syste ed time (e.g., elevator pitch	ems 1, etc.)
Grading through: • Written report • continuous, successful • documentation	participation in practical course, >80%		
Responsible for this module:			
 Prof. Dr. Philipp Rostals 	ki		
Teacher: • Institute of Computer E • Institute for Robotics an • Institute for Electrical E	ingineering nd Cognitive Systems ngineering in Medicine		
Language:			
• English, except in case	of only German-speaking participants		
Notes:			
The internship may be co company in the domain c	mpleted at the University of Lübeck or of robotics and autonomous systems.	^r any external domestic or f	foreign university, research laboratory, or



RO5001-KP12 - Internship Robotics and Autonomous Systems 2 (ProPraRAS2)			
Duration:	Turnus of offer:		Credit points:
1 Semester	each winter semester		12
Course of study, specific field and term: • Master Robotics and Autonomous	: Systems (compulsory), Rob	otics and Autonomous Syst	ems, 3rd semester
Classes and lectures:		Workload:	
Internship 2 (block practical course	e, 12 SWS)	 320 Hours work 40 Hours written	on project 1 report
Contents of teaching: • project task in a specific application • documentation, presentation, modify • the project task is embedded in a	on scenario tivation in a heterogeneous o heterogeneous and vivid en	environment vironment with substantial	communication and integration demands
Qualification-goals/Competencies: • deep understanding and realization • ability to document and present the ability to tailor a presentation to a • project experience in specific apple • development of project management	on of selected topics in robot he project results specific audience in a limite lication scenarios nent skills	ics and autonomous syster d time (e.g., elevator pitch,	ns etc.)
Grading through: • Written report • continuous, successful participatio • documentation	on in practical course, >80%		
Responsible for this module:			
Prof. Dr. Philipp Rostalski			
Teacher: Institute of Computer Engineering Institute for Robotics and Cognitiv Institute for Electrical Engineering Alle prüfungsberechtigten Dozen	re Systems in Medicine ntinnen/Dozenten des Studie	nganges	
Language:			
English, except in case of only Ger	man-speaking participants		
Notes: The internship may be completed at company in the domain of robotics a	the University of Lübeck or and autonomous systems.	any external domestic or fc	preign university, research laboratory, or



	RO5100 A - Module part: Adv	anced Topics in Robotics (FTdR)
Duration:	Turnus of offer:	Credit points:
1 Semester	each summer semester	4
Course of study, specific field	d and term:	
Master Robotics and Au	utonomous Systems (module part), Rol	potics and Autonomous Systems, 1st or 2nd semester
Classes and lectures:		Workload:
 Advanced Topics in Ro Advanced Topics in Ro 	botics (lecture, 2 SWS) botics (exercise, 1 SWS)	 55 Hours private studies 45 Hours in-classroom work 20 Hours exam preparation
Contents of teaching:		
 Dynamics and Control Motion Planning for Rc Augmented Reality Design of Robot Syster Intracorporal Robotics 	of Robots Ibots ns	
Qualification-goals/Compete	encies:	
 Students understand the processing and analysi Students have an exter They are able to implete 	ne connection to underlying mathemat s of algorithms. nded overview of application areas for 1 ment such methods and derive new ap	ical methods, especially in dynamics, optimization, and sensor data obotics. plications based on such methods.
Grading through:		
• written exam, oral exar	n and/or presentation as announced by	/ the examiner
Requires:		
 Module part: Medical R Robotics (CS2500-KP04 	obotics (CS4270 T) , CS2500)	
Responsible for this module:		
Prof. DrIng. Achim Sch	nweikard	
Teacher:	ad Cognitivo Systems	
	in Cognitive Systems	
Prof. DrIng. Achim Sch	nweikard	
Literature:		
Achim Schweikard, Flo	ris Ernst: Medical Robotics - Springer, 20)15, Jocelyne Troccaz (ed.): Medical Robotics, Wiley, 2009
Language:		
offered only in English		
Notes:		
Students are only require	d to have taken one of the listed modu	les.



RO5102-KP04 - Reinforcement Learning (RL)			
Duration:	Iration: Turnus of offer: Credit points:		
1 Semester	each summer semester	4	
Course of study, specific fi • Master Robotics and	eld and term: Autonomous Systems (optional subject),	Robotics and Autonomous Systems, 1st or 2nd semester	
Classes and lectures:	lasses and lectures: Workload:		
 Reinforcement Learn Reinforcement Learn	ing (lecture, 2 SWS) ing (exercise, 1 SWS)	 55 Hours private studies 45 Hours in-classroom work 20 Hours exam preparation 	
Contents of teaching: • Dynamics and Contro • Motion Planning for • Augmented Reality • Design of Robot Syst • Intracorporal Robotic	ol of Robots Robots tems cs		
Qualification-goals/Compe • Students understance processing and analy • Students have an exist • They are able to imp	etencies: I the connection to underlying mathemat /sis of algorithms. tended overview of application areas for r lement such methods and derive new apj	ical methods, especially in dynamics, optimization, and ser obotics. plications based on such methods.	nsor data
Grading through: • written exam. oral ex	am and/or presentation as announced by	the examiner	
Dominon			
Robotics (CS2500-KP	04, CS2500)		
Responsible for this modu Prof. Dr. Elmar Rücke Teacher: Institute for Robotics Prof. Dr. Elmar Rücke 	le: rt and Cognitive Systems rt		
Literature:	loris Frnst: Medical Robotics - Springer 20	115 Jocelyne Troccaz (ed.): Medical Robotics Wiley 2009	
offered only in Englis	h		



RO5200-KP08 - Bio-inspired Robotics (BRS)			5)
Duration:	Turnus of offer:		Credit points:
2 Semester	each semester		8
Course of study, specific field	d and term:		
Master Robotics and A	utonomous Systems (optional subject)	, Robotics and Autonomous	Systems, arbitrary semester
Classes and lectures: Workload:			
 Collective Robotics (lecture, 2 SWS) Collective Robotics (exercise, 1 SWS) Evolutionary Robotics (lecture, 2 SWS) Evolutionary Robotics (exercise, 1 SWS) 		 110 Hours private studies 110 Hours in-classroom work 20 Hours exam preparation 	
 Biological basics Self-organization, robu Robot swarms by land, Mathematical modelin Evolutionary computate Artificial evolution of robust Optimization and learn Qualification-goals/Compete Students get a compression Students are able to assist a students are able to in mobile robots in. Students are able to na 	istness, scalability, superlinear speedup , by sea, and by air g of swarms and collective decision-ma tion obot controllers and robot morphologic ning in robot experiments encies: whensive overview of biologically inspire sess chances and challenges of robust nplement reactive control for swarm rol nplement evolutionary algorithms and a ame challenges of evolutionary robotics	s aking es ed. and scalable robot systems. bots in simulation and on m artificial neural networks and s in applications and to disc	obile robots. d are able to apply them to problems of uss potential solutions.
Grading through:			
Written or oral exam as	s announced by the examiner		
Responsible for this module Prof. DrIng. Heiko Har Teacher: Institute for Robotics a Prof. DrIng. Heiko Har 	: nann nd Cognitive Systems nann		
Literature: • Nolfi, S., Floreano, D.: T • Hamann, H.: Swarm Ro	he Biology, Intelligence, and Technolog botics: A Formal Approach - Springer 2	gy of Self-Organizing Machir 018	nes - MIT Press, 2001
Language: • offered only in English			



RO5200-KP12 - Bio-inspired Robotics (BR)			
Duration:	Turnus of offer:		Credit points:
2 Semester	each semester		12
Course of study, specific field an • Master Robotics and Autor	nd term: nomous Systems (advanced modu	ıle), Robotics and Autonom	ious Systems, arbitrary semester
Classes and lectures:Workload:• Collective Robotics (lecture, 2 SWS)• 220 Hours private studies• Collective Robotics (exercise, 1 SWS)• 120 Hours in-classroom work• Evolutionary Robotics (lecture, 2 SWS)• 20 Hours exam preparation• Evolutionary Robotics (exercise, 1 SWS)• 20 Hours exam preparation• Seminar Bio-inspired Robotics (seminar, 2 SWS)• 20 Hours exam preparation		rate studies lassroom work n preparation	
Contents of teaching: Biological basics Self-organization, robustn Robot swarms by land, by Mathematical modeling of Evolutionary computation Artificial evolution of robo Optimization and learning Independent familiarization Writing and presentation	ess, scalability, superlinear speedu sea, and by air swarms and collective decision-m t controllers and robot morpholog in robot experiments n with an area of service robotics of an own scientific paper	ps naking yies based on technical literatur	re
 Qualification-goals/Competencia Students get a compreher Students are able to asses Students are able to imple Students are able to imple Students are able to name Die Teilnehmer sind in der The students are able to ir The participants can analy present their own scientification 	es: Isive overview of biologically inspines chances and challenges of robust ment reactive control for swarm ro ment evolutionary algorithms and challenges of evolutionary robotion Lage, eine wissenschaftliche Arbe ivestigate self-dependently sciention ze and reproduce the tenor with ro c work.	red. t and scalable robot system obots in simulation and on d artificial neural networks a cs in applications and to dis eit eigenständig zu verfasse ific publications, to analyze egard to their scope of wor	ns. mobile robots. and are able to apply them to problems of scuss potential solutions. n und vorzutragen. and understand their contents. rk. The students are competent to write and
Grading through: • Written or oral exam as an	nounced by the examiner		
Responsible for this module: • Prof. DrIng. Heiko Hamar Teacher: • Institute for Robotics and (• Prof. DrIng. Heiko Hamar	n Cognitive Systems n		
Literature: • Nolfi, S., Floreano, D.: The • Hamann, H.: Swarm Robot	Biology, Intelligence, and Technolo ics: A Formal Approach - Springer	ogy of Self-Organizing Macł 2018	hines - MIT Press, 2001
Language: • offered only in English			



RO5500-KP08 - Autonomous Vehicles (AV)			
Duration:	Turnus of offer:	Credit points:	
2 Semester	each semester	08	
Course of study, specific field and term:			
Master Robotics and Autonomous S	ystems (optional subject), R	obotics and Autonomous Systems, 1st and 2nd semester	
Classes and lectures:		Workload:	
 Vehicle Dynamics and Control (lect) Vehicle Dynamics and Control (exer) Perception for Autonomous Vehicle 	ure, 2 SWS) cise, 2 SWS) s (lecture, 2 SWS)	 140 Hours private studies 60 Hours in-classroom work 40 Hours exam preparation 	
Perception for Autonomous Vehicle	s (exercise, 2 SWS)	· · · · · · · · · · · · · · · · · · · ·	
Contents of teaching:			
 Contents of teaching: Content of teaching of the course Vehicle Dynamics and Control: Review of control methods and rigid body dynamics Basic terminology of vehicle dynamics Vehicle dynamic models (lateral, longitudinal, vertical) Component models (engine, transmission, brake, steering) Tire modeling Stability analysis Handling performance Active safety systems Autonomous driving Content of teaching of the course Perception for Autonomous Driving: The architecture of autonomous-driving systems Tracking, detection, classification Models of stochastic signals Transform-based analysis of stochastic signals System theory Parameter estimation Linear optimal filters and adaptive filters Graphical models and dynamic Bayes networks Neural networks Hidden Markov Models, Kalman Filter, Particle Filter, etc. 			
Qualification-goals/Competencies:			
 Educational objectives of the course Students master basic terminology 	e vehicle Dynamics and Con and concepts of vehicle dvn	troi: amics.	
 Students infaction basic terminology and concepts of venice dynamics. Students obtain a comprehensive understanding of the dynamics of a vehicle. 			
 Students understand the main objectives of vehicle control. Students can derive basic vehicle dynamics models for control design. 			
 Students are able to apply concepts of basic and advanced control and estimation to practical problems. 			
 Students get an insight into the field of active safety systems, driver assistance, and autonomous driving. Students are able to perform independent design, research and development work in this field. 			
 Educational objectives of the course Perception for Autonomous Driving: 			
 Students get an overview on autonomous-driving systems. Students become thoroughly acquainted with the perception layer of the architecture of an autonomous-driving system. 			
• Students get a comprehensive introduction to stochastic signals.			
 Students master tools for the analysis of stochastic signals. Students are able to make use of various models for stochastic signals. 			
• Students are able to design tracking algorithms.			
Students are able devise algorithmi	c solutions to decision probl	ems, while making use of prior knowledge.	
Grading through:			
Written or oral exam as announced	by the examiner		



Requires:
Control Systems (RO4400-KP08)
Technical Mechanics (RO1500-KP08)
Responsible for this module:
Prof. Dr. Georg Schildbach
Teacher:
Institute for Electrical Engineering in Medicine
Prof. Dr. Georg Schildbach
PD 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 Haukin, Adaptive Filter Theory. Proptice Hall, 1006
 Simon naykin: Adaptive Filer meory - Prenice nail, 1996 Christopher M Bishop: Pattern recognition and machine learning - Springer, 2006
 A. Mertins: Signaltheorie: Grundlagen der Signalbeschreibung, Filterbänke, Wavelets, Zeit-Frequenz-Analyse, Parameter- und Signalschätzung - Springer-Vieweg, 3. Auflage, 2013
Language:
offered only in English
Notes:
(RO5500-L1 Partial Exam Vehicle Dynamics and
Control (Graded Exam, 4 KP))
(RO5500-L2 Partial Exam Perception for
Autonomous Vehicles (Graded Exam, 4 KP))



RO5500-KP12 - Autonomous Vehicles (AVS)				
Duration:	Turnus of offer:		Credit points:	
2 Semester	starts every winter semester		12	
Course of study, specific field and term: • Master Robotics and Autonomous	Systems (advanced curriculu	um), Robotics and Autonor	mous Systems, 1st and 2nd semester	
Classes and lectures: • Vehicle Dynamics and Control (lect • Vehicle Dynamics and Control (exe • Perception for Autonomous Vehicl • Perception for Autonomous Vehicl • Current Topics in Autonomous Veh	Workload:(lecture, 2 SWS)• 220 Hours private studies(exercise, 2 SWS)• 80 Hours in-classroom workhicles (lecture, 2 SWS)• 60 Hours exam preparationhicles (seminar, 2 SWS)• 60 Hours exam preparation		te studies sroom work preparation	
Contents of teaching: Content of teaching of the course Review of control methods and rig Basic terminology of vehicle dynam Vehicle dynamic models (lateral, lo Component models (engine, transi Tire modeling Stability analysis Handling performance Active safety systems Autonomous driving Content of teaching of the course The architecture of autonomous-d Tracking, detection, classification Models of stochastic signals Transform-based analysis of stocha System theory Parameter estimation Linear optimal filters and adaptive Graphical models and dynamic Bay Neural networks Hidden Markov Models, Kalman Fil Applications in the domain of auto Content of teaching of the semina Current algorithms in machine lear	Vehicle Dynamics and Contro id body dynamics nics ngitudinal, vertical) mission, brake, steering) Perception for Autonomous riving systems astic signals filters yes networks ter, Particle Filter, etc. onomous driving r Current Topics in Autonom ring and artificial intelligence	ol: Driving: ous Vehicles: ce related to autonomous o	driving	
Qualification-goals/Competencies: Educational objectives of the course Students master basic terminology Students obtain a comprehensive Students understand the main objectives basic vehicle of Students can derive basic vehicle of Students are able to apply conception Students get an insight into the file Students are able to perform indege Educational objectives of the course Students become thoroughly acque Students are able to make use of vehicles are able to design tracking Students are able to make use of vehicles are able to design tracking Students are able to design tracking Students are able devise algorithm Educational objectives of the semitive 	se Vehicle Dynamics and Corr y and concepts of vehicle dyn understanding of the dynamic ectives of vehicle control. dynamics models for control ts of basic and advanced con- ed of active safety systems, of bendent design, research and se Perception for Autonomou- nomous-driving systems. nainted with the perception I oduction to stochastic signals. arious models for stochastic ig algorithms. ic solutions to decision prob- nar Current Topics in Autonomou- percential and the perception I of the stochastic signals. arious models for stochastic	ntrol: namics. iics of a vehicle. design. ntrol and estimation to prad friver assistance, and autor d development work in thi us Driving: ayer of the architecture of ls. signals. olems, while making use of pmous Vehicles:	ctical problems. nomous driving. s field. an autonomous-driving system.	


Module Guide

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. Bishop: Pattern recognition and machine learning - Springer, 2006 A. Mertins: Signaltheorie: Grundlagen der Signalbeschreibung, Filterbänke, Wavelets, Zeit-Frequenz-Analyse, Parameter- und Signalschätzung - Springer-Vieweg, 3. Auflage, 2013
Language:
offered only in English
Notes:
(RO5500-L1 Partial Exam Vehicle Dynamics and Control (Graded Exam, 4 KP)) (RO5500-L2 Partial Exam Perception for
Autonomous Vehicles (Graded Exam, 4 KP))
(RO5500-L3 Partial Exam Current Topics in Autonomous Vehicles (Ungraded Seminar, 4 KP))



	RO5800-KP08 - Advan	ced Topics in Robotics	(ATR)
Duration:	Turnus of offer:		Credit points:
2 Semester	each semester		8
Course of study, specific field • Master Robotics and Au Classes and lectures: • Advanced Topics in Rol • Advanced Topics in Rol • Rescue Robotics (lectur • Rescue Robotics (exerc	I and term: itonomous Systems (optional subject potics (lecture, 2 SWS) potics (exercise, 1 SWS) e, 2 SWS) ise, 2 SWS)	t), Robotics and Autonomou Workload: • 105 Hours in-cla • 95 Hours private • 40 Hours exam	s Systems, 1st or 2nd semester assroom work e studies preparation
Contents of teaching: • Content of teaching of • Motion Planning for Ro • Augmented Reality	the course Advanced Topics in Robo bots	tics:	
 Design of Robot System Intracorporal Robotics Dynamics and Control Content of teaching of Special requirements for Information structures Information exchange Command and control Tactical communication Design guidelines for h Casualty and vital sign Medical assistance at th Evaluation and benchm 	ns of Robots the course Rescue Robotics: or disaster management and respons for rescue systems between rescue robots systems for search and rescue robots n for cooperative SAR robot missions uman interfaces to rescue robots detection in rescue scenarios ne scene of incident and determination narking of SAR robots	e and the resulting conseque s as well as interoperability in on of vital signs	ences on rescue robot design. heterogeneous teams.
 Qualification-goals/Competer Educational objectives Students understand the processing and analysis Students have an exter They are able to impler Educational objectives The students can applz robotics, localization ar The students have know communcation and int The students have deveropersons, determine vita 	ncies: of the course Advanced Topics in Rol the connection to underlying mathem s of algorithms. Inded overview of application areas for nent such methods and derive new a of the course Rescue Robotics: the tools to program and simulate n and path planning in difficult scenarios wledge about the work and comman eraction of rescue robots with the pe eloped a notion of medical first respond al signs and realize medical assistance	botics: atical methods, especially in r robotics. applications based on such m nobile rescue robots. They ha s. d structures of rescue persor rsonnel. onse by rescue personnel as v e at the scene of incident.	dynamics, optimization, and sensor data nethods. ave developed a good overview about mobile nell and the requirements on control, well as technical solutions to locate missing
Grading through: • written exam, oral exan	n and/or presentation as announced	by the examiner	
Requires: • Robotics (CS2500-KP04 • Module part: Medical R	, CS2500) obotics (CS4270 T)		
Responsible for this module: • Prof. DrIng. Achim Sch Teacher: • Institute for Robotics ar	iweikard nd Cognitive Systems		

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Module Guide

- 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



RO5800-KP12 - Advanced Topics in Robotics (ATRS)			
	Credit points:		
	12		
 Course of study, specific field and term: Master Robotics and Autonomous Systems (advanced curriculum), Robotics and Autonomous Systems, 1st or 2nd semester 			
Workload: 135 Hours in-clas 95 Hours private 90 Hours work o presentation or o 40 Hours exam p	ssroom work studies n an individual topic with written and oral group work preparation		
obotics: onse and the resulting consequer oots ons as well as interoperability in h nation of vital signs Medicine: propriate methods ocesses for Sensor Data Analysis, h Calibration	nces on rescue robot design. neterogeneous teams. Motion Prediction, Correlation Methods for		
Robotics: iematical methods, especially in c s for robotics. w applications based on such me re mobile rescue robots. They hav rios. nand structures of rescue persone epersonnel. sponse by rescue personnel as w ince at the scene of incident. earning in Medicine: ch topic. ts in written or spoken presentati glish language. ext.	dynamics, optimization, and sensor data ethods. ve developed a good overview about mobile ell and the requirements on control, rell as technical solutions to locate missing ions.		
	anced Topics in Robotics (urriculum), Robotics and Autonor Workload: 135 Hours in-cla 95 Hours private 90 Hours work o presentation or 40 Hours exam p obotics: onse and the resulting conseque oots ons as well as interoperability in l ation of vital signs Medicine: propriate methods cesses for Sensor Data Analysis, l calibration Robotics: mematical methods, especially in o s for robotics. w applications based on such me te mobile rescue robots. They hav rios. nand structures of rescue person personnel. sponse by rescue personnel as w ince at the scene of incident. earning in Medicine: ch topic. ts in written or spoken presentat glish language. ext.		



• written exam, oral exam and/or presentation as announced by the examiner
Requires:
 Module part: Medical Robotics (CS4270 T) 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 Madia 2000 (ISBN 078 144715766)
 Siciliano, Bruno, and Oussama Khatib. eds.: Springer handbook of robotics Springer, 2016. (ISBN: 978-3319325507)
Language:
offered only in English



I	RO5801-KP04 - Advance	ed Topics in Robotics (ATIR)
Duration:	Turnus of offer:		Credit points:
1 Semester	each summer semester		4
Course of study, specific field and ter • Master Robotics and Autonomo	m: us Systems (optional subject)	, Robotics and Autonomous	Systems, 1st or 2nd semester
 Classes and lectures: Advanced Topics in Robotics (lecture, 2 SWS) Advanced Topics in Robotics (exercise, 1 SWS) 		Workload: • 55 Hours private • 45 Hours in-class • 20 Hours exam p	e studies sroom work preparation
Contents of teaching: • Dynamics and Control of Robots • Motion Planning for Robots • Augmented Reality • Design of Robot Systems • Intracorporal Robotics	5		
Qualification-goals/Competencies: Students understand the conne processing and analysis of algor Students have an extended ove They are able to implement suc 	ction to underlying mathema ithms. rview of application areas for h methods and derive new ap	tical methods, especially in o robotics. plications based on such me	dynamics, optimization, and sensor data ethods.
Grading through: • written exam, oral exam and/or	presentation as announced b	y the examiner	
Requires: • Module part: Medical Robotics (• Robotics (CS2500-KP04, CS2500)	CS4270 T))		
Responsible for this module: Prof. DrIng. Achim Schweikard Teacher: Institute for Robotics and Cogni Prof. DrIng. Achim Schweikard 	tive Systems		
Literature: • Achim Schweikard, Floris Ernst:	Medical Robotics - Springer, 2	015, Jocelyne Troccaz (ed.):	Medical Robotics, Wiley, 2009
Language: • offered only in English			



RO5990	0-KP30 - Master Thesis Robo	otics and Autonomous Systems (MScRAS)
Duration:	Turnus of offer:	Credit points:
1 Semester	each semester	30
Course of study, specific field a • Master Robotics and Auto	and term: onomous Systems (compulsory), R	obotics and Autonomous Systems, 4th semester
Classes and lectures: • Master's Thesis (supervised self studies, 1 SWS) • Colloquium (presentation (incl. preparation), 1 SWS)		 Workload: 870 Hours private studies 30 Hours oral presentation (including preparation)
Contents of teaching: • individual studies under	supervision	
Qualification-goals/Competent ability to solve a complex experience in writing a so becoming expert in a spe experience in working wi presentation skills	cies: < scientific problem with state of th cientific thesis within a given time ecial subfield of informatics ith scientific literature	e art methods period
Grading through: • oral presentation • 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: requirement for starting a r	naster's thesis are 75 credit points	



Module Guide

RO5100-KP08 - Medical Robotics (MedRob08)				
Duration:	Turnus of offer:	Credit points:		
2 Semester	every summer semester	8		
Course of study, specific field and terr • Master Robotics and Autonomou	n: ıs Systems (optional subject), E	lective, 1st or 2nd semester		
 Classes and lectures: ME4030 T: Inverse Probleme bei der Bildgebung (lecture with exercises, 3 SWS) RO5100 A: Advanced Topics in Robotics (lecture with exercises, 3 SWS) 		 Workload: 125 Hours private studies 90 Hours in-classroom work 25 Hours exam preparation 		
Contents of teaching: • see module parts				
Qualification-goals/Competencies: see module parts 				
Grading through: • Written or oral exam as announc	ed by the examiner			
Responsible for this module: • Prof. DrIng. Achim Schweikard Teacher: • Institute of Computer Engineerin • Institute for Electrical Engineering • Institute of Medical Engineering • Institute of Medical Informatics • Institute for Robotics and Cognit	g g in Medicine ive Systems			
Language: • offered only in English				