

UNIVERSITÄT ZU LÜBECK

# Module Guide for the Study Path

# **Master Computer Science 2019**

Version from 11. April 2025



21

### interdisciplinary competence

Seminar in English (CS5840-KP04, CS5840, SemiEngl)	1
General Business Administration (EC4001-KP04, EC4001, ABWL)	2
Entrepreneurship & Innovation (EC4008-KP04, EI)	4
Commercial Law (EC4010-KP04, EC4010, WirtRecht)	6
Scientific Teaching and Tutoring (PS5810-KP04, PS5810, WLehrKP04)	8

### **Applied computer science**

Information Systems (CS4130-KP06, CS4130, InfoSys)	9
Distributed Systems (CS4150-KP06, CS4150SJ14, VertSys14)	11

### Theoretical computer science

Algorithmics (CS4000-KP06, CS4000SJ14, ALG14)	13
Specification and Modelling (CS4020-KP06, CS4020SJ14, SpezMod14)	15

# technical computer science

Real-Time Systems (CS4160-KP06, CS4160SJ14, Echtzeit14)	17
Parallel Computer Systems (CS4170-KP06, CS4170SJ14, ParaRSys14)	19

### computer science

Master Thesis Computer Science (CS5990-KP30, CS5990, MasterInf)

# Module part

Module part: Computer-Aided Design of Digital Circuits (CS3110 T, SchaltEnta)	22
Module part: Model Checking (CS4138 T, ModelCha14)	23
Module part: Runtime Verification and Testing (CS4139 T, RVTestena)	25
Module part: Mobile and Distributed Databases (CS4140 T, MVDBa)	27
Module part: Architectures for Distributed Applications (CS4151 T, SVAa)	29
Module part: Pattern Recognition (CS4220 T, MEa)	31
Module part: NeuroInformatics (CS4405 T, NeuroInfa)	33
Module part: Molecular Bioinformatics (CS4440 T, MolBioInfa)	35
Module part: Ambient Computing (CS4670 T, AmbCompa)	37
Module part: Web-Mining Agents (CS5131 T, WebMininga)	39
Module part: Semantic Web (CS5140 T, SemWeba)	41
Module part: Organic Computing (CS5150 T, OrganicCoa)	43
Module part: Wireless Sensor Networks (CS5153 T, DISensorNa)	45



Module part: Advanced Internet Technologies (CS5158 T, AdInternea)	47
Module part: Hardware/Software Co-Design (CS5170 T, HWSWCoda)	49
Module part: Practical Project in Signal and Image Processing (CS5194 T, PrSigBildv)	51
Module parte: Static Analysis (CS5220 T, StatAnaa)	53
Module part: Speech and Audio Signal Processing (CS5260SJ14 T, SprachA14a)	55
Module part: Selected Topics of Signal Analysis and Enhancement (CS5275 T, AMSAVa)	57
Module part: Artificial Life (CS5410 T, ArtiLifea)	59
module part: Seminar Machine Learning (CS5430 T, SemMaschLa)	61
Module part: Seminar Neuro- and Bioinformatics (CS5440 T, SemNeurBia)	62
Module part: Machine Learning (CS5450 T, MaschLerna)	63
Module part: Project Bioinformatics (CS5549 T, PrBioinfa)	65
module part: System Biology (EW4170 T, SystBioT)	66
Module part: Organic Chemistry (LS1600 T, OCMIa)	67
Module part: Biostatistics 2 (MA2600 T, BioStat2a)	69
Module part: Stochastics 2 (MA4020 T, Stoch2a)	71
Module part: Chaos and Complexity of Biological Systems (MA4400 T, CKBSa)	73
Module part: Modeling Biological Systems (MA4450 T-INF, MoBSa)	75

# **Canonical Specialization SSE**

Distributed Systems (CS4150-KP06, CS4150SJ14, VertSys14)	11
Current Topics SSE (CS4212-KP04, CS4212, SSEaktuell)	77
Software Verification (CS4507-KP12, CS4507, SoftVeri)	78
Hardware/Software Co-Design (CS5170-KP04, CS5170, HWSWCod)	79
Lab Software Systems Engineering (CS5490-KP06, CS5490SJ14, PrSSE14)	81

# Elective

Current Topics SSE (CS4212-KP04, CS4212, SSEaktuell)	77
Computer Vision (CS4250-KP04, CS4250, CompVision)	83
Deep Learning (CS4295-KP04, DEEPL)	85
Privacy (CS4451-KP06, Privacy)	87
Reliability Engineering (CS4452-KP06, TechZuv)	88
Sequence Learning (CS4575-KP04, SEQL)	90
Advanced Cryptology (CS4703-KP06, AdvCrypto)	92
Cryptographic Engineering (CS4705-KP06, CryEng)	93
Energy Efficiency in Emebedded Systems (CS4720-KP06, EEE)	95
Algorithmic Learning and Causality (CS5020-KP06, ALKI)	96
Advanced Topics Data Science and AI (CS5070-KP04, Dataakuell)	97
Trustworthy AI (CS5075-KP06, TrustAI)	98



Hardware/Software Co-Design (CS5170-KP04, CS5170, HWSWCod)	79
Current Topics in IT Security (CS5195-KP04, AktTheITS)	100
Current Trends in Bioinformatics (CS5400-KP08, CS5400, WahlBioInf)	102
Lab Software Systems Engineering (CS5490-KP06, CS5490SJ14, PrSSE14)	81
Molecular Biology (LS3151-KP04, LS3151, MolBioINF)	103

# Canonical Specialization Bioinformatics and Systems Biology

Algorithmics (CS4000-KP06, CS4000SJ14, ALG14)	13
Learning Systems (CS4511-KP12, CS4511, LernSys)	104
Bioinformatics and System Biology (CS4516-KP12, BioinfVert)	106
Advanced Topics Data Science and AI (CS5070-KP04, Dataakuell)	97
Current Trends in Bioinformatics (CS5400-KP08, CS5400, WahlBioInf)	102
Molecular Biology (LS3151-KP04, LS3151, MolBioINF)	103

# **Canonical Specialization Data Science and AI**

Algorithmics (CS4000-KP06, CS4000SJ14, ALG14)	13
Information Systems (CS4130-KP06, CS4130, InfoSys)	9
Learning Systems (CS4511-KP12, CS4511, LernSys)	104
Intelligent Agents (CS4514-KP12, IntAgents)	107
Algorithmic Learning and Causality (CS5020-KP06, ALKI)	96
Advanced Topics Data Science and AI (CS5070-KP04, Dataakuell)	97

# advanced module

Algorithmics, Logic and Computational Complexity (CS4501-KP12, CS4501, ALK14)	109
Ambient Computing and Applications (CS4503-KP12, CS4503, AmbCompA)	111
Cyber Physical Systems (CS4504-KP12, CS4504, CPS)	113
System Architecture (CS4505-KP12, CS4505, SysArch)	115
Information and Communication Security (CS4506-KP12, CS4506, SDK)	116
Software Verification (CS4507-KP12, CS4507, SoftVeri)	78
Data Management (CS4508-KP12, CS4508, DatManag)	118
Internet Structures and Protocols / Internet Technologies (CS4509-KP12, CS4509, Internet)	119
Signal Analysis (CS4510-KP12, CS4510, SignalAna)	120
Learning Systems (CS4511-KP12, CS4511, LernSys)	104
Intelligent Agents (CS4514-KP12, IntAgents)	107
Computer and System Security (CS4515-KP12, ComSysSec)	122
Bioinformatics and System Biology (CS4516-KP12, BioinfVert)	106
Architectures for Distributed Communication Systems (CS4517-KP12, ArchVeK)	124





Current and Future Network Technologies (CS4518-KP12, AzuNet)	126
Case study in professional product development (CS4520-KP12, CS4520, Fallstudie)	128
Constructive Cognitive Science (CS4521-KP12, CCS)	130
Common Sense Reasoning and Natural Language Understanding (CS4522-KP12, CSRNLU)	132



	CS5840-KP04, CS5840 - Seminar in English (SemiEngl)				
Duration:	Turnus of offer:		Credit points:		
1 Semester	each semester		4 (Тур В)		
Course of study, specific field Master Artificial Intellige Master Computer Science Master Computer Science Master Computer Science	and term: ence 2023 (optional subject), for equ ce 2019 (optional subject), interdisci ce 2014 (optional subject), interdisci ce 2012 (optional suject), interdiscip	ivalence check, Arbitrar plinary competence, Ar plinary competence, Ar linary competence, Arb	y semester bitrary semester bitrary semester itrary semester		
Classes and lectures: • Seminar in Englisch (ser	Classes and lectures:       Workload:         • Seminar in Englisch (seminar, 2 SWS)       • 90 Hours work on an individual topic with written and or presentation         • 30 Hours in-classroom work				
Contents of teaching:					
<ul> <li>Familiarization in a dem</li> <li>Working on a scientific t</li> <li>Presentation and discust</li> </ul>	anding scientific topic topic and its answers for problems c sion of the topic in English	on their own			
Qualification-goals/Competer	ncies:				
<ul> <li>The students can obtain</li> <li>They can review a scien</li> <li>They are able to present</li> <li>The can present and dis</li> <li>They can follow a scient</li> </ul>	a solid grounding a demanding sci tific work. t the results in a written documenta cuss a scientific topic in English. ific presentation and assess critically	entific topic. tion and in a talk in an u y in an open discussion.	understandable way.		
Grading through: • oral presentation • Written report					
Responsible for this module: • Studiengangsleitung Ir Teacher: • Institutes of the Departr • Alle prüfungsberechtig	nformatik nent of Computer Science/ Enginee Iten Dozentinnen/Dozenten des Stu	ring dienganges			
Literature:					
• is selected individually:					
Language: • offered only in English					
Notes: Prerequisites for attending - None Prerequisites for the exam - Successful participation i the beginning of the seme Module exam(s): CS5840-L1: English Langua	g the module: : n the seminar incl. elaboration, pres ester. age Seminar, Seminar, 100% of (non	entation, contributions -existent) module grad	to the discussion according to the requirements at e.		
Registration and topic ass	ignment in a preliminary meeting at	t the end of the precedi	ng semester.		



EC4001	-KP04, EC4001 - Gene	ral Business Administra	ation (ABWL)
Duration:	Turnus of offer:		Credit points:
1 Semester	each winter semester		4
Course of study, specific field and ter Master Computer Science 2019 ( Master Psychology 2016 (option Master Interdisciplinary Courses Master psychology 2013 (option Master Media Informatics 2014 ( Master Computer Science 2014 (	m: (optional subject), interdisci al subject), interdisciplinary (optional subject), Interdisc al subject), interdisciplinary optional subject), interdisci (optional subject), interdisci	plinary competence, Arbitrary competence, Arbitrary semes iplinary modules, Arbitrary se competence, Arbitrary semes plinary competence, Arbitrary plinary competence, Arbitrary	v semester ster mester ster semester v semester
Classes and lectures:		Workload:	
<ul> <li>General Business Administration (lecture, 2 SWS)</li> <li>General Business Administration (exercise, 1 SWS)</li> <li>General Business Administration (exercise, 1 SWS)</li> <li>Hours in-classroom work</li> <li>To Hours exam preparation</li> </ul>		e studies sroom work oreparation	
<ul> <li>Theories in business administrat</li> <li>Organisational forms</li> <li>Legal forms</li> <li>Accounting basics</li> <li>Theories on leaderhip and motiv</li> </ul>	ion /ation		
Qualification-goals/Competencies: <ul> <li>The students get an important a</li> <li>Within this lecture, the students</li> <li>Furthermore, students will be ab</li> </ul>	and in-depth overview of th are empowered to identify ple to evaluate the different	e single parts of business adm and classify the different theo approaches and apply them t	ninistration. pretical areas of business administration. to specific situations.
Grading through: • portfolio exam			
Responsible for this module: • Prof. Dr. Christian Scheiner Teacher: • Institute for Entrepreneurship ar • Dr. Stefan Becker	nd Business Development		
Literature:			
<ul> <li>Wöhe: Einführung in die Allgem</li> <li>Hungenberg, Wulf: Grundlagen</li> </ul>	eine Betriebswirtschaftsleh der Unternehmensführung	e - Vahlen-Verlag, 24. Auflage - Gabler-Verlag, 4. Auflage, 20	e, 2010 )11
Language:			
<ul> <li>offered only in German</li> </ul>			
Notos			



Prerequisites for attending the module: - none

Prerequisites for participation in module exam(s):

- none

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

Module exam(s):

- EC4001-L1: General Business Administration, (online) tests, 100 % of module grade

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

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

(Is equal to EC4001 T-KP04)





	EC4008-KP04 - Entrepreneurship & Innovation (EI)			
Duration:	Turnus of offer:		Credit points:	
1 Semester	each winter semester		4	
Course of study, specific field ar	nd term:			
<ul> <li>Master Computer Science</li> <li>Master Medical Informatics</li> <li>Master Computer Science</li> <li>Master Media Informatics</li> <li>Master Medical Informatics</li> <li>Master Interdisciplinary Computer Science</li> </ul>	2019 (optional subject), interdiscip s 2019 (optional subject), interdisci 2014 (optional subject), interdiscip 2014 (optional subject), Interdiscip s 2014 (optional subject), interdisci purses (optional subject), Interdisci	linary competence, Arbitrary iplinary competence, 1st or 2r Ilinary competence, Arbitrary linary modules, Arbitrary sem iplinary competence, 1st or 2r plinary modules, Arbitrary ser	semester nd semester semester ester nd semester nester	
Classes and lectures:		Workload:		
<ul> <li>Entrepreneurship and Inno</li> <li>Entrepreneurship and Inno</li> </ul>	ovation (lecture, 2 SWS) ovation (exercise, 1 SWS)	<ul><li>60 Hours private</li><li>45 Hours in-class</li><li>15 Hours exam p</li></ul>	studies room work reparation	
Contents of teaching:				
<ul> <li>This course deals with function</li> <li>The content is also linked and the individual aspects of the end of the</li></ul>	damental theories, concepts and to to practical and current topics thus vent will be studied on selected ca	ools for the entrepreneurship s covering relevant applicatio sse studies.	and innovation management. ns.	
Qualification-goals/Competenci	es:			
<ul> <li>Students are able to master and innovation.</li> <li>Students are able to struct extent also even in a new,</li> <li>Students are able to define development and reflect t</li> <li>Students can work cooper</li> </ul>	<ul> <li>Students are able to master and apply scientific foundations and develop predominantly fundamental expertise in entrepreneurship and innovation.</li> <li>Students are able to structure and solve problems in innovation and technology management predominantly in a familiar be to some extent also even in a new, unfamiliar and multidisciplinary context.</li> <li>Students are able to define goals for their own development and reflect their own strengths and weaknesses, plan their own development and reflect the societal impact.</li> <li>Students can work cooperatively and responsibly in groups and reflect and enhance their own cooperative behavior in groups critical</li> </ul>			
Grading through: • portfolio exam				
Responsible for this module: • Prof. Dr. Christian Scheiner	· · · · · · · · · · · · · · · · · · ·			
Teacher: • Institute for Entrepreneurs	hip and Business Development			
Prof. Dr. Christian Scheiner				
<ul> <li>Literature:</li> <li>Nichols: Social Entrepreneurship - Oxford University Press 1. Auflage 2008</li> <li>Bessant &amp; Tidd: Innovation and Entrepreneurship - Wiley-Verlag 2. Auflage 2013</li> <li>Fisch &amp; Roß: Fallstudien zum Innovationsmanagement - Gabler-Verlag 1. Auflage 2009</li> <li>Bessant &amp; Tidd: Managing Innovation: Integrating Technological, Market and Organizational Change - Wiley-Verlag: 5. Auflage 2013</li> </ul>				
Language:				
Notes:				



Prerequisites for attending the module: - none

Prerequisites for participation in module exam(s):

- none

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

Module exam(s):

- EC4008-L1: Entrepreneurship and Innovation, portfolio exam, 100% of module grade

The portfolio exam consists of the following:

- Individual written assignment, 15 %

- Group work (Presentation), 45 %

- (Online)exams, 40 %

The commercial rounding is used to determine the overall grade.

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

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

(Is equal to EC4008 T-KP04) (Replaces PS5830-KP04)



EC4010-KP04, EC4010 - Commercial Law (WirtRecht)					
Duration:	Turnus of offer:		Credit points:		
1 Semester	each summer semester		4		
Course of study, specific field and term Master Computer Science 2019 (c Master Entrepreneurship in Digit. Master Medical Informatics 2019 Master Interdisciplinary Courses (c Master MES 2014 (optional subje Bachelor MES 2014 (optional subje Master Medical Informatics 2014 Master Computer Science 2014 (c Master Entrepreneurship in Digit	n: optional subject), interdisciplin al Technologies 2020 (optional (optional subject), interdiscipli optional subject), Interdisciplin ct), no specific field, Arbitrary s ject), no specific field, 3rd sem (optional subject), interdisciplin optional subject), interdisciplin al Technologies 2014 (optional	ary competence, Arbitrary I subject), interdisciplinary inary competence, 1st or 2 nary modules, Arbitrary ser semester ester at the earliest inary competence, 1st or 2 nary competence, Arbitrary I subject), interdisciplinary	semester competence, Arbitrary semester nd semester mester nd semester semester competence, Arbitrary semester		
Classes and lectures:		Workload:			
<ul> <li>Commercial Law (lecture, 2 SWS)</li> <li>Commercial Law (exercise, 1 SWS)</li> </ul>	j)	<ul><li>60 Hours private</li><li>45 Hours in-class</li><li>15 Hours exam p</li></ul>	studies sroom work preparation		
<ul> <li>Contents or teaching:</li> <li>The importance of legal aspects in entrepreneurship especially in the high-tech sector</li> <li>legal acts</li> <li>contract law</li> <li>technology protection and intellectual property (know how, patents, trademarks, designs, with license rights)</li> <li>labor law</li> <li>corporate law</li> <li>enforcement of legal claims</li> </ul>					
<ul> <li>Qualification-goals/Competencies:</li> <li>The objective of the course is to provide students with a basic knowledge of legal subjects relevant for scientists, medical doctors, engineers and computer scientists in technology-driven enterprises or in research at a university.</li> <li>Students will gain an understanding of legal reasoning to help them avoid pitfalls and exploit to the fullest extent opportunities in R&amp;E projects and startup companies.</li> </ul>					
Grading through: • written exam					
Responsible for this module: • Prof. Dr. Christian Scheiner Teacher: • Institute for Entrepreneurship and Business Development • Dr. Carsten Richter					
Literature: • Carsten Richter: Kurshandout • Ann/Hauck/Obergfell: Wirtschaftsrecht kompakt - München 2012 • Meyer: Wirtschaftsprivatrecht - Heidelberg 2012 • -: BGB Bürgerliches Gesetzbuch - Beck-Texte, neuste Auflage • Schönfelder: Deutsche Gesetze Textsammlung - neuste Auflage					
Language: • offered only in German	Language: <ul> <li>offered only in German</li> </ul>				
Notes:					



Prerequisites for attending the module: - none

Prerequisites for participation in module exam(s):

- none

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

Module exam(s):

- EC4010-L1: Commercial Law, written exam, 60 min, 100 % of module grade



PS5810-KP04, PS5810 - Scientific Teaching and Tutoring (WLehrKP04)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	irregularly		4 (Тур В)	
Semester       4 (1yp B)         Course of study, specific field and term:       Bachelor Interdisciplinary Courses for health sciences (optional subject), interdisciplinary competence, Arbitrary semester         Master Computer Science 2019 (optional subject), interdisciplinary competence, Arbitrary semester         Master Entrepreneurship in Digital Technologies 2020 (optional subject), interdisciplinary competence, Arbitrary semester         Master Interdisciplinary Courses (optional subject), Interdisciplinary modules, Arbitrary semester         Bachelor Interdisciplinary Courses (optional subject), Interdisciplinary modules, Arbitrary semester         Bachelor Interdisciplinary Courses (optional subject), Interdisciplinary modules, Arbitrary semester         Master CLS 2016 (optional subject), Interdisciplinary modules, 3rd semester         Master Entrepreneurship in Digital Technologies 2014 (optional subject), interdisciplinary competence, Arbitrary semester         Master Entrepreneurship in Digital Technologies 2014 (optional subject), interdisciplinary competence, Arbitrary semester         Master Entrepreneurship in Digital Technologies 2014 (optional subject), interdisciplinary competence, Arbitrary semester         Master Media Informatics 2014 (optional subject), interdisciplinary competence, Arbitrary semester         Bachelor MES 2014 (optional subject), no specific field, 1st or 2nd semester         Bachelor MES 2014 (optional subject), no specific field, Arbitrary semester         Master CLS 2010 (optional subject), interdisciplinary competence, Arbitrary semester				
Classes and lectures:		Workload:		
<ul> <li>Theory and Practice of Good Teaching (seminar, 1 SWS)</li> <li>Work as a tutor in a lecture (practical course, 2 SWS)</li> <li>Work as a tutor in a lecture (practical course, 2 SWS)</li> <li>15 Hours in-classroom work</li> </ul>		studies and exercises esentation (including preparation) sroom work		
<ul> <li>Contents of teaching:</li> <li>Organizing and running a scientific</li> <li>Basic didactics of scientific teaching</li> <li>Practical work in tutorials</li> </ul>	lecture			
Qualification-goals/Competencies: <ul> <li>The participants are able to lead a st</li> <li>Basic pedagogical and didactical ski</li> </ul>	udent working group and lls	to communicate technical	issues to it appropriately.	
Grading through:				
continuous participation in all course	es of the module			
<ul> <li>Responsible for this module:</li> <li>Prof. Dr. rer. nat. Nico Bunzeck</li> <li>Prof. Dr. rer. nat. Jürgen Prestin</li> </ul> Teacher: <ul> <li>Institute for Mathematics</li> <li>PD Dr. rer. nat. Jörn Schnieder</li> <li>Alle prüfungsberechtigten Dozentinnen/Dozenten des Studienganges</li> <li>Corinna Lütsch</li> </ul>				
Language:				
depends on the chosen courses				
Notes: The seminar must be attended before The course instructor in charge of the	working as a tutor. This ac	tivity cannot be remunerate	ed. nt for the module.	



CS4130-KP06, CS4130 - Information Systems (InfoSys)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each summer semester		6	
Course of study, specific field and a Master Computer Science 201 Master Entrepreneurship in D Master Media Informatics 202 Master Computer Science 201 Master Medical Informatics 202 Master Robotics and Autonor Master Robotics and Autonor Master IT-Security 2019 (basic Master Medical Informatics 201 Master Media Informatics 201 Master Entrepreneurship in D Master Computer Science 201 Master Computer Science 201	serm: 9 (compulsory), Canonical Speciali igital Technologies 2020 (basic mo 0 (optional subject), computer scie 9 (basic module), Applied comput nous Systems 2019 (optional subje module), Applied computer scien 014 (basic module), ehealth / infor 4 (optional subject), computer scie igital Technologies 2014 (basic mo 4 (optional subject), specialization 4 (basic module), Applied comput	ization Data Science and idule), Applied computer ence, Arbitrary semester er science, 1st or 2nd ser uter science, 1st or 2nd se ect), Elective, 1st or 2nd se ce, 1st or 2nd semester natics, 1st or 2nd semester dule), Applied computer field software systems e er science, 1st or 2nd ser	l Al, Arbitrary semester r science, 1st or 2nd semester mester emester semester er r science, 1st or 2nd semester engineering, 2nd or 3rd semester mester	
Classes and lectures:		Workload:		
<ul> <li>Information Systems (lecture,</li> <li>Information Systems (exercise</li> </ul>	2 SWS) 2, 2 SWS)	<ul><li>100 Hours priva</li><li>60 Hours in-clas</li><li>20 Hours exam</li></ul>	ate studies ssroom work preparation	
<ul> <li>Motivation of knowledge gra</li> <li>Overview over the W3C Sema</li> <li>Comparison between and the</li> <li>Graph Neural Networks and t</li> </ul>	phs and their relationship to the Se Intic Web family of languages Interaction of knowledge graphs heir applications for tasks of know	emantic Web and generative artificial ledge graphs	intelligence such as large language models	
<ul> <li>Qualification-goals/Competencies:</li> <li>Knowledge: Students acquire an overview of knowledge graphs and the Semantic Web as well as generative artificial intelligence such as large language models and graph neural networks.</li> <li>Skills: Students can assess the possibilities and limitations of knowledge graphs and the Semantic Web. They can estimate the consequences of the Semantic Web approach for data modeling, data administration and processing and for applications. They can develop Semantic Web applications. They can use generative artificial intelligence such as large language models and graph neural networks to solve tasks for and in addition to knowledge graphs. They can discuss open research questions in the area of knowledge graphs and the semantic web as well as in comparison to generative artificial intelligence and graph neural networks.</li> <li>Social skills and independence: Students work in groups to complete exercises and small projects. Students' independent practical work is encouraged through exercises, some of them directly on the computer.</li> </ul>				
Grading through:				
Written or oral exam as anno	unced by the examiner			
Responsible for this module: • Prof. Dr. Sven Groppe Teacher: • Institute of Information Syster • Prof. Dr. Sven Groppe	ms			
Literature: • M. Kejriwal, C. Knoblock: Knov • S. Groppe: Data Management • W. L. Hamilton: Graph Repres International Publishing, 2020 • D. Jurafsky, J. H. Martin: Speed • D. Foster: Generative deep lea	wledge graphs - MIT Press, 2021 and Query Processing in Semantic entation Learning. In Synthesis Lec ) ch and language processing - Uppo arning - Sebastopol, CA: O Reilly N	c Web Databases - Spring ctures on Artificial Intellig er Saddle River, NJ: Pears Iedia, 2023	ger, 2011 gence and Machine Learning - Springer son, 2008	



### Language:

• German and English skills required

### Notes:

Admission requirements for taking the module:

- None

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

Module Exam(s):

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

Previous name: Web Based Information Systems





CS4150-K	CS4150-KP06, CS4150SJ14 - Distributed Systems (VertSys14)				
Duration:	Turnus of offer:		Credit points:		
1 Semester	each winter semester		6		
Course of study, specific field and term: Master Computer Science 2019 (comp Master Entrepreneurship in Digital Tea Master Media Informatics 2020 (option Master Computer Science 2019 (basic Master Medical Informatics 2019 (basi Master Robotics and Autonomous Sys Master IT-Security 2019 (basic module Master Medical Informatics 2014 (basi Master Medical Informatics 2014 (option Master Entrepreneurship in Digital Tea Master Computer Science 2014 (option Master Computer Science 2014 (basic	pulsory), Canonical Special chnologies 2020 (basic mo nal subject), computer scie module), Applied comput c module), Applied comput tems 2019 (optional subje c), Applied computer scien c module), ehealth / infon nal subject), computer scie chnologies 2014 (basic mo nal subject), specializatior module), Applied comput	ization SSE, Arbitrary seme odule), Applied computer s ence, Arbitrary semester ter science, 1st or 2nd seme ect), Elective, 1st or 2nd ser face, 1st or 2nd semester natics, 1st or 2nd semester ence, Arbitrary semester odule), Applied computer s n field software systems en ter science, 1st or 2nd seme	ister cience, 1st or 2nd semester ester nester nester cience, 1st or 2nd semester gineering, 2nd or 3rd semester ester		
Classes and lectures:		Workload:			
<ul> <li>Distributed Systems (lecture, 2 SWS)</li> <li>Distributed Systems (exercise, 2 SWS)</li> </ul>		<ul> <li>60 Hours in-class</li> <li>60 Hours private</li> <li>40 Hours e-learni</li> <li>20 Hours exam p</li> </ul>	room work studies ng reparation		
<ul> <li>Protocols and layered models</li> <li>Message representations</li> <li>Realization of network services</li> <li>Communication mechanisms</li> <li>Addresses, names and directory service</li> <li>Synchronisation</li> <li>Replication and consistency</li> <li>Fault tolerance</li> <li>Distributed transactions</li> <li>Security</li> </ul>	ces				
<ul> <li>Qualification-goals/Competencies:</li> <li>The participants will accquire a deep thandling, naming etc.</li> <li>They know the most important service</li> <li>They are able to program simple distribution.</li> <li>They know the most important algorithmutual exclsuion.</li> <li>They have a good feeling for when it</li> <li>They have a good feeling for what king</li> </ul>	understanding for probler es in distributed systems s ibuted applications and sy thms in distributed systen makes sense to use distrib id of solutions could best	ns to be solved in distribut such as name service, distri ystems themselves. ns, for instance for time syr puted instead of centralized be used for what kind of pi	ed systems, such as synchronization, error buted file systems etc. nchronization, for leader election, or for d systems. roblems in distributed Internet applications.		
Grading through: • written exam					
Responsible for this module: • Prof. Dr. Stefan Fischer Teacher: • Institute of Telematics • Prof. Dr. Stefan Fischer • Dr. rer. nat. Florian-Lennert Lau					



<ul> <li>Literature:</li> <li>A. Tanenbaum, M. van Steen: Distributed Systems: Principles and Paradigms - Prentice Hall 2006</li> <li>G. Coulouris, J. Dollimore, T. Kindberg, G. Blair: Distributed Systems - Concepts and Design - Addison Wesley 2012</li> </ul>	
Language: • offered only in German	
Notes: Admission requirements for taking the module: - None Admission requirements for participation in module examination(s): - None Module Exam(s):	



CS4000-KP06, CS4000SJ14 - Algorithmics (ALG14)					
Duration:	Turnus of offer:		Credit points:		
1 Semester	each winter semester		6		
<ul> <li>Course of study, specific field and term:</li> <li>Master Computer Science 2019 (compulsory), Canonical Specialization Data Science and AI, Arbitrary semester</li> <li>Master Computer Science 2019 (compulsory), Canonical Specialization Bioinformatics and Systems Biology, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2020 (advanced module), specific, Arbitrary semester</li> <li>Master Computer Science 2019 (basic module), Theoretical computer science, 1st or 2nd semester</li> <li>Master Medical Informatics 2019 (optional subject), Theoretical computer science, 1st or 2nd semester</li> <li>Master IT-Security 2019 (compulsory), Theoretical computer science, 1st or 2nd semester</li> <li>Master Medical Informatics 2014 (basic module), computer science, 1st or 2nd semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (basic module), technology field computer science, 1st or 2nd semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (basic module), technology field computer science, 1st or 2nd semester</li> <li>Master Computer Science 2014 (optional subject), specialization field IT security and safety, 2nd or 3rd semester</li> <li>Master Computer Science 2014 (basic module), Theoretical computer science, 1st or 2nd semester</li> </ul>					
Classes and lectures:		Workload:			
<ul> <li>Algorithmics (lecture, 2 SWS)</li> <li>Algorithmics (exercise, 2 SWS)</li> </ul>		<ul> <li>100 Hours private</li> <li>60 Hours in-class</li> <li>20 Hours exam p</li> </ul>	e studies and exercises room work reparation		
Contents of teaching: • complexity analysis of algorithmic problems • discrete optimization problems, linear programming • satisfiability and constraint satisfaction problems • randomized algorithms • approximation algorithms and heuristics • algorithms for algebraic problems					
<ul> <li>The students can model real problem</li> <li>They can apply basic algorithmic tect</li> <li>They can analyze algorithms, in parties</li> <li>They can design efficient algorithms</li> </ul>	<ul> <li>Qualification-goals/Competencies:</li> <li>The students can model real problems in an algorithmic manner.</li> <li>They can apply basic algorithmic techniques with full command.</li> <li>They can analyze algorithms, in particular with respect to corrrectness and complexity.</li> <li>They can design efficient algorithms for complex problems.</li> </ul>				
Grading through: • written exam					
Requires: • Theoretical Computer Science (CS20) • Algorithm Design (CS3000-KP04, CS3	Requires: • Theoretical Computer Science (CS2000-KP08, CS2000) • Algorithm Design (CS3000-KP04, CS3000)				
Responsible for this module: • Prof. Dr. Rüdiger Reischuk Teacher: • Institute for Theoretical Computer Sc • Prof. Dr. Rüdiger Reischuk • Prof. Dr. rer. nat. Till Tantau • Prof. Dr. Maciej Liskiewicz Literature: • Aho, Hopcroft, Ullman: Design and A	ience nalysis of Computer Algor	ithms - Addison Wesley, 19	78		
<ul> <li>Cormen, Leiserson, Rivest, Stein: Intra</li> <li>Mitzenmacher, Upfal: Probability and</li> <li>Kreher, Stinson: Combinatorial Algor</li> <li>Williamson, Shmoys: The Design of A</li> </ul>	oduction to Algorithms - T I Computing - Cambridge ithms - CRC Press, 1999 approximation Algorithms	ne MII Press, 2009 University Press, 2005 - Cambridge University Pres	ss, 2011		



### Language:

# German and English skills required

### Notes:

Admission requirements for taking the module:

- None (the competencies of the modules listed under

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CS4020-KP06, CS4020SJ14 - Specification and Modelling (SpezMod14)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each summer semester		6	
Course of study, specific field a Master Media Informatics Master Entrepreneurship Master Computer Science Master Medical Informatio Master IT-Security 2019 (c Master Medical Informatics Master Media Informatics Master Entrepreneurship Master Computer Science Master Computer Science	nd term: 2020 (optional subject), computer so in Digital Technologies 2020 (advance 2019 (basic module), Theoretical con compulsory), Theoretical computer so compulsory), Theoretical computer so 2014 (basic module), computer so 2014 (optional subject), computer so in Digital Technologies 2014 (basic m 2014 (optional subject), specialization 2014 (basic module), Theoretical com	cience, 3rd semester red module), specific, Arbitra mputer science, 1st or 2nd s l computer science, 1st or 2 cience, 1st or 2nd semester ence, 1st or 2nd semester cience, Arbitrary semester nodule), technology field co on field IT security and safet mputer science, 1st or 2nd s	ary semester emester nd semester mputer science, 1st or 2nd semester y, 2nd or 3rd semester emester	
Classes and lectures:		Workload:		
<ul> <li>Specification and Modelli</li> <li>Specification and Modelli</li> </ul>	ng (lecture, 2 SWS) ng (exercise, 2 SWS)	<ul> <li>80 Hours private</li> <li>60 Hours in-class</li> <li>20 Hours exam p</li> <li>20 Hours work or</li> </ul>	studies and exercises room work reparation n project	
Contents of teaching:				
<ul> <li>Introduction to modelling</li> <li>Modelling concepts (data</li> <li>Modelling software comp</li> <li>Modelling concurrency</li> <li>Algebraic specification</li> <li>Composing, refining, ana</li> <li>Specification languages a</li> </ul>	<ul> <li>Introduction to modelling and specification</li> <li>Modelling concepts (data, streams, traces, diagrams, tables)</li> <li>Modelling software components (state, behaviour, structure, interface)</li> <li>Modelling concurrency</li> <li>Algebraic specification</li> <li>Composing, refining, analysing and transforming specifications and models</li> <li>Specification languages and tools for specification and modelling</li> </ul>			
Qualification-goals/Competend The students can argue of They can characterize, ap They can model and speci They can describe a syste They can apply specificat They can analyse specific	<b>:ies:</b> In the importance of specifications ar ply, adapt and extent important spec ify simple software/hardware system m from different views and on differe ions and modelsin software develops ations and models.	nd models for software deve cification and modelling tech i in an adequate way. ent levels of abstraction. ment.	lopment. hniques.	
Grading through: • Written or oral exam as a	nnounced by the examiner			
Responsible for this module: • Prof. Dr. Martin Leucker Teacher: • Institute of Software Tech • Dr. Annette Stümpel • Prof. Dr. Martin Leucker	nology and Programming Language	s		
Literature:				
<ul> <li>V.S. Alagar, K. Periyasamy</li> <li>M. Broy, K. Stølen: Specifi</li> <li>J. Loeckx, HD. Ehrich, M.</li> <li>D. Bjorner: Software Engii</li> <li>U. Kastens, H. Kleine Büni</li> </ul>	: Specification of Software Systems - cation and Development of Interactiv Wolf: Specification of Abstract Data nneering 1-3 - Springer 2006 ng: Modellierung - Grundlagen und f	Springer 2013 /e Systems - Springer 2001 Types - John Wiley & Sons 1 Formale Methoden - Hanser	997 2005	



### Language:

### • German and English skills required

### Notes:

Admission requirements for taking the module:

- None

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

Module Examination(s):

- CS4020-L1: Specification and Modeling, written exam, 90min, 100% of the module grade.



CS4160-KP06, CS4160SJ14 - Real-Time Systems (Echtzeit14)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each summer semester		6	
Course of study, specific field and terr Master MES 2020 (optional subje Master Entrepreneurship in Digit Master Media Informatics 2020 ( Master Computer Science 2019 ( Master Medical Informatics 2019) Master IT-Security 2019 (basic m Master MES 2014 (optional subje Master Medical Informatics 2014 ( Master Media Informatics 2014 ( Master Entrepreneurship in Digit Master Computer Science 2014 (	n: ect), computer science / electric cal Technologies 2020 (advance optional subject), computer sc basic module), technical comp (optional subject), technical co odule), technical computer sci ect), computer science / electric (basic module), computer sci optional subject), computer sc cal Technologies 2014 (basic m basic module), technical comp	cal engineering, Arbitrary se ed module), specific, Arbitra ience, Arbitrary semester outer science, 1st or 2nd ser omputer science, 1st or 2nd ence, 1st or 2nd semester cal engineering, 1st semester sence, 1st or 2nd semester ience, Arbitrary semester odule), specific, 1st or 2nd se outer science, 1st or 2nd se	emester ary semester nester d semester er semester nester	
Classes and lectures:		Workload:		
<ul> <li>Real-Time Systems (lecture, 2 SW</li> <li>Real-Time Systems (exercise, 2 SW</li> </ul>	/S) WS)	<ul> <li>100 Hours privat</li> <li>60 Hours in-class</li> <li>20 Hours exam p</li> </ul>	e studies room work reparation	
Contents of teaching: • Real-time processing (definitions • Process automation systems • Real-time programming • Process connectivity and networ • Modelling of discrete event system • Modelling of continuous system • Application of design tools (Mat	s, requirements) king ems (automata, state charts) s (differential equations, Lapla lab/Simulink, Stateflow)	ce transformation)		
Qualification-goals/Competencies: <ul> <li>The students are able to describ.</li> <li>They are able to explain real-tim.</li> <li>They are able to program real-tim.</li> <li>They are able to elucidate proce.</li> <li>They are able to model, analyze.</li> <li>They are able to make use of describered.</li> </ul>	e the fundamental problems o e computer systems for proces me systems in the IEC languag ss interfaces and real-time bus and implement event discrete and implement continuous systems	f real-time processing. ss automation, in particular es. system. systems, in particular proce stems, in particular feedbac s.	SPS. ess control systems. k control systems.	
Grading through: • written exam				
Responsible for this module: • Prof. DrIng. Mladen Berekovic Teacher: • Institute of Computer Engineerir • Prof. DrIng. Mladen Berekovic	ng			
Literatura				
<ul> <li>R. C. Dorf, R. H. Bishop: Modern G</li> <li>L. Litz: Grundlagen der Automati</li> <li>M. Seitz: Speicherprogrammierb</li> <li>H. Wörn, U. Brinkschulte: Echtzei</li> <li>S. Zacher, M. Reuter: Regelungst</li> </ul>	Control Systems - Prentice Hall isierungstechnik - Oldenbourg are Steuerungen - Fachbuchve tsysteme - Berlin: Springer 200 echnik für Ingenieure - Springe	2010 2012 rrlag Leipzig 2012 5 er-Vieweg 2014		



### Language:

### • offered only in English

### Notes:

Admission requirements for taking the module: - None

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

### Module Exam(s):

- CS4160-L1: Real-Time Systems, written exam, 90min, 100% of the module grade



CS4170-KP06, CS4170SJ14 - Parallel Computer Systems (ParaRSys14)			
Duration:	Turnus of offer:	Credit points:	
1 Semester	r each winter semester 6		
Course of study, specific field and term: • Certificate in Artificial Intelligence (a • Master Entrepreneurship in Digital • Master Computer Science 2019 (base • Master Medical Informatics 2019 (op • Master Robotics and Autonomous S • Master IT-Security 2019 (basic mode • Master Medical Informatics 2014 (base • Master Entrepreneurship in Digital • Master Computer Science 2014 (base	compulsory), Artificial Intelli Fechnologies 2020 (advance ic module), technical comp otional subject), technical co ystems 2019 (optional subj ule), technical computer scie asic module), computer scie Fechnologies 2014 (basic m ic module), technical comp	gence, 1st semester ed module), specific, Arbitrary semester uter science, 1st or 2nd semester omputer science, 1st or 2nd semester ect), Elective, 1st or 2nd semester ence, 1st or 2nd semester ence, 1st or 2nd semester odule), specific, 1st or 2nd semester uter science, 1st or 2nd semester	
Classes and lectures:		Workload:	
<ul> <li>Parallel Computer Systems (lecture,</li> <li>Parallel Computer Systems (exercise)</li> </ul>	ercise, 2 SWS) ercise, 2 SWS) • 100 Hours private studies • 60 Hours in-classroom work • 20 Hours exam preparation		
Contents of teaching:			
<ul> <li>Parallel computing models</li> <li>Taxonomy of parallel computers</li> <li>Multi/manycore-systems</li> <li>Graphic Processing Units (GPUs)</li> <li>OpenCL</li> <li>Specification languages</li> <li>Hardware architectures</li> <li>System management of many-core</li> </ul>	systems		
<ul> <li>Qualification-goals/Competencies:</li> <li>Students are able to characterize di</li> <li>They are able to explain models of</li> <li>They are able to make use of comm</li> <li>They are able to judge which kind of used.</li> <li>They are able to evaluate the pros a</li> <li>They are able to write programs for</li> <li>They are able to compare methods</li> </ul>	fferent parallel computing a parallel computing. Ion programming interfaces of parallel computing syster and cons of different hardw parallel computing system for dynamic voltage and fre	architectures. s for parallel computing systems. n is best suited for a dedicated problem and how many cores should be are architectures. s under considerations of the underlying hardware architecture. equency scaling (DVFS) for manycore systems.	
Grading through:			
Responsible for this module: <ul> <li>Prof. DrIng. Mladen Berekovic</li> </ul> <li>Teacher: <ul> <li>Institute of Computer Engineering</li> <li>Prof. DrIng. Mladen Berekovic</li> </ul> </li>			
l iterature:			
<ul> <li>G. Bengel, C. Baun, M. Kunze, K. U. S</li> <li>M. Dubois, M. Annavaram, P. Stenst</li> <li>B. R. Gaster, L. Howes, D. R. Kaeli, P.</li> <li>B. Wilkinson; M. Allen: Parallel Progra</li> <li>J. Jeffers, J. Reinders: Intel Xeon Phi</li> </ul>	tucky: Masterkurs Parallele röm: Parallel Computer Org Mistry, D. Schaa: Heteroger ramming - Englewood Cliffs Coprozessor High-Performa	und Verteilte Systeme - Vieweg + Teubner, 2008 anization and Design - University Press 2012 neous Computing with OpenCL - Elsevier/Morgan Kaufman 2013 : Pearson 2005 ance Programming - Elsevier/Morgan Kaufman 2013	



# D. A. Patterson, J. L. Hennessy: Computer Organization and Design - Morgan Kaufmann, 2013 Language: offered only in German Notes: Admission requirements for taking the module: None Admission requirements for participation in module examination(s): Successful completion of exercise assignments as specified at the beginning of the semester Module Exam(s): CS4170-L1: Parallel Computer Systems, oral exam, 100% of the module grade



CS5990-KP30, CS5990 - Master Thesis Computer Science (MasterInf)					
Duration:	Turnus of offer:		Credit points:		
1 Semester	each semester		30		
<ul> <li>Course of study, specific field and term:</li> <li>Master Computer Science 2019 (compulsory), computer science, 4th semester</li> <li>Master Computer Science 2014 (compulsory), computer science, 4th semester</li> <li>Master Computer Science 2012 (compulsory), computer science, 4th semester</li> </ul>					
<ul> <li>Classes and lectures:</li> <li>Master's Thesis (supervised self studies, 1 SWS)</li> <li>Colloquium (colloquium, 1 SWS)</li> </ul>		<ul> <li>Workload:</li> <li>870 Hours research for and write up of a thesis</li> <li>30 Hours oral presentation and discussion (including preparation)</li> </ul>			
Contents of teaching: • individual studies under su	pervision				
<ul> <li>Qualification-goals/Competencies:</li> <li>The students are able to structure a comprehensive and complex problem from the field of computer sciece or its applications and to solve it within limited time.</li> <li>They are able to get acquainted with a problem int he field of computer science in a detailed way, to analyse corresponding literature, to work out a solution and to document the solution in a written thesis.</li> <li>They can evaluate their solution critically and present it in a talk and defend it in a scientific discussion.</li> </ul>					
<ul> <li>oral presentation</li> <li>Written report</li> </ul>					
Responsible for this module: • Studiengangsleitung Infor Teacher: • Institutes of the Departmer • Alle prüfungsberechtigter	rmatik nt of Computer Science/ Engineer n Dozentinnen/Dozenten des Stur	ring dienganges			
Literature: • links will be given by the s	upervisor:				
Language: • thesis can be written in German or English					
Notes: requirements for starting a m	aster's thesis see Academic Regu	lations and Procedures f	or Students, e.g. at least 75 credit points		



CS3110 T - Module part: Computer-Aided Design of Digital Circuits (SchaltEnta)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	semester each winter semester		4	
<ul> <li>Course of study, specific field and term:</li> <li>Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester</li> <li>Master IT-Security 2019 (module part), Module part, 1st or 2nd semester</li> <li>Master Computer Science 2019 (module part), Module part, Arbitrary semester</li> </ul>				
Classes and lectures: Workload:				
<ul> <li>Computer-Aided Design of Digital Ci</li> <li>Computer-Aided Design of Digital Ci</li> </ul>	rcuits (lecture, 2 SWS) rcuits (exercise, 1 SWS)	<ul> <li>55 Hours private studies</li> <li>45 Hours in-classroom work</li> <li>20 Hours exam preparation</li> </ul>		
Contents of teaching:				
<ul> <li>Abstraction levels in circuit design</li> <li>Design cycle and design strategies</li> <li>FPGA architectures</li> <li>Introduction of the hardware description language VHDL</li> <li>Design of standard components in VHDL</li> <li>Circuit design at different abstraction levels</li> <li>Circuit design for synthesis</li> <li>VHDL simulation cycle</li> <li>VHDL circuit design for FPGAs</li> <li>Designing Testbenches</li> <li>High-Level-Synthesis</li> </ul>				
<ul> <li>Qualification-goals/Competencies:</li> <li>Based on a non-formal description of a digital system, students are able to design digital circuits using VHDL</li> <li>They are able to simulate and test VHDL descriptions</li> <li>They are able to explain the internal structures of FPGAs</li> <li>They are able to determine which VHDL construct will result in which circuit structure</li> <li>They are able to explain the VHDL simulation cycle</li> <li>They are able to write synthesizable VHDL code</li> </ul>				
Grading through: <ul> <li>exam type depends on main module</li> </ul>				
Responsible for this module: • Prof. DrIng. Mladen Berekovic Teacher: • Institute of Computer Engineering • Prof. DrIng. Mladen Berekovic				
Literature:				
<ul> <li>F. Kesel, R. Bartholomä: Entwurf von digitalen Schaltungen und Systemen mit HDLs und FPGAs - Oldenbour Verlag 2009</li> <li>C.Maxfield: The Design Warrior's Guide to FPGAs - Newnes 2004</li> </ul>				
<ul><li>Language:</li><li>English, except in case of only German-speaking participants</li></ul>				
Notes:				
Admission requirements for taking the module: - None				



CS4138 T - Module part: Model Checking (ModelCha14)				
Duration:	ration: Turnus of offer:			
1 Semester	each winter semester	6		
Course of study, specific fie Master Computer Scie Master MES 2020 (mo Master Entrepreneurs Master Entrepreneurs Master MES 2014 (mo Master Computer Scie	eld and term: ence 2019 (module part), Module part, odule part), computer science / electrica hip in Digital Technologies 2020 (mod hip in Digital Technologies 2014 (mod odule part), computer science / electrica ence 2014 (Module part of a compulso	Arbitrary semester al engineering, Arbitrary semester ule part), Module part, Arbitrary semester ule part), Module part, Arbitrary semester al engineering, 1st semester ry module), Module part, Arbitrary semester		
Classes and lectures:		Workload:		
<ul><li>Model Checking (lect</li><li>Model Checking (exercise)</li></ul>	Checking (lecture, 3 SWS)• 100 Hours private studies and exercisesI Checking (exercise, 1 SWS)• 60 Hours in-classroom work• 20 Hours exam preparation			
Analysis and verificati     Basic techniques for r     Advanced techniques      Qualification-goals/Compe     The students can des     They can construct a	tencies systems ion techniques for software systems model checking s for model checking tencies: cribe and compare analysis and verifications of compare analysis analysis analysis anad	ation techniques.		
<ul> <li>They can construct, analyse and evaluate specifications of correctness and safety properties.</li> <li>They can characterize different system models and can formally represent systems in suitable models.</li> <li>They can illustrate different techniques for model checking hardware and software systems and can select and apply suitable techniques.</li> <li>They can explain the structure of model checkers and can use model checkers.</li> <li>They can evaluate the possibilities and limitations of model checking.</li> </ul>				
Grading through:				
<ul> <li>exam type depends or</li> </ul>	on main module			
Responsible for this modul <ul> <li>Siehe Hauptmodul</li> </ul> Teacher: <ul> <li>Institute of Software 1</li> <li>Prof. Dr. Martin Leuck</li> </ul>	e: Fechnology and Programming Languag	ges		
Literature:				
• C. Baier, JP. Katoen:	Principles of Model Checking - MIT Pre	ss, 2008		
Language: • English, except in cas	e of only German-speaking participant	S		
Notes:				



(Is equal to CS4138SJ14) (Part of Module CS4507)

Prerequisites for attending the module: - None

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



CS4139 T - Module part: Runtime Verification and Testing (RVTestena)					
Duration:	Turnus of offer:		Credit points:		
1 Semester	each summer semester		6		
<ul> <li>Course of study, specific field and term:</li> <li>Master Computer Science 2019 (module part), Module part, Arbitrary semester</li> <li>Master MES 2020 (module part), computer science / electrical engineering, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> <li>Master MES 2014 (module part), computer science / electrical engineering, 2nd semester</li> <li>Master Computer Science 2014 (Module part of a compulsory module), Module part, Arbitrary semester</li> </ul>					
Classes and lectures:       Workload:         • Runtime Verification and Testing (lecture, 3 SWS)       • 100 Hours private studies and exercises         • Runtime Verification and Testing (exercise, 1 SWS)       • 60 Hours in-classroom work			e studies and exercises room work		
		20 Hours exam p	reparation		
Contents of teaching: <ul> <li>Quality aspects of software systems</li> <li>Analysis and verification techniques for software systems</li> <li>Testing levels</li> <li>Testing process</li> <li>Kinds of tests</li> <li>Test case generation</li> <li>Specification of correctness properties</li> <li>synthesis of monitors for the observation of software systems</li> <li>diagnosis of errors in software systems</li> </ul>					
<ul> <li>Qualification-goals/Competencies:</li> <li>The students can describe and compare analysis and verification techniques.</li> <li>They can construct, analyse and evaluate specifications of correctness and safety properties.</li> <li>They can illustrate different techniques for testing hardware and software systems and can select and apply suitable techniques.</li> <li>They can explain the operation process of test case generation tools and can clasify suitable applications.</li> <li>They can describe and apply techniques for the synthesis of monitors.</li> <li>With the acquired techniques they can develop software of higher quality.</li> </ul>					
Grading through: <ul> <li>exam type depends on main module</li> </ul>					
Responsible for this module: <ul> <li>Siehe Hauptmodul</li> </ul> Teacher: <ul> <li>Institute of Software Technology and Programming Languages</li> <li>Prof. Dr. Martin Leucker</li> </ul>					
<ul> <li>Literature:</li> <li>G.J. Myers: The Art of Software Testing - John Wiley, 1979</li> <li>B. Beizer: Software Testing Techniques - Van Nostrand Reinhold, 1999</li> <li>M. Broy, B. Jonsson, JP. Katoen, M. Leucker, A. Pretschner: Model-Based Testing of Reactive Systems - Springer, 2005</li> <li>A. Bauer, M. Leucker, C. Schallhart: Runtime Verification for LTL and TLTL - ACM TOSEM, 2011</li> <li>C. Baier, JP. Katoen: Principles of Model Checking - MIT Press, 2008</li> <li>D. Peled: Software Reliability Methods - Springer, 2001</li> </ul>					
English, except in case of only German-speaking participants					



### Notes:

(Is equal to CS4139) (Part of Module CS4507)

Prerequisites for attending the module: - None

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



CS4140 T - Module part: Mobile and Distributed Databases (MVDBa)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each winter semester		4	
Course of study, specific field and term: • Master Computer Science 2019 (mo • Master Entrepreneurship in Digital T • Master IT-Security 2019 (module pa • Master Entrepreneurship in Digital T • Master Computer Science 2014 (mo	dule part), Module part, Arl <sup>-</sup> echnologies 2020 (module rt), Module part, 1st or 2nd <sup>-</sup> echnologies 2014 (module dule part), Module part, Arl	pitrary semester part), Module part, Arbitra semester part), Module part, Arbitra pitrary semester	ry semester ry semester	
Classes and lectures:		Workload:		
<ul> <li>Mobile und verteilte Datenbanken</li> <li>Mobile und verteilte Datenbanken</li> </ul>	<ul> <li>Mobile und verteilte Datenbanken (lecture, 2 SWS)</li> <li>Mobile und verteilte Datenbanken (exercise, 1 SWS)</li> <li>45 Hours in-clas</li> <li>10 Hours exam</li> </ul>		studies room work reparation	
Contents of teaching:				
<ul> <li>The contents of the lecture covers query processing, transactions and replication in         <ul> <li>centralised database management systems</li> <li>parallel database management systems</li> <li>distributed database management systems</li> <li>mobile database management systems</li> </ul> </li> <li><b>Qualification-goals/Competencies:</b> <ul> <li>Students can explain the differences between centralised, parallel, distributed and mobile database management systems.</li> <li>They can judge about the practical suitability of different synchronization approaches for distributed and mobile transactions for a given problem.</li> </ul> </li> </ul>				
<ul> <li>They can choose suitable replication approaches for a given application and justify their choices.</li> <li>They can recognize and deal with the special difficulties and sources of error in distributed and mobile environments.</li> </ul> Grading through:				
exam type depends on main modul	e 			
Responsible for this module:         • Siehe Hauptmodul         Teacher:         • Institute of Information Systems         • Prof. Dr. Sven Groppe				
<ul> <li>A. Kemper, A. Eickler: Datenbanksysteme - 2006</li> <li>T. Conolly, C. Begg: Database Systems - A Practical Approach to Design, Implementation, and Management - Addison-Wesley 2005</li> <li>E. Rahm: Mehrrechner-Datenbanksysteme - Addison-Wesley 1994</li> <li>P. Dadam: Verteilte Datenbanken und Client/Server Systeme - Springer 1996</li> <li>H. Höpfner, C. Türker, B. König-Ries: Mobile Datenbanken und Informationssysteme - dpunkt.verlag 2005</li> <li>B. Mutschler, G. Specht: Mobile Datenbanksysteme - Springer 2004</li> <li>V. Kumar: Mobile Database Systems - Wiley-Interscience 2006</li> </ul>				
Language:				
offered only in German				
Notes:				



(Is equal to CS4140) (Is module part of CS4508)

Entry requirements for taking the module: - None

Admission requirements for taking module examination(s): - see higher-level module

Module examination(s): - see superordinate module





CS4151 T - Module part: Architectures for Distributed Applications (SVAa)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	Semester each summer semester			
<ul> <li>Course of study, specific field and term:</li> <li>Master Computer Science 2019 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester</li> <li>Master IT-Security 2019 (module part), Module part, 1st or 2nd semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> <li>Master Computer Science 2014 (module part), Module part, Arbitrary semester</li> </ul>				
Classes and lectures:Workload:• Architectures for Distributed Applications (lecture, 2 SWS)• 45 Hours in-classes• Architectures for Distributed Applications (exercise, 1 SWS)• 45 Hours privat• 30 Hours exam		Workload: • 45 Hours in-class • 45 Hours private • 30 Hours exam p	room work studies reparation	
Contents of teaching: • Motivation • Software Architectures • Basics: HTTP, XML & Co • N-Tier Applications • Service-Oriented and Event-Driven Architectures (SOA and EDA) • Web-Oriented Architectures (Web 2.0) • Overlay Networks • Peer-to-Peer • Grid and Cloud Computing • Internet of Things				
<ul> <li>Qualification-goals/Competencies:</li> <li>The students are able to name the most important archiectures for distributed systems, explain them, and compare them to each other.</li> <li>For each architecture, they know the most prominent and important implementation platforms and basically know how to use them.</li> <li>For a given problem, they can analyze which architecture is best suited to solve it, and they can design a plan for the solution's realization.</li> </ul>				
Grading through: <ul> <li>exam type depends on main module</li> </ul>				
Responsible for this module: • Prof. DrIng Horst Hellbrück Teacher: • Institute of Telematics • Prof. DrIng Horst Hellbrück				
<ul> <li>Literature:</li> <li>J. Dunkel, A. Eberhart, S. Fischer, C. Kleiner, A. Koschel: Systemarchitekturen für verteilte Anwendungen - Hanser-Verlag 2008</li> <li>I. Melzer et.al.: Service-Orientierte Architekturen mit Web Services - Spektrum-Verlag 2010</li> </ul>				
Language: • offered only in German				
Notes:				



IMPORTANT: No longer takes place as a module part of CS4509. Please now pay attention to the modules CS4151 and CS4517!

(Was module part of CS4509) (Is equal to CS4151) (Share of telematics in everything is 100%)

Entry requirements for taking the module: - None

Admission requirements for taking module examination(s): - see higher-level module

Module examination(s): - see superordinate module



CS4220 T - Module part: Pattern Recognition (MEa)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	not available anymore		4	
<ul> <li>Course of study, specific field and term:</li> <li>Master Computer Science 2019 (module part), Module part, Arbitrary semester</li> <li>Master MES 2020 (module part), computer science / electrical engineering, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester</li> <li>Master IT-Security 2019 (module part), Module part, 1st or 2nd semester</li> <li>Master Computer Science 2014 (module part), advanced curriculum, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> <li>Master MES 2014 (module part), computer science / electrical engineering, 1st semester</li> <li>Master Computer Science 2014 (Module part of a compulsory module), specialization field robotics and automation, Arbitrary semester</li> </ul>				
Classes and lectures:		Workload:		
<ul> <li>Pattern Recognition (lecture, 2 SWS)</li> <li>Pattern Recognition (exercise, 1 SWS)</li> </ul>	)	<ul> <li>55 Hours private</li> <li>45 Hours in-classi</li> <li>20 Hours exam private</li> </ul>	studies room work reparation	
Contents of teaching: <ul> <li>Introduction to probability theory</li> <li>Principles of feature extraction and pattern recognition</li> <li>Bayes decision theory</li> <li>Discriminance functions</li> <li>Neyman-Pearson test</li> <li>Receiver Operating Characteristic</li> <li>Parametric and nonparametric density estimation</li> <li>kNN classifiers</li> <li>Linear classifiers</li> <li>Support vector machines and kernel trick</li> <li>Random Forest</li> <li>Neural Nets</li> <li>Feature reduction and feature transforms</li> <li>Validation of classifiers</li> <li>Selected application scenarios: acoustic scene classification for the selection of hearing-aid algorithms, acoustic event recognition, attention classification based on EEG data, speaker and emotion recognition</li> </ul>				
<ul> <li>Students are able to describe the main elements of reature extraction and pattern recognition.</li> <li>They are able to explain the basic elements of statistical modeling.</li> <li>They are able to use feature extraction, feature reduction and pattern classification techniques in practice.</li> </ul>				
Grading through:				
exam type depends on main module				
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				
Language: <ul> <li>offered only in German</li> </ul>				


#### Notes:

Admission requirements for the module:

- None

Admission requirements for the examination:

- Successful completion of the exercises during the semester (at least 50% of the achievable points).

Module Exam:

- CS4220-L1: Pattern Recognition, written exam, 90 min, 100% of module grade.

(Is equal to CS4220SJ14) (Is module part of CS4510, CS4290, CS5274-KP08)



CS4405 T - Module part: NeuroInformatics (NeuroInfa)					
Duration: Turnus of offer: Credit points:			Credit points:		
1 Semester	each summer semester		4		
<ul> <li>Course of study, specific field and term:</li> <li>Master Biophysics 2023 (module part), advanced curriculum, 2nd semester</li> <li>Master Computer Science 2019 (module part), Module part, Arbitrary semester</li> <li>Master MES 2020 (module part), computer science / electrical engineering, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester</li> <li>Master Medical Informatics 2019 (module part), Module part, Arbitrary semester</li> <li>Master Biophysics 2019 (module part), advanced curriculum, 2nd semester</li> <li>Master IT-Security 2019 (module part), Module part, 1st or 2nd semester</li> <li>Master Medical Informatics 2014 (module part). Module part, Arbitrary semester</li> </ul>					
<ul> <li>Master Entrepreneurship in Digital 10</li> <li>Master MES 2014 (module part), com</li> <li>Master Computer Science 2014 (mod</li> </ul>	echnologies 2014 (module iputer science / electrical e Jule part), Module part, Ark	part), Module part, Arbitral ngineering, 2nd semester pitrary semester	ry semester		
Classes and lectures:		Workload:			
<ul> <li>NeuroInformatics (lecture, 2 SWS)</li> <li>NeuroInformatics (exercise, 1 SWS)</li> </ul>		<ul> <li>55 Hours private</li> <li>45 Hours in-class</li> <li>20 Hours exam p</li> </ul>	studies room work reparation		
Contents of teaching:					
<ul> <li>Learning with a single neuron:* Perce</li> <li>Network architectures:* Hopfield-Ne</li> <li>Unxupervised Learning:* k-means, N</li> <li>Qualification-goals/Competencies:</li> <li>The students are able to understand</li> <li>They know abstract neuronal model</li> <li>They are able to derive a learning ru</li> <li>They are able to apply (and implement</li> </ul>	<ul> <li>The human brain and abstract neuron models</li> <li>Learning with a single neuron:* Perceptrons* Max-Margin Classification* LDA and logistic Regression</li> <li>Network architectures:* Hopfield-Networks* Multilayer-Perceptrons* Deep Learning</li> <li>Unxupervised Learning:* k-means, Neural Gas and SOMs* PCA &amp; ICA* Sparse Coding</li> </ul> Qualification-goals/Competencies: <ul> <li>The students are able to understand the principle function of a single neuron and the brain as a whole.</li> <li>They know abstract neuronal models and they are able to name practical applications for the different variants.</li> <li>They are able to derive a learning rule from a given error function.</li> </ul>				
Grading through:					
<ul> <li>exam type depends on main module</li> </ul>	2				
Responsible for this module:					
Siehe Hauptmodul					
• Institute for Neuro- and Bioinformati	cs				
Prof. Dr. rer. nat. Thomas Martinetz					
<ul> <li>Literature:</li> <li>S. Haykin: Neural Networks - London: Prentice Hall, 1999</li> <li>J. Hertz, A. Krogh, R. Palmer: Introduction to the Theory of Neural Computation - Addison Wesley, 1991</li> <li>T. Kohonen: Self-Organizing Maps - Berlin: Springer, 1995</li> <li>H. Ritter, T. Martinetz, K. Schulten: Neuronale Netze: Eine Einführung in die Neuroinformatik selbstorganisierender Netzwerke - Bonn: Addison Wesley, 1991</li> </ul>					
Language: • offered only in German Notes:					



Examination prerequisites can be defined at the beginning of the semester. If prerequisite courses are defined, they must have been completed and positively evaluated before the first examination.

(Is module part of CS4410, CS4511) (Is equal to CS4405)

Admission requirements for the module: - None

Admission requirements for the examination:

- Successful completion of exercises during the semester.

Translated with www.DeepL.com/Translator (free version)





CS4440 T - Module part: Molecular Bioinformatics (MolBioInfa)						
Duration:	uration: Turnus of offer: C		Credit points:			
1 Semester	each winter semester		4			
Course of study, specific field and term: Master Biophysics 2023 (module par Master Biophysics 2019 (module par Master Computer Science 2019 (mod Master Entrepreneurship in Digital T Master Medical Informatics 2019 (mod Master MLS 2009 (Module part of a d Master Medical Informatics 2014 (mod Master Computer Science 2014 (mod	<ul> <li>Course of study, specific field and term:</li> <li>Master Biophysics 2023 (module part), advanced curriculum, Arbitrary semester</li> <li>Master Biophysics 2019 (module part), advanced curriculum, Arbitrary semester</li> <li>Master Computer Science 2019 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester</li> <li>Master Medical Informatics 2019 (module part), Module part, Arbitrary semester</li> <li>Master MLS 2009 (Module part of a compulsory module), interdisciplinary competence, 1st semester</li> <li>Master Medical Informatics 2014 (module part), Module part, Arbitrary semester</li> </ul>					
Classes and lectures:		Workload:				
<ul> <li>Molecular Bioinformatics (lecture, 2</li> <li>Molecular Bioinformatics (exercise, 1</li> </ul>	SWS) SWS)	<ul> <li>45 Hours private</li> <li>45 Hours in-class</li> <li>20 Hours exam p</li> </ul>	studies room work reparation			
Contents of teaching: • Methods for fast genome compariso • Analysis of data describing gene exp • Advanced usage of biological datab	n pression profiles and seque ases (for sequences, motifs,	nce variation structures, gene regulatio	n and interactions)			
Qualification-goals/Competencies: <ul> <li>The students can apply indexing base</li> <li>They can use and design databases</li> <li>They are able to detect statistically statistically</li></ul>	sed software to Next Gener for molecularbiological rese ignificant changes in Micro	ation sequence data. earch. array data.				
Grading through: • exam type depends on main module	2					
Requires: • Introduction to Bioinformatics (CS14	00-KP04, CS1400)					
Responsible for this module:						
<ul> <li>Siehe Hauptmodul</li> <li>Teacher: <ul> <li>Institute for Neuro- and Bioinformatics</li> <li>Prof. Dr. Bernhard Haubold</li> <li>Prof. Dr. rer. nat. Thomas Martinetz</li> <li>Prof. Lars Bertram</li> <li>MitarbeiterInnen des Instituts</li> </ul> </li> </ul>						
Literature:						
<ul> <li>M. S. Waterman: Introduction to Computational Biology - London: Chapman and Hall 1995</li> <li>B. Haubold, T. Wiehe: Introduction to Computational Biology - Birkhäuser 2007</li> <li>R. Durbin, S. Eddy, A. Krogh, G. Mitchison: Biological sequence analysis. Probabilistic models - Cambridge, MA: Cambridge University Press</li> <li>J. Setubal, J. Meidanis: Introduction to computational molecular - Pacific Grove: PWS Publishing Company</li> <li>D. M. Mount: Bioinformatics - Sequence and Genome - New York: Cold Spring Harbor Press</li> </ul>						
Language: • offered only in German						



#### Notes:

Prerequisites for attending the module:

- None (The competences of the required modules are required for this module, but the modules are not a prerequisite for admission.)

Prerequisites for the exam:

- Preliminary examinations can be determined at the beginning of the semester. If preliminary work has been defined, it must have been completed and positively assessed before the initial examination.

This modul is for Master MLS the Modulpart B of Modul LS4060 with 5 credit points.



CS4	670 T - Module part: An	nbient Computing (An	nbCompa)	
Duration: Turnus of offer: Credit points:			Credit points:	
1 Semester	each summer semester		4	
Course of study, specific field and te Master Computer Science 2019 Master Entrepreneurship in Dig Master IT-Security 2019 (modu Master Entrepreneurship in Dig Master Computer Science 2014	e <b>rm:</b> 9 (module part), Module part, A gital Technologies 2020 (modu le part), Module part, 1st or 2n gital Technologies 2014 (modu 4 (module part), Module part, A	Arbitrary semester le part), Module part, Arbitr d semester le part), Module part, Arbitr Arbitrary semester	ary semester ary semester	
Classes and lectures:		Workload:		
Ambient Computing (lecture, 3 SWS)     S5 Hours private studies     45 Hours in-classroom work     20 Hours exam preparation				
Contents of teaching:				
<ul> <li>Smart components</li> <li>Software architectures</li> <li>Context-sensitive systems</li> <li>Ambient Intelligence</li> <li>Interactive ambient media syst</li> <li>Ambient Computing Application</li> <li>Ethical, Legal and Social Implication</li> <li>Qualification-goals/Competencies:</li> <li>The students are able to evalu</li> <li>They have an overview about -</li> </ul>	tems ons (AAL) ations (ELSI). ate possibilities, concepts and current technologies and syste	challenges of Ambient Syste ms for developing Ambient	ems Systems	
Grading through: • exam type depends on main n	nodule			
<ul> <li>Siehe Hauptmodul</li> <li>Teacher:         <ul> <li>Institute of Telematics</li> <li>Prof. DrIng. Andreas Schrader</li> </ul> </li> </ul>				
Literature:				
<ul> <li>John Krumm: Ubiquitous Com</li> <li>Stefan Poslad: Ubiquitous Com</li> <li>Uwe Hansman et al: Pervasive</li> </ul>	puting Fundamentals - CRC Pre nputing: Smart Devices, Enviror Computing - Springer, 2003	ess, 2009 nments and Interactions - W	iley, 2009	
Language: • English, except in case of only	German-speaking participants			
Notes:				



(Is part of the module CS4503-KP12)

Admission requirements for taking the module: - None

Admission requirements for participation in module examination(s): - see higher-level module

Module examination(s): - see superordinate module



CS5131 T - Module part: Web-Mining Agents (WebMininga)					
Duration:	Turnus of offer:		Credit points:		
1 Semester	not available anymore		8		
<ul> <li>Course of study, specific field and term:</li> <li>Certificate in Artificial Intelligence (Module part of a compulsory module), Module part, 1st semester</li> <li>Master IT-Security 2019 (module part), Module part, 1st or 2nd semester</li> <li>Master Computer Science 2019 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> <li>Master Computer Science 2014 (module part) Module part, Arbitrary semester</li> </ul>					
Classes and lectures:		Workload:			
<ul> <li>Web-Mining Agents (lecture, 4 SWS)</li> <li>Web-Mining Agents (exercise, 1 SWS)</li> <li>Web-Mining Agents (practical cours)</li> </ul>	) 5) e, 1 SWS)	<ul><li>120 Hours private</li><li>90 Hours in-classi</li><li>30 Hours exam p</li></ul>	e studies room work reparation		
<ul> <li>Probabilities and generative models for discrete data</li> <li>Gaussian models, Bayesian and frequentist statistics, regression,</li> <li>Probabilistic graphical models (e.g., Bayesian networks), learning parameters and structures of probabilistic graphical models (BME, MAP, ML, EM algorithm), probabilistic classification, probabilistic relational models</li> <li>Probabilistic reasoning over time (dynamic Bayesian networks, Markov assumption, transition model, sensor model, inference problems: filtering, prediction, smoothing, most-likely explanation, hidden Markov models, Kalman filters, exact inferences and approximations, learning dynamic Bayesian networks)</li> <li>Structural Causal Networks (Intervention, instrumental Variables, counterfactuals)</li> <li>Mixture models, latent linear models (LDA, LSI, PCA), sparse linear models,</li> <li>Decision making under uncertainty (utility theory, decision networks, value of information, sequential decision problems, value iteration, policy iteration, MDPs, decision-theoretic agents, POMDPs, reduction to multidimensional continuous MDPs, dynamic decision networks)</li> <li>Game theory, decisions with multiple agents (Nash equilibrium, Bayes-Nash equilibrium), social choice (voting, preferences, paradoxes, Arrow's Theorem, mechanism design (controlled autonomy), rules of encounter</li> <li>Building and exchanging symbolic annotations for web data (from named entity recognition to discourse representations)</li> <li>Information association, retrieval, query answering and recommendation</li> </ul>					
<ul> <li>Qualification-goals/Competencies:</li> <li>Knowledge:Students can explain the mining agents (goals, utilities, enviro cooperation can be discussed in terr real-world scenarios, students can su formalism in static and dynamic sett settings, with and with complete ac (partially observable) Markov decision identify techniques for simultaneous Students can explain coordination prochoice functions, voting protocol, ar model-based learning approaches, a either on the basis of static data, or suitable representation formalisms</li> </ul>	e agent abstraction, define v onments). They can describe ms of decision problems and ummarize how Bayesian net tings. In addition, students c cess to the state of the envir on problems, and they can r s localization and mapping, problems and decision makin and mechanism design techn and they can enumerate bas on the basis of incrementall and they explain how axiom	veb mining of rational beh e the main features of envi d algorithms for solving the works can be employed as an define decision making ronment. In this context, st ecall techniques for measu and can explain planning ing in a multi-agent setting iques.Students can explair ic machine learning techn y incoming data . For deali	avior, and give details about the design of ronments. The notion of adversarial agent ese problems. For dealing with uncertainty in s a knowledge representation and reasoning procedures in simple and sequential tudents can describe techniques for solving uring the value of information. Students can techniques for achieving desired states. in term of different types of equilibria, social in the difference between instance-based and ique for each of the two basic approaches, ing with uncertainty, students can describe r structures used in these formalisms can be		

learning theory. Algorithms for reinforcement learning can also be explained by students.
Skills:Students can select an appropriate agent architecture for concrete agent application scenarios. For simplified agent application students can derive decision trees and apply basic optimization techniques. For those applications they can also create Bayesian networks/dynamic Bayesian networks and apply Bayesian reasoning for simple queries. Students can also name and apply different sampling techniques for simplified agent scenarios. For simple and complex decision making students can compute the best action or policies for concrete settings. In multi-agent situations students will apply techniques for finding different equilibria states, e.g., Nash

learned automatically with different algorithms. Students are also able to sketch different clustering techniques. They depict how the performance of learned classifiers can be improved by ensemble learning, and they can summarize how this influences computational



equilibria. For multi-agent decision making students will apply different voting protocols and compare and explain the results. Students derive decision trees and, in turn, propositional rule sets from static data as well and temporal or streaming data. Students present and apply the basic idea of first-order inductive leaning. They apply the BME, MAP, ML, and EM algorithms for learning parameters of Bayesian networks and compare the different algorithms. They also know how to carry out Gaussian mixture learning. Students can describe basic clustering techniques and explain the basic components of those techniques. Students compare related machine learning techniques, e.g., k-means clustering and nearest neighbor classification. They can distinguish various ensemble learning techniques and compare the different goals of those techniques.

 Social competence: Students work in groups in order to solve small exercise and project assignments and present them in short talks in the plenum. In the associated project lab the students the develop a larger project using up-to-date programing languages and software tools for data science applications.

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#### Grading through:

· exam type depends on main module

#### Responsible for this module:

• Siehe Hauptmodul

#### Teacher:

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

#### Literature:

- M. Hall, I. Witten and E. Frank: Data Mining: Practical Machine Learning Tools and Techniques Morgan Kaufmann, 2011
- D. Koller, N. Friedman: Probabilistic Graphical Models: Principles and Techniques MIT Press, 2009
- K. Murphy: Machine Learning: A Probabilistic Perspective MIT Press, 2012
- S. Russel, P. Norvig: Artificial Intelligence: A Modern Approach Pearson Education, 2010
- Y. Shoham, K. Leyton-Brown: Multiagent-Systems: Algorithmic, Game-Theoretic, and Logical Foundations Cambridge University Press, 2009
- · : References to journal articles on special themes are given in the lecture

#### Language:

• offered only in English

#### Notes:

Admission requirements for the module:

- None

Admission requirements for the examination:

- Examination prerequisites may be defined at the beginning of the semester. If prerequisites are defined, they must have been completed and positively evaluated prior to the initial examination.

The competencies of the following modules are required for this module (no hard admission requirement):

- Algorithms and Data Structures (CS1001).

- Linear Algebra and Discrete Structures I + II (MA1000, MA1500)
- Databases (CS2700)
- Stochastics 1 (MA2510) or Fundamentals of Statistics (PY1800)
- Introduction to Logic (CS1002)
- Artificial Intelligence 1 (CS3204)
- Information Systems (CS4130)

(Equals CS5131) (Is module part of CS4513, CS4514-KP12)





CS5140 T - Module part: Semantic Web (SemWeba)					
Duration:	Turnus of offer:		Credit points:		
1 Semester	each winter semester		4		
<ul> <li>Course of study, specific field and term:</li> <li>Master Computer Science 2019 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester</li> <li>Master IT-Security 2019 (module part), Module part, 1st or 2nd semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> <li>Master Computer Science 2014 (module part), Module part, Arbitrary semester</li> </ul>					
Classes and lectures:		Workload:			
<ul> <li>Semantic Web (lecture, 2 SWS)</li> <li>Semantic Web (exercise, 1 SWS)</li> </ul>		<ul> <li>65 Hours private</li> <li>45 Hours in-class</li> <li>10 Hours exam p</li> </ul>	studies sroom work preparation		
Contents of teaching: Introduction with overview of the W Data management for Semantic We Query processing for Semantic We Processing strategies for Semantic	V3C Semantic Web family o 2b data, in particular indexin 3 queries (central, parallel, a Web rules and ontologies	f languages ng approaches nd distributed, in particula	r in the cloud)		
<ul> <li>Qualification-goals/Competencies:</li> <li>Students can judge about the possibilities and limits of the Semantic Web.</li> <li>They can evaluate the consequences of the Semantic Web approach for data modelling, adminstration and processing, and finally for applications.</li> <li>They can develop Semantic Web applications.</li> <li>They can explain and apply specialized approaches for Semantic Web databases.</li> <li>They can discuss about open research questions in the area of the Semantic Web.</li> </ul>					
Grading through: • exam type depends on main modu	le				
Responsible for this module:         • Siehe Hauptmodul         Teacher:         • Institute of Information Systems         • Prof. Dr. Sven Groppe					
<ul> <li>Literature:</li> <li>P. Hitzler, M. Krötzsch, S. Rudolph: Foundations of Semantic Web Technologies - Chapman &amp; Hall / CRC, 2009</li> <li>T. Segaran, J. Taylor, C. Evans: Programming the Semantic Web - O'Reilly, 2009</li> <li>F. Bry, J. Maluszynski: Semantic Techniques for the Web - Springer, 2009</li> <li>J. T. Pollock: Semantic Web for Dummies - Wiley, 2009</li> <li>J. Hebeler, M. Fisher, R. Blace, A. Perez-Lopez, M. Dean: Semantic Web Programming - Wiley, 2009</li> <li>G. Antoniou, F. van Harmelen: A Semantic Web Primer - MIT Press, 2008</li> <li>V. Kashyap, C. Bussler, M. Moran: The Semantic Web - Springer, 2008</li> <li>S. Groppe: Data Management and Query Processing in Semantic Web Databases - Springer, 2011</li> </ul>					
Language: • offered only in German	<ul><li>Language:</li><li>• offered only in German</li></ul>				
Notes:					



(Is equal to CS5140) (Is module part of CS4508)

Entry requirements for taking the module: - None

Admission requirements for taking module examination(s): - see higher-level module

Module examination(s): - see superordinate module





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CS5150 T - Module part: Organic Computing (OrganicCoa)					
Duration:	Turnus of offer:		Credit points:		
1 Semester	normally each year in the	winter semester	4		
Course of study, specific field and terr • Master Computer Science 2019 ( • Master Entrepreneurship in Digit • Master IT-Security 2019 (module • Master Entrepreneurship in Digit • Master Computer Science 2014 (	n: module part), Module part, Arb al Technologies 2020 (module part), Module part, 1st or 2nd s al Technologies 2014 (module Module part of a compulsory m	itrary semester part), Module part, Arbitr semester part), Module part, Arbitr nodule), Module part, Arb	rary semester rary semester vitrary semester		
Classes and lectures:		Workload:			
<ul> <li>Organic Computing (lecture, 2 SWS)</li> <li>Organic Computing (exercise, 1 SWS)</li> <li>Organic Computing (exercise, 1 SWS)</li> <li>15 Hours exam preparation</li> </ul>			e studies ssroom work preparation		
<ul> <li>Basic principles of Organic Computing</li> <li>Self-organization and emergence</li> <li>Architecture and design of Organic Computing systems</li> <li>Organic Computing for distributed systems</li> <li>Organic Computing in Neuro- and Bionformatics</li> <li>Organic Grid</li> <li>Autonomous Systems</li> </ul>					
<ul> <li>Qualification-goals/Competencies:</li> <li>Students are able to utilize the principles of organic computing on exemplary designs.</li> <li>They are able to explain the principles of Organic Computing.</li> <li>They are able to analyze emergence behavior in Organic Computing systems.</li> </ul>					
Grading through: • exam type depends on main module					
Responsible for this module: <ul> <li>Siehe Hauptmodul</li> </ul> Teacher: <ul> <li>Institute of Computer Engineering</li> <li>Dr. rer. nat. Javad Ghofrani</li> </ul>					
<ul> <li>Literature:</li> <li>C. Müller-Schloer, H. Schmeck, T. Ungerer: Organic Computing A Paradigm Shift for Complex Systems - Birkhäuser, 2011</li> <li>R. P. Würtz: Organic Computing - Springer, 2008</li> <li>C. Klüver, J. Kluever, J. Schmidt: Modellierung komplexer Prozesse durch naturanaloge Verfahren - Springer Vieweg 2012</li> </ul>					
Language: • offered only in German					
Notes:					



(Part of Module CS4290, CS4504-KP12)

Admission requirements for taking the module: - None

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

Module Exam(s):

- CS5150-L1: Organic Computing, oral exam, 100% of the module grade



CS5153 T - Module part: Wireless Sensor Networks (DISensorNa)					
Duration:	Duration: Turnus of offer: Credit points:				
1 Semester	Semester each summer semester				
Course of study, specific field and term: • Master Computer Science 2019 (moo • Master Entrepreneurship in Digital Te • Master IT-Security 2019 (module par • Master Computer Science 2014 (Moo • Master Entrepreneurship in Digital Te • Master Computer Science 2014 (moo	dule part), Module part, Arb echnologies 2020 (module t), Module part, 1st or 2nd : dule part of a compulsory n echnologies 2014 (module dule part), advanced curricu	pitrary semester part), Module part, Arbitrar semester nodule), specialization field part), Module part, Arbitrar ulum, Arbitrary semester	y semester robotics and automation, Arbitrary semester y semester		
		Waldaad			
<ul> <li>Wireless Sensor Networks (lecture, 2</li> <li>Wireless Sensor Networks (exercise,</li> </ul>	Classes and lectures:       Workload:         • Wireless Sensor Networks (lecture, 2 SWS)       • 60 Hours private studies         • Wireless Sensor Networks (exercise, 1 SWS)       • 45 Hours in-classroom work         • 15 Hours exam preparation				
Contents of teaching:					
<ul> <li>Basics of Sensor Networks</li> <li>Architecture of Sensor Nodes and Se</li> <li>Identities and addressing</li> <li>Wireless communication</li> <li>Data management and topology con</li> <li>Localization</li> <li>Energy harvesting</li> <li>Applications</li> </ul>	<ul> <li>Basics of Sensor Networks</li> <li>Architecture of Sensor Nodes and Sensor Networks</li> <li>Identities and addressing</li> <li>Wireless communication</li> <li>Data management and topology control</li> <li>Localization</li> <li>Energy harvesting</li> <li>Applications</li> </ul>				
Oualification-goals/Competencies:					
<ul> <li>The students are able to present the</li> <li>They are able to cope with analysis,</li> <li>They are able to interpret and pursu</li> </ul>	potential, benefits and lim design, and evaluation of p e current research activities	itations of sensor networks protocols in sensor network s for sensor networks.	S.		
Grading through:					
• exam type depends on main module	2				
Responsible for this module:					
Siehe Hauptmodul					
Teacher:					
Institute of Computer Engineering					
• Dr. rer. nat. Javad Ghofrani					
<ul> <li>Literature:</li> <li>H. Karl, A. Willig: Protocols and Architectures of Wireless Sensor Networks, - Wiley, 2005</li> <li>F. Zhao, L. Guibas: Wireless Sensor Networks - Morgan Kaufmann, 2004</li> <li>BC. Renner: Sustained Operation of Sensor Nodes with Energy Harvesters and Supercapacitors - Books on Demand 2013</li> </ul>					
Language:					
offered only in English					
Notes:					



(Part of Modules CS4504-KP12) (Is equal to CS5153)

Admission requirements for taking the module: - None

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

Module Exam(s):

- CS5153-L1: Wireless Sensor Networks, oral exam, 100% of the module grade



Duration:       Turnus of offer:         I Semester       every summer semester         Course of study, specific field and term:       • Master Computer Science 2019 (module part), Module part, Ark         • Master Entrepreneurship in Digital Technologies 2020 (module	Credit points: 4			
<ul> <li>Semester</li> <li>every summer semester</li> <li>Course of study, specific field and term:         <ul> <li>Master Computer Science 2019 (module part), Module part, Ark</li> <li>Master Entrepreneurship in Digital Technologies 2020 (module</li> </ul> </li> </ul>	4			
Course of study, specific field and term: <ul> <li>Master Computer Science 2019 (module part), Module part, Arb</li> <li>Master Entrepreneurship in Digital Technologies 2020 (module</li> </ul>				
<ul> <li>Master IT-Security 2019 (module part), Module part, 1st or 2nd</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module</li> <li>Master Computer Science 2014 (module part), Module part, Ark</li> </ul>	pitrary semester part), Module part, Arbitrary semester semester part), Module part, Arbitrary semester pitrary semester			
Classes and lectures:	Workload:			
<ul> <li>Advanced Internet Technologies (lecture, 2 SWS)</li> <li>Advanced Internet Technologies (exercise, 1 SWS)</li> <li>45 Hours in-classroom work</li> <li>15 Hours exam preparation</li> </ul>				
<ul> <li>Introduction and fundamentals</li> <li>Fundamental Internet design principles</li> <li>Problems of today's Internet architecture</li> <li>Backbone Technologies</li> <li>Mobile Internet</li> <li>IPv6 und related topics</li> <li>Delay Tolerant Networks (DTN)</li> <li>Internet of Services / Internet of Things</li> <li>Peer-To-Peer networks</li> <li>Big Data</li> <li>Goals, architectures, algorithms, and protocols for the future In</li> </ul>	ternet			
<ul> <li>Qualification-goals/Competencies:</li> <li>Understand the fundamental design decisions that have led to</li> <li>Understand the original design goals of the Internet and realized networks</li> <li>Learn about essential, universally valid criteria for the design of etc.)</li> <li>Know technological as well as societal developments that have innovations, mobile communications, )</li> <li>Identify problems of the Internet's architecture and understance</li> <li>Become acquainted with the Future Internet research field and future</li> </ul>	today's Internet architecture e the implications that the emphasis on certain of them has on today's <sup>-</sup> networks and applications (e.g., end-to-end argument, fate sharing, led to massive changes in the Internet's infrastructure (growth, potential solutions by comparing different approaches learn about novel approaches to research and shape the Internet of the			
Grading through: • exam type depends on main module				
Responsible for this module: <ul> <li>Prof. Dr. Stefan Fischer</li> </ul> Teacher: <ul> <li>Institute of Telematics</li> <li>Dr. Mohamed Hail</li> </ul>				
Literature: • Olivier Hersent, David Boswarthick, Omar Elloumi: The Internet • Athanasios V. Vasilakos, Yan Zhang, Thrasyvoulos Spyropoulos: • E. Pacitti, R. Akbarinia, M. El-Dick: P2P Techniques for Decentral	of Things: Key Applications and Protocols - Wiley, 2012 Delay Tolerant Networks: Protocols and Applications - CRC Press, 2012 ized Applications - Morgan & Claypool Publishers			



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#### German and English skills required

Notes:

(Was module part of CS4509) (Is equal to CS5158)

Entry requirements to take the module: - None

Admission requirements for participation in module examination(s): - See higher-level module

Module examination(s): - see superordinate module



CS5170 T - Module part: Hardware/Software Co-Design (HWSWCoda)					
Duration:	Duration: Turnus of offer: Credit points:				
1 Semester	er each winter semester				
<ul> <li>Course of study, specific field and term:</li> <li>Master Computer Science 2019 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester</li> <li>Master IT-Security 2019 (module part), Module part, 1st or 2nd semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> <li>Master Computer Science 2014 (module part), Module part, Arbitrary semester</li> </ul>					
Classes and lectures:Workload:• Hardware/Software Co-Design (lecture, 2 SWS)• 55 Hours private studies• Hardware/Software Co-Design (exercise, 1 SWS)• 45 Hours in-classroom work• 20 Hours exam preparation			studies sroom work preparation		
Contents of teaching:					
<ul> <li>System design flow</li> <li>Basic architectures for HW/SW systems</li> <li>System design and modelling</li> <li>System synthesis</li> <li>Algorithms for scheduling</li> <li>System partitioning</li> <li>Algorithms for system partitioning</li> <li>Design systems</li> <li>Performance analysis</li> <li>System design and specification with SystemC</li> </ul>					
<ul> <li>Qualification-goals/Competencies:</li> <li>Students are able to determine a suitable hardware/software architecture for a given system description</li> <li>They are able to determine and describe the pros and cons of implementation alternatives</li> <li>They are able to apply methods for system partitioning</li> <li>They are able to translate non-formal system descriptions into formal models</li> <li>They are able to explain the different steps in system synthesis</li> <li>They are able to create system descriptions in SystemC</li> </ul>					
	:				
Responsible for this module:         • Siehe Hauptmodul         Teacher:         • Institute of Computer Engineering         • Prof. DrIng. Mladen Berekovic					
Literature:					
<ul> <li>F. Kesel: Modellierung von digitalen Systemen mit SystemC - Oldenbourg Verlag 2012</li> <li>Teich, J., Haubelt, C.: Digital Hardware/Software-Systeme. Synthese und Optimierung - Berlin: Springer 2007</li> </ul>					
Language: • offered only in German Notes:	<ul> <li>Teicn, J., Haubeit, C.: Digital Hardware/Software-Systeme. Synthese und Optimierung - Berlin: Springer 2007</li> <li>Language:         <ul> <li>offered only in German</li> </ul> </li> <li>Notes:</li> </ul>				



(Is module part of CS4290, CS4505) (Is equal to CS5170)

Admission requirements for taking the module: - None

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

Module Exam(s):

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



CS5194 T -	Module part: Practical Project	in Signal and Image	Processing (PrSigBildv)	
Duration:	Turnus of offer:		Credit points:	
Semester	every second semester		4 (Тур В)	
Course of study, specific field Master Biophysics 2023 Master Computer Science Master MES 2020 (modu Master Entrepreneurship Master Biophysics 2019 Master IT-Security 2019 Master MES 2014 (modu Master Entrepreneurship Master Computer Science	and term: (module part), advanced curriculum, 1 :e 2019 (module part), Module part, A ile part), computer science / electrical o in Digital Technologies 2020 (modul (module part), advanced curriculum, 7 (module part), Module part, 1st or 2nd ile part), computer science / electrical o in Digital Technologies 2014 (modul ce 2014 (module part), Module part, A	1st or 2nd semester rbitrary semester engineering, Arbitrary sem le part), Module part, Arbitr 1st or 2nd semester d semester engineering, 1st or 2nd se le part), Module part, Arbitr rbitrary semester	lester ary semester mester ary semester	
Classes and lectures:		Workload:		
• iRoom (practical course,				
Contents of teaching: • Planning and realization	۱ of typical signal processing applicati	ons in a team		
Qualification-goals/Competer				
<ul> <li>Students will have competent</li> <li>They are able to realize</li> <li>They have the communication</li> </ul>	prehensive knowledge of using signal signal processing systems in teamwor ication competency to document and	and image processing algo rk and in a self-directed ma l present project results.	prithms in practice. nner.	
Grading through: • exam type depends on a	main module			
Requires: • Signal processing (CS31 • Image processing (CS32	00-KP04) 03)			
Responsible for this module: • Siehe Hauptmodul				
Teacher:				
Institute for Signal Proce	essing			
<ul><li> Prof. DrIng. Markus Kal</li><li> MitarbeiterInnen des Ir</li></ul>	linger hstituts			
Language: • offered only in German				
Notes:				
(Part of Module CS4510)				
Prerequisites for attending - None	J the module:			
Prerequisites for the exam - The project must be com	: pleted in order to take the exam in th	ne module CS4510		
Modul Exam: - CS4510-L1: Signal Analys	is, oral exam consisting out of Pattern	n Recognition, Selected Top	ics of Signal Analysis and Enhancement ar	



this project, 100% of module grade



	CS5220 T - Module parte	: Static Analysis (	StatAnaa)	
Duration:	Turnus of offer:		Credit points:	
1 Semester	ester normally each year in the winter semester		6	
Course of study, specific field and • Master MES 2020 (module pa • Master MES 2014 (module pa • Master Entrepreneurship in I • Master Computer Science 20	<b>term:</b> art), computer science / electrical e art), computer science / electrical e Digital Technologies 2020 (module 119 (module part), Module part, Ar	engineering, Arbitrary engineering, Arbitrary e part), Module part, A bitrary semester	semester semester rbitrary semester	
Classes and lectures:		Workload:		
<ul> <li>Static Analysis (lecture, 3 SWS)</li> <li>Static Analysis (exercise, 1 SWS)</li> <li>Static Analysis (exercise, 1 SWS)</li> <li>O Hours in-classroom work</li> <li>20 Hours exam preparation</li> </ul>				
<ul> <li>Program analysis</li> <li>Data flow analysis</li> <li>Abstract Interpretation</li> <li>Symbolic Execution</li> <li>SMT/SAT Solvers</li> <li>Hoare logic, wp calculus</li> <li>Software metrics</li> <li>Bytecode analysis</li> <li>Manual code inspection</li> </ul>				
Qualification-goals/Competencies • The students can illustrate th • They can explain and classify • They can select appropriate • They can relate, compare an • They can describe approach • They can select and apply co • They can organize and exect	: ne capabilities of static analysis. y the techniques for automatic sta analysis methods, and employ and d evaluate various static methods es for bytecode analysis. ommon tools for static analysis. ute manual code inspections.	tic source code analys d combine them. in order to increase s	is. oftware quality.	
Grading through: • exam type depends on main	module			
Responsible for this module: <ul> <li>Prof. Dr. Martin Leucker</li> </ul> Teacher: <ul> <li>Institute of Software Techno</li> <li>Prof. Dr. Martin Leucker</li> </ul>	logy and Programming Language	s		
Literature: • F. Nielson, H.R. Nielson, C. Ha • H. Seidl, R. Wilhelm, S. Hack:	ankin: Principles of Program Analy Übersetzerbau Band 3: Analyse ur	sis - Springer, 2010 nd Transformation - Sp	oringer 2010	
Language: • English, except in case of on	ly German-speaking participants			
Notes:				



(Part of Module CS4507-KP12)

Prerequisites for attending the module: - None

Prerequisites for the exam:

- Successful completion of homework assignments during the semester



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CS5260SJ14 T - Module part: Speech and Audio Signal Processing (SprachA14a)					
Duration:	Turnus of offer:		Credit points:		
1 Semester	Semester normally each year in the summer semester 4				
<ul> <li>Course of study, specific field and term:</li> <li>Master Computer Science 2019 (module part), Module part, Arbitrary semester</li> <li>Master Biophysics 2023 (module part), advanced curriculum, 1st and 2nd semester</li> <li>Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester</li> <li>Master Biophysics 2019 (module part), advanced curriculum, 1st or 2nd semester</li> <li>Master Biophysics 2019 (module part), advanced curriculum, 1st or 2nd semester</li> <li>Master IT-Security 2019 (module part), Module part, Arbitrary semester</li> <li>Master Computer Science 2014 (Module part of a compulsory module), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> </ul>					
Classes and lectures:		Workload:			
<ul> <li>Speech and Audio Signal Processing</li> <li>Speech and Audio Signal Processing</li> </ul>	<ul> <li>Speech and Audio Signal Processing (lecture, 2 SWS)</li> <li>Speech and Audio Signal Processing (exercise, 1 SWS)</li> <li>Speech and Audio Signal Processing (exercise, 1 SWS)</li> <li>45 Hours in-classroom work</li> <li>20 Hours exam preparation</li> </ul>				
Contents of teaching:					
<ul> <li>Speech production and human hearing</li> <li>Physical models of the auditory System</li> <li>Dynamic compression</li> <li>Spectral analysis: Spectrum and Cepstrum</li> <li>Spectral perception and masking</li> <li>Vocal tract models</li> <li>Linear prediction</li> <li>Coding in time and frequency domains</li> <li>Speech synthesis</li> <li>Noise reduction and echo compensation</li> <li>Source localization and spatial reproduction</li> </ul>					
Qualification-goals/Competencies:					
<ul> <li>Students are able to describe the basics of human speech production and the corresponding mathematical models.</li> <li>They are able to describe the process of human auditory perception and the corresponding signal processing tools for mimicing auditory perception.</li> <li>They are able to present basic knowledge of statistical speech modeling and automatic speech recognition.</li> <li>They can describe and use signal processing methods for source separation and room-acoustic measurements.</li> </ul>					
Grading through:					
<ul> <li>exam type depends on main module</li> </ul>	2				
Responsible for this module:         • Siehe Hauptmodul         Teacher:         • Institute for Signal Processing         • Prof. DrIng. Markus Kallinger					
Literature:					
<ul> <li>L. Rabiner, BH. Juang: Fundamenta</li> <li>J. O. Heller, J. L. Hansen, J. G. Proakis</li> </ul>	ls of Speech Recognition : Discrete-Time Processing	- Upper Saddle River: Prent g of Speech Signals - IEEE P	rice Hall 1993 Press		
Language: • offered only in German					



#### Notes:

Prerequisites for attending the module: - None

Prerequisites for the exam:

- Successful completion of assignments during the semester.

Module examination(s):

- see superordinate module

(Is modul part of CS4290, CS4510, RO4290-KP04) (Is the same as CS5260SJ14)



CS5275 T - Module part: Selected Topics of Signal Analysis and Enhancement (AMSAVa)			
Duration:	Turnus of offer:		Credit points:
1 Semester	each summer semester		4
Course of study, specific field and term: Master Robotics and Autonomous Systential Master Biophysics 2023 (module part Master Computer Science 2019 (module Master MES 2020 (module part), com Master Entrepreneurship in Digital Te Master Biophysics 2019 (module part Master IT-Security 2019 (module part Master Entrepreneurship in Digital Te Master Entrepreneurship in Digital Te Master Entrepreneurship in Digital Te Master Entrepreneurship in Digital Te Master Computer Science 2014 (module part), com	tems 2019 (module part), Mo t), advanced curriculum, 2nd dule part), Module part, Arbi nputer science / electrical er echnologies 2020 (module p t), advanced curriculum, 2nd t), Module part, 1st or 2nd s echnologies 2014 (module p nputer science / electrical er dule part), Module part, Arbi	dule part Current Issues Rot d semester itrary semester ngineering, Arbitrary semes part), Module part, Arbitrar d semester emester part), Module part, Arbitrar ngineering, 1st or 2nd seme itrary semester	potics and Automation, 1st and/or 2nd semester ster y semester y semester ester
Classes and lectures:		Workload:	
<ul> <li>Selected Topics of Signal Analysis an SWS)</li> <li>Selected Topics of Signal Analysis an 1 SWS)</li> </ul>	<ul> <li>Selected Topics of Signal Analysis and Enhancement (lecture, 2 SWS)</li> <li>Selected Topics of Signal Analysis and Enhancement (exercise, 1 SWS)</li> <li>Workload:</li> <li>• 55 Hours private studies</li> <li>• 45 Hours in-classroom work</li> <li>• 20 Hours exam preparation</li> </ul>		
Contents of teaching:			
<ul> <li>Linear estimators</li> <li>Linear optimal filters</li> <li>Adaptive filters</li> <li>Multichannel signal processing, beamforming, and source separation</li> <li>Compressed sensing</li> <li>Basic concepts of multirate signal processing</li> <li>Nonlinear signal processing algorithms</li> <li>Application scenarios in auditory technology, enhancement, and restauration of one- and higher-dimensional signals, Sound-field measurement, noise reduction, deconvolution (listening-room compensation), inpainting</li> </ul>			
Qualification-goals/Competencies:			
<ul> <li>Students are able to explain the basi</li> <li>They are able to describe and apply</li> <li>Students are able to describe the coil</li> <li>They are able to describe and apply</li> <li>They are able to describe the concept</li> <li>They are able to analyze and design</li> <li>Students are able to explain various</li> <li>They are able to create and implement</li> </ul>	ic elements of stochastic sig linear estimation theory. ncepts of adaptive signal pr the concepts of multichann ot of compressed sensing. multirate systems. applications of nonlinear ar ent linear optimum filters an	nal processing and optimu ocessing. el signal processing. nd adaptive signal processi nd nonlinear signal enhanc	um filtering. ing. ement techniques on their own.
Grading through:			
<ul> <li>exam type depends on main module</li> </ul>	2		
Responsible for this module: <ul> <li>Siehe Hauptmodul</li> </ul> Teacher: <ul> <li>Institute for Signal Processing</li> <li>Prof. DrIng. Markus Kallinger</li> </ul>			
Literature:			
A. Mertins: Signaltheorie: Grundlage	n der Signalbeschreibung, F	ilterbänke, Wavelets, Zeit-	Frequenz-Analyse, Parameter- und



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





CS5410 T - Module part: Artificial Life (ArtiLifea)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	irregularly		4	
<ul> <li>Course of study, specific field and term:</li> <li>Master Computer Science 2019 (module part), Module part, Arbitrary semester</li> <li>Master Computer Science 2014 (module part), Module part, Arbitrary semester</li> </ul>				
Classes and lectures: • Artificial Life (lecture, 2 SWS) • Artificial Life (exercise, 1 SWS)	nd lectures:Workload:ificial Life (lecture, 2 SWS)60 Hours private studiesificial Life (exercise, 1 SWS)45 Hours in-classroom work15 Hours exam preparation		e studies sroom work preparation	
Contents of teaching:   Properties, flavors and kinds of (artificial) life Artificial chemistry and self-replicating code Introduction to information theory Introduction to statistical mechanics and thermodynamics Complex networks and NK models Evolutionary algorithms Emergence Cellular automata Game of life Tierra Artificial				
<ul> <li>Qualification-goals/Competencies:</li> <li>Students are able to classify models of artificial life, artificial chemistry and self-replicating code.</li> <li>Students have the competence to explain the mathematical concepts of information theory.</li> <li>Students are able to implement and mathematically analyze cellular automata and complex networks.</li> <li>Students can formulate mutualistic interactions through Boolean networks and game-theoretic models and can relate them to biological or socioeconomic systems.</li> <li>Students have the methodogical competence to design evolutionary algorithms and to review them in the context of statistical mechanics and thermodynamics.</li> </ul>				
Grading through: • exam type depends on main module	e			
Responsible for this module:         • Siehe Hauptmodul         Teacher:         • Institute for Neuro- and Bioinformatics         • Prof. Dr. rer. nat. Thomas Martinetz         • PD Dr. rer. nat. Jens Christian Claussen				
Literature: • Christoph Adami: Introduction to Ar	tificial Life - Springer Verla	g, 1998		
Language:     English, except in case of only German-speaking participants				
Notes:				



Prerequisites for attending the module: - None

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



CS5430 T - module part: Seminar Machine Learning (SemMaschLa)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each summer semester	4		
<ul> <li>Course of study, specific field and term:</li> <li>Master Biophysics 2023 (module part), advanced curriculum, 2nd semester</li> <li>Master Computer Science 2019 (module part), Module part, Arbitrary semester</li> <li>Master MES 2020 (module part), computer science / electrical engineering, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2020 (module part), Module part, Arbitrary semester</li> <li>Master Biophysics 2019 (module part), advanced curriculum, 2nd semester</li> <li>Master Biophysics 2019 (module part), advanced curriculum, 2nd semester</li> <li>Master IT-Security 2019 (module part), Module part, 1st or 2nd semester</li> <li>Master MES 2014 (module part), computer science / electrical engineering, 1st or 2nd semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (module part), Module part, Arbitrary semester</li> </ul>				
Classes and lectures: • Seminar Machine Lea	arning (seminar, 2 SWS)	<ul> <li>Workload:</li> <li>70 Hours private studies</li> <li>30 Hours in-classroom work</li> <li>20 Hours work on an individual topic with written and oral presentation</li> </ul>		
Contents of teaching: • Independent study of	f a specific field of machine learning			
Qualification-goals/Compe • Students can read ar • Students can presen	e <b>tencies:</b> Ind understand scientific articles in the field t the contents of scientific articles in the fie	of machine learning. eld of machine learning in a	a talk.	
Grading through: • exam type depends on main module				
Responsible for this module:         • Siehe Hauptmodul         Teacher:         • Institute for Neuro- and Bioinformatics         • Prof. DrIng. Erhardt Barth         • MitarbeiterInnen des Instituts				
Language: • German and English	skills required			
Notes: Admission requiremen - None	ts for the module:			
Admission requirements for the examination: - Examination prerequisites may be defined at the beginning of the semester. If prerequisites are defined, they must have been completed and positively evaluated prior to the initial examination.				
(Is part of the module CS4511)				



CS5440 T - Module part: Seminar Neuro- and Bioinformatics (SemNeurBia)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	irregularly		4	
Course of study, specific field and term: • Master Computer Science 2019 (ma • Master Computer Science 2014 (ma	odule part), Module part, A odule part), Module part, A	rbitrary semester rbitrary semester		
Classes and lectures:       Workload:         • Seminar Neuro- and Bioinformatics (seminar, 2 SWS)       • 70 Hours private studies         • 30 Hours in-classroom work       • 20 Hours work on an individual topic with written an presentation		studies room work n an individual topic with written and oral		
Contents of teaching: • Introduce students to a current res	earch topic in Neuro- and	Bioinformatics		
Qualification-goals/Competencies: <ul> <li>The students are able to read and</li> <li>They are able to present orally and</li> <li>The students can master basic scie</li> <li>They can summarize a scientific to</li> <li>They can give an intelligible and co</li> <li>They have communication competencies</li> </ul>	understand scientific publi in a written paper the con ntific methodology. pic in written form. oncise oral presentation of sency to discuss a current r	cations in the field of neuro- itent of scientific publication a current research topic. esearch topic.	uand bioinformatics. s in the field of neuro- and bioinformatics.	
Grading through: • oral presentation • term paper • exam type depends on main modu	le			
Responsible for this module: • Siehe Hauptmodul Teacher: • Institute for Neuro- and Bioinforma • Prof. Dr. rer. nat. Thomas Martinetz • Prof. DrIng. Erhardt Barth • MitarbeiterInnen des Instituts	ıtics			
Language: • English, except in case of only Gerr	nan-speaking participants			
Notes: Prerequisites for attending the modu - None	le:			





CS5450 T - Module part: Machine Learning (MaschLerna)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each winter semester		4	
Course of study, specific field an Master Biophysics 2023 (m Master Computer Science Master MES 2020 (module Master Entrepreneurship in Master Biophysics 2019 (m Master IT-Security 2019 (m Master Entrepreneurship in Master MES 2014 (module Master Computer Science	nd term: nodule part), advanced curriculum, 1 2019 (module part), Module part, Ar part), computer science / electrical e n Digital Technologies 2020 (module nodule part), advanced curriculum, 1 nodule part), Module part, 1st or 2nd n Digital Technologies 2014 (module part), computer science / electrical e 2014 (module part), Module part, Ar	st semester bitrary semester engineering, Arbitrary seme e part), Module part, Arbitra st semester semester e part), Module part, Arbitra engineering, 1st or 2nd sen bitrary semester	ister ry semester ry semester lester	
Classes and lectures:		Workload:		
<ul> <li>Machine Learning (lecture</li> <li>Machine Learning (exercis)</li> </ul>	ercise, 1 SWS) • 20 Hours exam preparation			
<ul> <li>Representation learning, including manifold learning</li> <li>Statistical learning theory</li> <li>VC dimension and support vector machines</li> <li>Boosting</li> <li>Deep learning</li> <li>Limits of induction and importance of data ponderation</li> </ul>				
Qualification-goals/Competence • Students can understand a • They can explain and appl • They can chose and then a • They can understand and	es: and explain various machine-learnin y different machine learning methor evaluate an appropriate method for explain the limits of automatic data	g problems. ds and algorithms. a particular learning proble analysis.	m.	
Grading through: • exam type depends on ma	in module			
Responsible for this module: • Siehe Hauptmodul Teacher: • Institute for Neuro- and Bi • Prof. DrIng. Erhardt Barth • Prof. Dr. rer. nat. Thomas M	oinformatics Aartinetz			
Literature: • Chris Bishop: Pattern Reco • Vladimir Vapnik: Statistica • Tom Mitchell: Machine Lea	gnition and Machine Learning - Spri   Learning Theory - Wiley-Interscienc arning - McGraw Hill. ISBN 0-07-0428	nger ISBN 0-387-31073-8 e, ISBN 0471030031 07-7		
Language:     • English, except in case of only German-speaking participants				
Notes:				



Admission requirements for taking the module: - None

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

Module Exam(s):

- CS5450-L1: Machine Learning, oral exam, 100% of module grade.

(Is part of the module CS4290, CS4511, CS5400, CS4251-KP08)



# Module Guide

CS5549 T - Module part: Project Bioinformatics (PrBioinfa)					
Duration:	Turnus of offer:	Credit points:			
1 Semester	each winter semester	4			
Course of study, specific field an • Master Computer Science	<b>nd term:</b> 2019 (module part), Module part, A	rbitrary semester			
Classes and lectures:Workload:• Projektpraktikum Bioinformatik (practical course, 3 SWS)• 45 Hours private studies • 45 Hours in-classroom work • 30 Hours group work		<ul> <li>Workload:</li> <li>45 Hours private studies</li> <li>45 Hours in-classroom work</li> <li>30 Hours group work</li> </ul>			
Contents of teaching: • Project for solving a moleo • Project for implementing	<ul> <li>Contents of teaching:</li> <li>Project for solving a molecular biology problem with computational methods</li> <li>Project for implementing biological information principles in technical systems</li> </ul>				
<ul> <li>Qualification-goals/Competencies:</li> <li>The students can plan a project and realize in a team and with milestones.</li> <li>They can apply bioinformatics software.</li> <li>They are able to implement learning algorithms.</li> </ul>					
Grading through: • exam type depends on ma • continuous, successful par	ain module rticipation in practical course, >80%				
Responsible for this module: • Prof. Dr. rer. nat. Thomas Martinetz Teacher: • Institute for Neuro- and Bioinformatics • Prof. Dr. rer. nat. Thomas Martinetz • Prof. DrIng. Erhardt Barth • Prof. Dr. Bernhard Haubold • MitarbeiterInnen des Instituts					
Language: • German and English skills	required				



EW4170 T - module part: System Biology (SystBioT)				
r:	Credit points:			
mester	4			
0 (module part), Module part, Art le part, Arbitrary semester	pitrary semester			
classic and translational system biology classic and translational system biology classic and translational system biology )				
<ul> <li>Contents of teaching:</li> <li>Introduction to the genome and proteome of cellular systems</li> <li>Networks: cellular, genetic, gene-regulatory networks, interactomes</li> <li>Analysis of dynamical systems: fixed points, bifurcations and feedback</li> <li>Bioinformatic analysis of Omics data</li> <li>Introduction to public databases: e.g. STRING, Gene Expression Omnibus, TCGA, KEGG, Reactome, MSigDB</li> <li>Exercises: computer lab for analysis of dynamical systems and cellular pathways in R</li> <li>Usage, analysis and visualization of high-dimensional data in R</li> <li>Exercises for the analysis of protein interaction networks</li> </ul>				
<ul> <li>Qualification-goals/Competencies:</li> <li>The students can explain the principles of signal transduction in the cell</li> <li>The students can relate to the genome, transcriptome, interactome and proteome</li> <li>They can analyse and characterize dynamical systems</li> <li>They know common methods to analyse high-throughput data</li> <li>Lab work will enable the students to continue studying this subject on their own</li> </ul>				
ogie (Lübeck Institute of Experime	ental Dermatology)			
<ul> <li>Literature:</li> <li>Marian Walhout, Marc Vidal, Job Dekker: Handbook of Systems Biology: Concepts and Insights - (Englisch) Gebundene Ausgabe 15. November 2012</li> <li>Edda Klipp, Wolfram Liebermeister, Christoph Wierling, Axel Kowald;: Systems Biology: A Textbook - Englisch) Taschenbuch 20. April 2016</li> <li>Yoram Vodovotz and Gary: An Translational Systems Biology, Concepts and Practice for the Future of Biomedical Research</li> </ul> Language: <ul> <li>offered only in English</li> </ul>				
	<b>Jie part: System Biology (S</b> r:         mester         0 (module part), Module part, Arl         le part, Arbitrary semester         ogy         • 60 Hours in-         ogy         • 50 Hours pri         ogy         • 10 Hours exa         ar systems         s, interactomes         ons and feedback         Expression Omnibus, TCGA, KEGO         tems and cellular pathways in R         Id data in R         orks         orks         bisduction in the cell         ne, interactome and proteome         s         ghput data         ing this subject on their own         of Systems Biology: Concepts and         price (Lübeck Institute of Experiments         pailogy, Concepts and Practice f			





LS1600 T - Module part: Organic Chemistry (OCMIa)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each summer semester		4	
Course of study, specific field and term:				
<ul> <li>Master Computer Science 2019 (mo</li> <li>Master Computer Science 2014 (mo</li> </ul>	dule part), Module part, Arb dule part), Module part, Arb	itrary semester itrary semester		
Classes and lectures:		Workload:		
Organic Chemistry (lecture, 3 SWS)		<ul><li>80 Hours private studies</li><li>40 Hours in-classroom work</li></ul>		
Contents of teaching:				
<ul> <li>Introduction</li> <li>Alkanes, cycloalkanes</li> <li>Alkene and alkynes</li> <li>Aromatic compounds</li> <li>Stereoisomery</li> <li>Substitution and elimination reaction</li> <li>Alcohols, phenols and thiols</li> <li>Ether and epoxides</li> <li>Aldehydes and ketones</li> <li>Carboxylic acids and derivates</li> <li>Heterocycles</li> <li>Lipids</li> <li>Carbohydrates</li> <li>Amino acids and peptides</li> <li>Nucleotides and nucleic acids</li> </ul>	ns			
Qualification-goals/Competencies: <ul> <li>Understanding the principles of org</li> </ul>	anic chemistry			
Grading through: • written exam				
Requires: • Basic Chemistry (LS1100-INF)				
Responsible for this module: <ul> <li>Siehe Hauptmodul</li> </ul> Teacher: <ul> <li>Institute of Chemistry and Metabolo</li> <li>PD Dr. phil. nat. Thomas Weimar</li> </ul>	mics			
Literature: • Hart, H., L. E. Craine, D. J. Hart: Organ • Buddrus, J.: Organische Chemie - De	nische Chemie - Wiley-VCH Gruyter Verlag			
Language: • offered only in German				
Notes:				


Knowledge of basic chemistry (such as from LS1100-INF) is required.

Prerequisites for attending the module: - None



MA2600 T - Module part: Biostatistics 2 (BioStat2a)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each summer semester		4	
Course of study, specific field and Master Computer Science 2 Master Computer Science 2	<b>d term:</b> 019 (module part), Module part, Arb 014 (module part), Module part, Arb	itrary semester itrary semester		
Classes and lectures:		Workload:		
<ul> <li>Biostatistics 2 (lecture, 2 SWS)</li> <li>Biostatistics 2 (exercise, 1 SWS)</li> <li>Biostatistics 2 (exercise, 1 SWS)</li> <li>35 Hours private studies</li> <li>25 Hours programming</li> <li>15 Hours exam preparation</li> </ul>		assroom work ite studies ramming n preparation		
Contents of teaching:				
<ul> <li>Knowledge of model assumptions and mathematical foundation of model assumptions for the linear model</li> <li>Knowledge of possible sources of errors in the modelling</li> <li>Competence in independent analysis of a study using the linear model</li> <li>Competence in correctly interpreting study results</li> <li>Competence in parameter interpretation and regression diagnostics</li> <li>Knowledge of model assumptions and mathematical foundation of the generalized linear model</li> <li>Competence in the independent analysis of a simple study with a dichotomous outcome</li> <li>Competence in correctly interpreting study results of a study with a dichotomous outcome</li> <li>Competence in correctly interpreting study results of a study with a dichotomous outcome</li> <li>Competence in correctly interpreting study results of a study with a dichotomous outcome</li> </ul> Qualification-goals/Competencies: <ul> <li>The students are able to enumerate and explain the assumptions of the classical linear model.</li> <li>The students are able to describe typical applications of the classical linear model.</li> <li>The students are able to list the differences between the linear model and the logistic regression model.</li> <li>The students are able to calculate the estimators (point and interval estimators, residual) in the linear model by hand.</li> <li>The students are able to evaluate the graphics for regression diagnostics in the linear model. <ul> <li>The students are able to interpret the results of studies, where a linear, a logistic or a Cox regression model was applied.</li> <li>The students are able to draw and interpret Kaplan-Meier curves.</li> </ul></li></ul>				
Grading through: • exam type depends on mai	n module			
Is requisite for: • Multivariate Statistics (MA4944) • Interdisciplinary Seminar (MA3300)				
Requires:     Biostatistics 1 (MA1600-KP04, MA1600, MA1600-MML)				
Responsible for this module: <ul> <li>Siehe Hauptmodul</li> </ul> Teacher: <ul> <li>Institute of Medical Biometri</li> <li>Prof. Dr. rer. biol. hum. Inke</li> <li>Dr. rer. hum. biol. Markus Social</li> </ul> Literature: <ul> <li>Ludwig Coherenia: Thereory</li> </ul>	y and Statistics König :heinhardt	No Mothodon und Aug		
<ul> <li>Ludwig Fahrmeir, Thomas F</li> <li>Dobson, Annette J &amp; Barnei</li> <li>2008</li> </ul>	theid, Stefan Lang: Regression: Mode t, Adrian: An Introduction to Genera	elle, Methoden und Anw lized Linear Models, 3rd	vendungen - ISBN-13 9783540339328 I ed Chapman & Hall/CRC: Boca Raton (FL),	



### Language:

#### • offered only in German

### Notes:

Prerequisites for attending the module:

- None (The competences of the required modules are required for this module, but the modules are not a prerequisite for admission.)

Prerequisites for the exam:

- Preliminary examinations can be determined at the beginning of the semester. If preliminary work has been defined, it must have been completed and positively assessed before the initial examination.



MA4020 T - Module part: Stochastics 2 (Stoch2a)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each winter semester		4	
Course of study, specific field and term:				
<ul> <li>Master Computer Science 2019 (m</li> <li>Master Computer Science 2014 (m</li> </ul>	odule part), Module part, Arb odule part), Module part, Arb	itrary semester itrary semester		
Classes and lectures:		Workload:		
<ul> <li>Stochastics 2 (lecture, 2 SWS)</li> <li>Stochastics 2 (exercise, 1 SWS)</li> </ul>		<ul> <li>65 Hours private</li> <li>45 Hours in-class</li> <li>10 Hours exam p</li> </ul>	e studies and exercises sroom work preparation	
Contents of teaching:				
<ul> <li>Lebesgue integral and Riemann in</li> <li>Transformations of measures and i</li> <li>Product measures and Fubini's the</li> <li>Moments and dependency measu</li> <li>Normally distributed random vector</li> </ul>	tegral ntegrals orem res ors and distributions closely r	elated to the normal distri	bution	
<ul> <li>Qualification-goals/Competencies:</li> <li>Studends get insights into basic stochastic structures</li> <li>They master techniques of integration being relevant to stochastics</li> <li>They master the treatment of (particularly normally distributed) random vectors and their distributions</li> <li>They are able to formalize complex stochastic problems</li> </ul>				
Grading through: • exam type depends on main modu • Exercises	ıle			
Is requisite for: • Modeling Biological Systems (MA4 • Stochastic processes and modeling	450) 9 (MA4610-KP04, MA4610)			
Requires: • Stochastics 1 (MA2510-KP04, MA2510) • Linear Algebra and Discrete Structures 2 (MA1500-KP08, MA1500) • Analysis 2 (MA2500-KP04, MA2500)				
Responsible for this module:				
<ul> <li>Siehe Hauptmodul</li> <li>Teacher: <ul> <li>Institute for Mathematics</li> <li>Nachfolge von Prof. Dr. rer. nat. Karsten Keller</li> </ul> </li> </ul>				
Literature:				
<ul> <li>J. Elstrodt: Maß- und Integrationstheorie - Springer</li> <li>M. Fisz: Wahrscheinlichkeitsrechnung und mathematische Statistik - Deutscher Verlag der Wissenschaften</li> </ul>				
Language: • offered only in German				
Notes:				



The lecture is identical to that in module MA4020-MML.

Prerequisites for attending the module: - None

Prerequisites for the exam:

- Successful completion of homework assignments during the semester.





MA4400 T - Module part: Chaos and Complexity of Biological Systems (CKBSa)					
Duration:	Turnus of offer:		Credit points:		
1 Semester	irregularly	       	4		
Course of study, specific field • Master Computer Scient • Master Computer Scient	a <b>nd term:</b> ce 2019 (module part), Module part, Arb ce 2014 (module part), Module part, Arb	itrary semester itrary semester			
Classes and lectures:		Workload:			
<ul> <li>Chaos and Complexity o</li> <li>Chaos and Complexity o</li> </ul>	of Biological Systems (lecture, 2 SWS) of Biological Systems (exercise, 1 SWS)	<ul> <li>65 Hours private st</li> <li>45 Hours in-classro</li> <li>10 Hours exam pre</li> </ul>	udies and exercises om work paration		
Contents of teaching:					
<ul> <li>Time-discrete dynamica</li> <li>Nonlinearity and chaos</li> <li>Ergodicity</li> <li>Lyapunov exponents ar</li> <li>Symbolic dynamics</li> <li>Information-theoretic co</li> <li>Biological and medical and</li> </ul>	al systems and stochastic processes and fractal dimensions omplexity measures applications, in particular EEG analysis				
Qualification-goals/Competer • Students get insights in • They have skills in analy • They have competencie	ncies: to basic ideas of nonlinear dynamics /zing and modeling complex data and ti es in simulating and illustrating nonlinea	me series ır dynamic phenomena			
Grading through: • exam type depends on	main module				
Requires: • Stochastics 1 (MA2510-I • Analysis 1 (MA2000-KPC	KP04, MA2510) )8, MA2000)				
Responsible for this module: • Siehe Hauptmodul					
Teacher: • Institute for Mathematic	-c				
Nachfolge von Prof. Dr.	Nachfolge von Prof. Dr. rer. nat. Karsten Keller				
literature	· · · · · · · · · · · ·				
<ul> <li>M. Brin, G. Stuck: Introd</li> <li>J. M. Amigó: Permutatic</li> <li>R. L. Devaney: An Introc</li> </ul>	uction to Dynamical Systems - Cambridg on Complexity in Dynamical Systems - Sp luction to Chaotic Dynamical Systems - '	ge University Press 2002 pringer 2010 Westview Press 2003			
Language: • depends on the chosen	courses				
Notes:					



Lecture and tutorial in English (in German only if desired by all students), lecture notes in English, exam can be taken either in English or German language

Prerequisites for attending the module: - None

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



MA4450 T-INF - Module part: Modeling Biological Systems (MoBSa)			
Duration:	Turnus of offer:		Credit points:
1 Semester	each winter semester		4
Course of study, specific field and • Master Computer Science 20 • Master Entrepreneurship in I • Master Medical Informatics 2 • Master Medical Informatics 2 • Master Computer Science 20	term: D19 (module part), Module part, Al Digital Technologies 2020 (modul 2019 (module part), Module part, A 2014 (module part), Module part, A D14 (module part), Module part, A	rbitrary semester e part), Module part, Arbit Arbitrary semester Arbitrary semester rbitrary semester	rary semester
Classes and lectures:		Workload:	
<ul> <li>Modeling Biological Systems</li> <li>Modeling Biological Systems</li> </ul>	Aodeling Biological Systems (lecture, 2 SWS)• 65 Hours private studies and exercisesModeling Biological Systems (exercise, 1 SWS)• 45 Hours in-classroom work• 10 Hours exam preparation		
Contents of teaching:			
<ul> <li>Elementary time-discrete de</li> <li>Structured time-discrete pop</li> <li>Generating functions, Galtor</li> <li>Modeling of data and data a</li> </ul>	terministic models pulation dynamics n-Watson-processes inalysis		
Qualification-goals/Competencies • Students have knowledge of • They develop skills in conne • They have competencies in a • They develop competencies	s: f elementary time-discrete models cting ideas from different fields of data analysis and modelling in interdisciplinary work	s for modeling biological p f mathematics	processes
Grading through: • Exercises • exam type depends on main	n module		
Requires:			
<ul> <li>Stochastics 1 (MA2510-KP04</li> <li>Analysis 2 (MA2500-KP04, M</li> <li>Linear Algebra and Discrete</li> </ul>	, MA2510) A2500) Structures 2 (MA1500-KP08, MA15	500)	
Responsible for this module:			
Nachfolge von Prof. Dr. rer. r	nat. Karsten Keller		
Teacher:			
Institute for Mathematics			
Nachfolge von Prof. Dr. rer. r	nat. Karsten Keller		
Literature: • F. Braer, C. Castillo-Chavez: M • H. Caswell: Matrix Population • S. N. Elaydi: An Introduction • B. Huppert: Angewandte Lin • U. Krengel: Einführung in die • E. Seneta: Non-negative Mat	Mathematical Models in Populatio n Modells - Sunderland: Sinauer A to Difference Equations - New Yo eare Algebra - Berlin: de Gruyter e Wahrscheinlichkeitstheorie und rices and Markov Chains - New Yo	n Biology and Epidemiolog ssociates 2001 rk: Springer 1999 1990 Statistik - Wiesbaden: View ork: Springer 1981	gy - New York: Springer 2000 veg 2002
Language: • offered only in German			
Notes:			



Is part of CS4441. The lecture is identical to that in module MA4450-MML.

Prerequisites for attending the module:

- None (The competences of the required modules are required for this module, but the modules are not a prerequisite for admission.)

Prerequisites for the exam:

- Preliminary examinations can be determined at the beginning of the semester. If preliminary work has been defined, it must have been completed and positively assessed before the initial examination.





CS4212-KP04, CS4212 - Current Topics SSE (SSEaktuell)				
Duration:	on: Turnus of offer: Credit points:			
1 Semester	each winter semester		4	
Course of study, specific field and term: • Master Computer Science 2019 (opt • Master Computer Science 2019 (con • Master Computer Science 2014 (con • Master Artificial Intelligence 2023 (o	ional subject), Elective, Arbitr npulsory), Canonical Specializ npulsory), specialization field ptional subject), for equivaler	ary semester ation SSE, Arbitrary seme software systems engine nce check, Arbitrary seme	ester ering, 2nd or 3rd semester ester	
Classes and lectures:		Workload:		
<ul> <li>Current Topics SSE (lecture, 2 SWS)</li> <li>Current Topics SSE (seminar, 1 SWS)</li> <li>60 Hours private studies and exercises</li> <li>45 Hours in-classroom work</li> <li>15 Hours exam preparation</li> </ul>		studies and exercises room work reparation		
Contents of teaching: • Model based development • Quality assurance • Development of web and mobile ap	oplications			
<ul> <li>Qualification-goals/Competencies:</li> <li>The students can apply modern soft</li> <li>They can classify and evaluate current</li> </ul>	tware engineering technolog nt trends in software systems	ies in practice. s engineering.		
Grading through: • Written or oral exam as announced	by the examiner			
Responsible for this module: <ul> <li>Prof. Dr. Martin Leucker</li> </ul> Teacher: <ul> <li>Institute of Software Technology and Programming Languages</li> <li>Prof. Dr. Martin Leucker</li> </ul>				
Literature: • Aktuelle Forschungsartikel werden in der Veranstaltung bekanntgegeben.:				
Language: • German and English skills required				
Notes: Prerequisites for attending the module: - None				
Prerequisites for the exam: - Successful completion of homework assignments during the semester				





CS4507-KP12, CS4507 - Software Verification (SoftVeri)				
Duration: Turnus of offer:		Credit points:		
2 Semester	each year, can be started in winter or summer semester		12	
<ul> <li>Course of study, specific field and term:</li> <li>Master Computer Science 2019 (compulsory), Canonical Specialization SSE, Arbitrary semester</li> <li>Master MES 2020 (advanced module), computer science / electrical engineering, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2020 (advanced module), specific, Arbitrary semester</li> <li>Master Computer Science 2019 (optional subject), advanced module, Arbitrary semester</li> <li>Master Computer Science 2014 (compulsory), specialization field software systems engineering, 1st and 2nd semester</li> <li>Master MES 2014 (advanced module), computer science / electrical engineering, 1st and 2nd semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (advanced module), specific, 2nd and 3rd semester</li> <li>Master Computer Science 2014 (advanced module) advanced curriculum 2nd and 3rd semester</li> </ul>				
Classes and lectures:		Workload:		
<ul> <li>CS4138 T: Model Checking (lecture v</li> <li>CS4139 T: Runtime Verification and <sup>-</sup> exercises, 4 SWS)</li> <li>CS5220 T: Static Analysis (lecture with</li> </ul>	vith exercises, 4 SWS) Festing (lecture with h exercises, 4 SWS)	<ul> <li>210 Hours private</li> <li>120 Hours in-class</li> <li>30 Hours exam private</li> </ul>	e studies sroom work reparation	
Contents of teaching: • see module parts				
Qualification-goals/Competencies:				
<ul><li>The students can relate different app</li><li>For further competencies see modul</li></ul>	proaches to software verific e parts	ation.		
Grading through: • Oral examination				
Responsible for this module: <ul> <li>Prof. Dr. Martin Leucker</li> </ul> Teacher: <ul> <li>Institute of Software Technology and Programming Languages</li> <li>Prof. Dr. Martin Leucker</li> </ul>				
Literature: • : see module parts				
Language: • German and English skills required				
Notes: (The module consists of CS4138 T, CS4139 T and CS5220 T)				
2 of the 3 module parts must be chosen.				
Prerequisites for attending the module: - None				
Prerequisites for the exam: - depending on the module parts				



CS5170-KP04, CS5170 - Hardware/Software Co-Design (HWSWCod)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each winter semester		4	
Course of study, specific field and term: Master Computer Science 2019 (con Master Computer Science 2019 (opt Master Media Informatics 2020 (opti Master Robotics and Autonomous S Master Computer Science 2014 (con Master MES 2011 (advanced curricul Master Media Informatics 2014 (opti Master Computer Science 2012 (contined)	npulsory), Canonical Special ional subject), Elective, Arbi onal subject), computer scie ystems 2019 (optional subje npulsory), specialization field um), imaging systems, sign onal subject), computer scie ional subject), specializatior onal subject), advanced cur ional subject), advanced cur	ization SSE, Arbitrary seme trary semester ence, Arbitrary semester ect), Elective, 1st or 2nd ser d software systems engine al and image processing, 1 ence, Arbitrary semester n field robotics and automa iculum parallel and distribu riculum intelligent embed d software systems engine	nester ering, 1st or 2nd semester st or 3rd semester ation, 2nd or 3rd semester uted system architecutres, 2nd or 3rd semester ded systems, 2nd or 3rd semester ering, 2nd semester	
Classes and lectures:		Workload:		
<ul> <li>Hardware/Software Co-Design (lectule)</li> <li>Hardware/Software Co-Design (exerule)</li> </ul>	ure, 2 SWS) cise, 1 SWS)	<ul><li>55 Hours private</li><li>45 Hours in-class</li><li>20 Hours exam p</li></ul>	studies room work reparation	
<ul> <li>20 Hours exam preparation</li> <li>Contents of teaching: <ul> <li>System design flow</li> <li>Basic architectures for HW/SW systems</li> <li>System design and modelling</li> <li>System synthesis</li> <li>Algorithms for scheduling</li> <li>System partitioning</li> <li>Algorithms for system partitioning</li> <li>Design systems</li> <li>Performance analysis</li> <li>System design and specification with SystemC</li> <li>Application examples</li> </ul> </li> <li>Qualification-goals/Competencies: <ul> <li>Students are able to determine a suitable hardware/software architecture for a given system description</li> <li>They are able to determine and describe the pros and cons of implementation alternatives</li> <li>They are able to translate non-formal system partitioning</li> <li>They are able to explain the different steps in system synthesis</li> <li>They are able to explain the different steps in system synthesis</li> <li>They are able to estimate the quality of system design</li> <li>They are able to create system descriptions in SystemC</li> </ul> </li> <li>Grading through: <ul> <li>Written example methods by the examiner.</li> </ul> </li> </ul>				
Responsible for this module:				
Prof. DrIng. Mladen Berekovic				
Teacher:				
Institute of Computer Engineering				
• Prot. Dring. Miaden Berekovic				
Literature: • F. Kesel: Modellierung von digitalen • Teich, J., Haubelt, C.: Digital Hardwa	Systemen mit SystemC - Ol re/Software-Systeme. Synth	denbourg Verlag 2012 ese und Optimierung - Ber	lin: Springer 2007	



### Language:

### • offered only in German

### Notes:

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s):

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

Module Exam(s):

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



CS549	0-KP06, CS5490SJ14 - Lab Soft	tware Systems Engin	eering (PrSSE14)
Duration:	Turnus of offer:		Credit points:
1 Semester	each winter semester		6 (Тур В)
Course of study, specific field a • Master Artificial Intelligen • Master Computer Science • Master Computer Science • Master Computer Science	and term: nce 2023 (optional subject), for equival 2 2019 (compulsory), Canonical Special 2 2019 (optional subject), Elective, Arbi 2 2014 (compulsory), specialization fiel	ence check, Arbitrary sem ization SSE, Arbitrary sem trary semester d software systems engine	ester ester eering, 2nd or 3rd semester
Classes and lectures:		Workload:	
<ul> <li>Lab Software Systems En- SWS)</li> </ul>	<ul> <li>Lab Software Systems Engineering (programming project, 4 SWS)</li> <li>60 Hours group work</li> <li>60 Hours in-classroom work</li> <li>40 Hours private studies</li> <li>20 Hours oral presentation and discussion (including preparation)</li> </ul>		work sroom work e studies resentation and discussion (including
Contents of teaching:			
Design and implementat	ion of an advanced component-based	software/hardware syster	n in team work
<ul> <li>The students can realize of They can derive a system</li> <li>They can construct a com</li> <li>They can implement, test</li> <li>They can document, press</li> <li>They can cooperate within</li> </ul> Grading through: <ul> <li>continuous, successful page</li> </ul>	complex software/hardware systems w design from a requirements specificat ponent-based architecture meeting th t, and integrate components. sent, evaluate and improve the implem in a teamfor a successful project.	vith the acquired techniqu tion. ne system design. nented system.	ies.
Responsible for this module:			
<ul> <li>Prof. Dr. Martin Leucker</li> <li>Teacher: <ul> <li>Institute for Theoretical C</li> <li>Institute of Information Sy</li> <li>Institute of Telematics</li> <li>Institute of Software Tech</li> <li>Prof. Dr. Martin Leucker</li> <li>Prof. Dr. rer. nat. habil. Ra</li> </ul> </li> </ul>	Computer Science ystems nnology and Programming Languages If Möller		
Prot. Dr. Stefan Fischer			
Literature: • : Projektspezifische Litera	tur wird in der Veranstaltung angegeb	ben	
Language: • English, except in case of	only German-speaking participants		
Notes:			



Prerequisites for attending the module: - None

Prerequisites for the exam:

- Successful participation in the internship (including successful solution of the project tasks) with presentation and documentation as specified at the beginning of the semester

Module exam(s):

CS5490-L1: Project Internship Software Systems Engineering, ungraded internship, 0% of module grade, must be passed.



CS4250-KP04, CS4250 - Computer Vision (CompVision)					
Duration:	Turnus of offer:	Credit points:			
1 Semester	each summer semester	4			
Ocurse of study, specific field and term:       • Master CLS 2023 (optional subject), computer science, 2nd or 3rd semester         • Master MES 2020 (optional subject), computer science / electrical engineering, Arbitrary semester         • Master Computer Science 2019 (optional subject), Elective, Arbitrary semester         • Master Media Informatics 2020 (optional subject), Elective, Arbitrary semester         • Master Biophysics 2019 (optional subject), Elective, Arbitrary semester         • Master Biophysics 2019 (optional subject), Elective, Arbitrary semester         • Master Biomedical Engineering (optional subject), advanced curriculum, 2nd semester         • Master MES 2014 (optional subject), computer science, 2nd or 3rd semester         • Master Media Informatics 2014 (optional subject), computer science, Arbitrary semester         • Master Media Informatics 2012 (optional subject), computer science, Arbitrary semester         • Master Media Informatics 2014 (optional subject), computer science, Arbitrary semester         • Master Computer Science 2012 (optional subject), advanced curriculum imaging systems, 2nd or 3rd semester         • Master CLS 2010 (compulsory), computational life science / imaging, 2nd semester         • Master Computer Science 2012 (optional subject), advanced curriculum signal and image processing, 2nd or 3rd semester         • Master Computer Science 2012 (optional subject), advanced curriculum signal and image processing, 2nd or 3rd semester         • Master Computer Science 2012 (optional subject), advanced curriculum signal and image processing, 2nd					
Classes and lectures:		Workload:			
<ul> <li>Computer Vision (lecture, 2 SWS)</li> <li>Computer Vision (exercise, 1 SWS)</li> <li>Somputer Vision (exercise, 1 SWS)</li> <li>Computer Vision (exercise, 1 SWS)</li> <li>Somputer Vision (exercise, 1 SWS)</li> </ul>		<ul> <li>55 Hours private studies</li> <li>45 Hours in-classroom work</li> <li>20 Hours exam preparation</li> </ul>			
<ul> <li>Introduction to human a</li> <li>Sensors, cameras, optics</li> <li>Image features: edges, i</li> <li>Range imaging and 3-D</li> <li>Motion and optical flow</li> <li>Object recognition</li> <li>Example applications</li> </ul>	<ul> <li>Contents of teaching:</li> <li>Introduction to human and computer vision</li> <li>Sensors, cameras, optics and projections</li> <li>Image features: edges, intrinsic dimension, Hough transform, Fourier descriptors, snakes</li> <li>Range imaging and 3-D cameras</li> <li>Motion and optical flow</li> <li>Object recognition</li> <li>Example applications</li> </ul>				
<ul> <li>Qualification-goals/Competencies:</li> <li>Students can understand the basics of computer vision.</li> <li>They can explain and perform camera choice and calibration.</li> <li>They can explain and apply the basic methods for feature extraction, motion estimation, and object recognition.</li> <li>They can indicate appropriate methods for different kinds of computer-vision applications.</li> </ul>					
Grading through:  Oral examination					
Responsible for this module: <ul> <li>Prof. DrIng. Erhardt Barth</li> </ul> <li>Teacher: <ul> <li>Institute for Neuro- and Bioinformatics</li> <li>Prof. DrIng. Erhardt Barth</li> </ul> </li>					
Literature: <ul> <li>Richard Szeliski: Computer Vision: Algorithms and Applications - Springer, Boston, 2011</li> <li>David Forsyth and Joan Ponce: Computer Vision: A Medern Approach – Breatice Holl 2003</li> </ul>					
Language:					





CS4295-KP04 - Deep Learning (DEEPL)					
Duration:	Turnus of offer:		Credit points:		
1 Semester	each winter semester		4		
Course of study, specific field an Master Computer Science 2 Master Psychology 2016 (o Master Biophysics 2023 (op Master Media Informatics 2 Master MES 2020 (optional Master Entrepreneurship in	d term: 2019 (optional subject), Elective, A ptional subject), Elective, Arbitrary ptional subject), Elective, Arbitrary 2020 (optional subject), Elective, A subject), Elective, Arbitrary semes n Digital Technologies 2020 (optio	arbitrary semester y semester semester rbitrary semester ster nal subject), specific, Arbitra	ary semester		
Classes and lectures:		Workload:			
<ul> <li>CS4295-V: Deep Learning (</li> <li>CS4295-Ü: Deep Learning (</li> </ul>	lecture, 2 SWS) (exercise, 2 SWS)	<ul><li>75 Hours privat</li><li>45 Hours in-cla</li></ul>	te studies Issroom work		
Approximation Theorem, N Optimization (Stochastic G Convolutional Neural Netw Techniques, Transposed Co Regularization (Early Stopp Very Deep Networks (High Dimensionality Reduction Generative Neural Networks (G Fooling Deep Neural Networks (G Fooling Deep Neural Networks (G Fooling Deep Neural Netw Physics-Aware Deep Learn Qualification-goals/Competenci Students get a fundament auto-differentiation Students understand the in Students learn to analyze t Students will understand t Students know how to ana their relevance	<ul> <li>Foundations and Deep Learning Basics (Learning Paradigms, Classification and Regression, Underfitting and Overfitting)</li> <li>Shallow Neural Networks (Basic Neuron Model, Multilayer Perceptions, Backpropagation, Computational Graphs, Universal Approximation Theorem, No-Free Lunch Theorems, Inductive Biases)</li> <li>Optimization (Stochastic Gradient Descent, Momentum Variants, Adaptive Optimizer)</li> <li>Convolutional Neural Networks (1D Convolution, 2D Convolution, 3D Convolution, ReLUs and Variants, Down and Up Sampling Techniques, Transposed Convolution)</li> <li>Regularization (Early Stopping, L1 and L2 Regularization, Label Smoothing, Dropout Strategies, Batch Normalization)</li> <li>Very Deep Networks (Highway Networks, Residual Blocks, ResNet Variants, DenseNets)</li> <li>Dimensionality Reduction (PCA, t-SNE, UMAP, Autoencoder)</li> <li>Generative Neural Networks (Graph Convolutional Networks, Graph Attention Networks)</li> <li>Fooling Deep Neural Networks (Adversarial Attacks, White Box and Black Box Attacks, One-Pixel Attacks)</li> <li>Physics-Aware Deep Learning (Physical Knowledge as Inductive Bias, PINN, PhyDNet, Neural ODE, FINN)</li> </ul> Qualification-goals/Competencies: <ul> <li>Students get a fundamental understanding deep learning basics such as backpropagation, computational graphs, and auto-differentiation</li> <li>Students get a fundamental understanding deep learning basics such as backpropagation, computational graphs, and auto-differentiation</li> <li>Students get a comprehensive understanding of most relevant deep learning approaches</li> <li>Students learn to analyze the challenges in deep learning tasks and to identify well-suited approaches to solve them</li> <li>Students learn to analyze the challenges in deep learning tasks and to identify well-suited approaches to solve them</li> </ul>				
Grading through:					
Written or oral exam as an	nounced by the examiner				
Responsible for this module: • Prof. Dr. Sebastian Otte Teacher: • Institute for Robotics and Cognitive Systems • MitarbeiterInnen des Instituts • Prof. Dr. Sebastian Otte					
<ul> <li>Literature:</li> <li>Goodfellow, I., Bengio, Y., &amp; Courville, A. (2016): Deep Learning - MIT Press. ISBN 978-0262035613</li> <li>Prince, S. J. D. (2023): Understanding Deep Learning - The MIT Press. ISBN 978-0262048644</li> <li>Deisenroth, M. P., Faisal, A. A., &amp; Ong, C. S. (2020): Mathematics for Machine Learning - Cambridge University Press, 2020. ISBN 978-1108470049</li> </ul>					



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• Bishop, C. M. (2006): Pattern Recognition and Machine Learning - Springer. ISBN 978-0387310732

## Recent publications on the related topics:

#### Language:

## • offered only in English

#### Notes:

Admission requirements for taking the module:

- None

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

Module Exam(s):

- CS4295-L1: Deep Learning, exam, 90 min

According to the decision of the examination board of computer science of 19.8.2024 this module can be chosen by students Master Computer Science SGO from 2019 in the area of 5th elective.



CS4451-KP06 - Privacy (Privacy)				
Duration:	Turnus of offer: Credit points:			
1 Semester	each winter semester		6	
Course of study, specific field and term: • Master Computer Science 2019 (opti • Master Medical Informatics 2014 (op • Master Medical Informatics 2019 (op • Master IT-Security 2019 (optional sub	ional subject), Elective, Arb tional subject), ehealth / in tional subject), ehealth / in bject), IT Security and Priva	itrary semester fomatics, 1st or 2nd semes fomatics, 1st or 2nd semes cy, 1st, 2nd, or 3rd semeste	ter ter r	
Classes and lectures:Workload:• Privacy (lecture, 2 SWS)• 100 Hours private studies• Privacy (exercise, 2 SWS)• 60 Hours in-classroom work• 20 Hours exam preparation		e studies room work reparation		
<ul> <li>Contents of teaching:</li> <li>Private statistics (Differential Privacy)</li> <li>Privacy preserving machine learning</li> <li>Privacy attacks against machine-learned models</li> <li>Privacy-preserving computation in distributed systems.</li> <li>Stylometry: de-anonymization via writing style</li> <li>Anonymity</li> </ul>				
Qualification-goals/Competencies: <ul> <li>Deep understanding for algorithmic</li> <li>Skills to analyze complex security red</li> </ul>	and algebraic methods to quirements	secure private data		
Grading through: • Oral examination				
Requires: • Trustworthy Al (CS5075-KP06)				
Responsible for this module: • Prof. Dr. rer. nat. Esfandiar Mohammadi Teacher: • Institute for IT Security • Prof. Dr. rer. nat. Esfandiar Mohammadi				
<ul> <li>Literature:</li> <li>C. Dwork, A. Roth: The Algorithmic Foundations of Differential Privacy - Now Publishers Inc, 2014</li> <li>Stanford: Encyclopedia of Philosophy on Privacy</li> <li>Andrej Bogdanov: Lecture notes by Andrej Bogdanov from Chinese University of Hong Kong</li> <li>Journal und Konferenz-Publikationen: wird aktuell benannt</li> </ul>				
Language: • English, except in case of only German-speaking participants				
Notes: Admission requirements for taking the module: - None (the competencies under				





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

According to the decision of the examination board of computer science of 15.1.2020 this module can be chosen by students Master Computer Science SGO from 2019 in the area of 5th elective.





CS4575-KP04 - Sequence Learning (SEQL)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	every summer semester		4	
<ul> <li>Course of study, specific field and term:         <ul> <li>Master Computer Science 2019 (optional subject), Elective, Arbitrary semester</li> <li>Master Medical Informatics 2019 (optional subject), Medical Data Science / Artificial Intelligence, 1st or 2nd semester</li> <li>Master Psychology 2016 (optional subject), Elective, Arbitrary semester</li> <li>Master Biophysics 2023 (optional subject), Elective, Arbitrary semester</li> <li>Master Media Informatics 2020 (optional subject), Elective, Arbitrary semester</li> <li>Master Media Informatics 2020 (optional subject), Elective, Arbitrary semester</li> <li>Master MES 2020 (optional subject), Elective, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2020 (optional subject), specific, Arbitrary semester</li> </ul> </li> </ul>				
Classes and lectures:		Workload:		
<ul> <li>CS4575-V: Sequence Learning (lectu</li> <li>CS4575-Ü: Sequence Learning (exer</li> </ul>	re, 2 SWS) cise, 1 SWS)	<ul> <li>75 Hours private</li> <li>45 Hours in-class</li> </ul>	studies sroom work	
<ul> <li>Introduction to Sequence Learning (Formalisms, Metrics, Recapitulation of Relevant Machine Learning Techniques)</li> <li>Recurrent Neural Networks (Simple RNN Models, Backpropagation Through Time)</li> <li>Gated Recurrent Networks (Vanishing Gradient Problem in RNNs, Long Short-Term Memories, Gated Recurrent Units, Stacked RNNs)</li> <li>Important Techniques for RNNs (Teacher Forcing, Scheduled Sampling, h-Detach)</li> <li>Bidirectional RNNs and related concepts</li> <li>Hierarchical RNNs and Learning on Multiple Time Scales</li> <li>Online Learning and Learning without BPTT (Real-Time Recurrent Learning, e-Prop, Forward Propagation Through Time)</li> <li>Reservoir Computing (Echo State Networks, Deep ESNs)</li> <li>Spiking Neural Networks (Spiking Neuron Models, Learning in SNNs, Neuromorphic Computing, Recurrent SNNs)</li> <li>Temporal Convolution Networks (Causal Convolution, Temporal Dilation, TCN-ResNets)</li> <li>Introduction to Transformers (Sequence-to-Sequence Learning, Basics on Attention, Self-Attention and the Query-Key-Value Principle, Large Language Models)</li> <li>State Space Models (Structured State Space Sequence Models Mamba)</li> </ul>				
<ul> <li>Qualification-goals/Competencies:</li> <li>Students get a comprehensive understanding of most relevant sequence learning approaches</li> <li>Students learn to analyze the challenges in sequence learning tasks and to identify well-suited approaches to solve them</li> <li>Students will understand the pros and cons of various sequence learning models</li> <li>Students can implement common and custom sequence learning models for time series analysis, classification, and forecasting</li> <li>Students know how to analyze the models and results, to improve the model parameters, and to interpret the model predictions and their relevance</li> </ul>				
Grading through:	by the examiner			
Responsible for this module:         • Prof. Dr. Sebastian Otte         Teacher:         • Institute for Robotics and Cognitive Systems         • MitarbeiterInnen des Instituts         • Prof. Dr. Sebastian Otte				
<ul> <li>Goodfellow, I., Bengio, Y., &amp; Courville, A. (2016): Deep Learning - MIT Press. ISBN 978-0262035613</li> <li>Prince, S. J. D. (2023): Understanding Deep Learning - The MIT Press. ISBN 978-0262048644</li> <li>Deisenroth, M. P., Faisal, A. A., &amp; Ong, C. S. (2020): Mathematics for Machine Learning - Cambridge University Press, 2020. ISBN 978-1108470049</li> <li>Nakajima, K., &amp; Fischer, I. (2021): Reservoir Computing: Theory, Physical Implementations, and Applications - Cambridge University</li> </ul>				



Press, 2020. ISBN 978-1108470049

• Sun, R., & Giles, C. (2001): Sequence Learning: Paradigms, Algorithms, and Applications - Springer Berlin Heidelberg. ISBN 978-3540415978

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• Bishop, C. M. (2006): Pattern Recognition and Machine Learning - Springer. ISBN 978-0387310732

• Recent publications on the related topics:

#### Language:

#### offered only in English

#### Notes:

Admission requirements for taking the module:

- None, but it is recommended to complete the course Deep Learning (CS4295-KP04) first

Admission requirements for participation in module examination(s):

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

Module Exam(s):

- CS4575-L1: Sequence Learning, exam, 90 min

According to the decision of the examination board of computer science of 19.8.2024 this module can be chosen by students Master Computer Science SGO from 2019 in the area of 5th elective.

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



CS4705-KP06 - Cryptographic Engineering (CryEng)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	every summer semester		6	
Course of study, specific field and term: • Master Entrepreneurship in Digital • Master Robotics and Autonomous • Master Computer Science 2019 (op • Master IT-Security 2019 (optional se	Technologies 2020 (advanced Systems 2019 (optional subje tional subject), Elective, Arbit ubject), IT Security and Privac	d module), specific, Arbi ct), Additionally recogni trary semester cy, 1st, 2nd, or 3rd semes	itrary semester ized elective module, Arbitrary semester ster	
Classes and lectures:		Workload:		
<ul> <li>Cryptographic Engineering (lecture</li> <li>Cryptographic Engineering (exercise)</li> </ul>	raphic Engineering (lecture, 2 SWS)• 100 Hours private studiesraphic Engineering (exercise, 2 SWS)• 60 Hours in-classroom work• 20 Hours exam preparation			
Contents of teaching: • Efficient Implementation of Finite I • Stream Ciphers: Design and hardw • Block Ciphers: Design, hardware Im • Hash Functions: Design and hardw • Public-Key Cryptography over GF(2 • True and Pseudo Random Number • Physical Unclonable Functions (PU	Field Arithmetic for cryptogra are Implementation. aplementation, and Lightweig are Implementation. 2m): Design and Implementat Generators (TRNG): Design, t Fs): Design Challenges and H	phic Applications. ght Encryption Algorithr ion. est, and hardware Imple ardware- Architectures.	ns. ementation.	
<ul> <li>Qualification-goals/Competencies:</li> <li>Students will become familiar with the concept of cryptographic engineering and the associated topics with it.</li> <li>They can expand and enhance their knowledge about a cryptography and applied cryptography.</li> <li>They can become more familiar with the concepts of hardware-security.</li> <li>They can learn efficient implementation of Finite Field Arithmetic in hardware and its applications in cryptography.</li> <li>They can learn the techniques for hardware-implementation of cryptographic algorithms</li> <li>They can demonstrate a deep understanding of several structures and designs of stream and block ciphers</li> <li>They can take an advanced step towards hardware and physical security such as TRNG, PUFs.</li> </ul>				
Grading through: • written exam				
Requires: • Cryptology (CS3420-KP04, CS3420)				
Responsible for this module: <ul> <li>Prof. DrIng. Mladen Berekovic</li> </ul> Teacher: <ul> <li>Institute of Computer Engineering</li> <li>DrIng. Saleh Mulhem</li> </ul>				
<ul> <li>Literature:</li> <li>Ferguson, Niels, Bruce Schneier, and Tadayoshi Kohno: Cryptography Engineering: Design Principles and Practical Applications - 2012</li> <li>Koç Ç.K.: Cryptographic Engineering - Springer, Boston, MA, (2009)</li> <li>Wachsmann, Christian, and Ahmad-Reza Sadeghi: Physically unclonable functions (PUFs): Applications, models, and future directions - Morgan &amp; Claypool Publishers, 2014</li> <li>Johnston, David: Random Number Generators Principles and Practices: A Guide for Engineers and Programmers - Walter de Gruyter GmbH &amp; Co KG, 2018</li> <li>Language: <ul> <li>offered only in English</li> </ul> </li> </ul>				
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### Notes:

Admission requirements for taking the module:

- None

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

Module examination(s):

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





CS4720-KP06 - Energy Efficiency in Emebedded Systems (EEE)				
Duration:	Turnus of offer: Credit points:			
1 Semester	every summer semester		6	
Course of study, specific field and term: • Master Robotics and Autonomous Sy • Master Computer Science 2019 (optic	stems 2019 (module part), onal subject), Elective, Arbit	Additionally recognized ele trary semester	ective module, Arbitrary semester	
Classes and lectures:Workload:• Energy Efficiency in Emebedded Systems (lecture, 2 SWS)• 85 Hours private s• Energy Efficiency in Emebedded Systems (exercise, 2 SWS)• 70 Hours in-classre• 25 Hours exam pre		studies and exercises room work reparation		
Contents of teaching: • Motivation and power dissipation or • Power dissipation of digital circuits, i • Power Management in Hard- and So • Energy efficient system design (appli • Energy Harvesting and Transiently Po	a semiconductor level nparticular CMOS ftware (Sleep Modes, DVS, I cations) owered Computing (TPC)	FS, Undervolting)		
<ul> <li>Qualification-goals/Competencies:</li> <li>students will have a deeper understanding of hardware and software mechanisms for evaluating and developing energy-efficient embedded systems</li> <li>They have a deeper understanding of the electrotechnical basics of power dissipation in digital systems</li> <li>They can analyze the power dissipation of systems at any level and apply appropriate methods to increase efficiency</li> <li>They can use a variety of standard techniques to achieve</li> <li>They can model and evaluate energy-autonomous systems</li> </ul>				
<ul><li>Grading through:</li><li>Written or oral exam as announced by the examiner</li></ul>				
Responsible for this module: • Prof. DrIng. Mladen Berekovic Teacher: • Institute of Computer Engineering • Dr. Ulf Kulau				
<ul> <li>Literature:         <ul> <li>Ulf Kulau: Course: Energy Efficiency in Embedded Systems A System-Level Perspective for Computer Scientists - EWME, 2018</li> <li>David Harris and N. Weste: CMOS VLSI Design ed Pearson Education, 2010</li> <li>Jan Rabaey: Low Power Design Essentials (Integrated Circuits and Systems) - Springer, 2009</li> </ul> </li> <li>Language:</li> </ul>				
English, except in case of only German-speaking participants				
Notes: Prerequisites for attending the module: - None Prerequisites for the exam: - Successful completion of practice and project assignments during the semester.				





CS5020-KP06 - Algorithmic Learning and Causality (ALKI)					
Duration:	Turnus of offer:		Credit points:		
1 Semester	normally each year in th	e summer semester	6		
Course of study, specific field and term • Master Computer Science 2019 (c • Master Computer Science 2019 (c	n: optional subject), Elective, Ar compulsory), Canonical Speci	bitrary semester alization Data Science ar	ıd Al, Arbitrary semester		
Classes and lectures:		Workload:			
<ul> <li>Algorithmic Learning and Causal</li> <li>Algorithmic Learning and Causal</li> </ul>	ity (lecture, 4 SWS) ity (exercise, 1 SWS)	<ul><li> 105 Hours pr</li><li> 75 Hours in-c</li></ul>	vate studies lassroom work		
Contents of teaching: • inductive inferenz • algorithmic learning strategies, c • causality, structures and effects • structural learning, linear models	omplexity analysis counterfactual inference				
Qualification-goals/Competencies: <ul> <li>The students can understand and</li> <li>They dan compare statistic and letter</li> </ul>	d analyse methods for the ge ogic approaches.	neration of knowlege.			
Grading through: • Oral examination	Grading through: • Oral examination				
Requires: • Machine Learning (CS5450-KP04,	CS5450)				
Responsible for this module: • Prof. Dr. Rüdiger Reischuk Teacher: • Institute for Theoretical Compute • Prof. Dr. Maciej Liskiewicz • Prof. Dr. Rüdiger Reischuk	er Science				
Literature: • : • : • :					
Language: •					
Notes: Prerequisites for attending the mod - None	dule:				



CS5070-KP04 - Advanced Topics Data Science and AI (Dataakuell)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each semester		4	
Course of study, specific field and terr • Master Computer Science 2019 ( • Master Media Informatics 2020 ( • Master Computer Science 2019 ( • Master Computer Science 2019 (	n: compulsory), Canonical Specia optional subject), computer sci compulsory), Canonical Specia optional subject), Elective, Arbi	lization Bioinformatics and S ience, 3rd semester lization Data Science and AI, itrary semester	Systems Biology, Arbitrary semester , Arbitrary semester	
Classes and lectures:Workload:• CS5070-V: Advanced Topics Data Science and AI (lecture, 2 SWS)• 60 Hours private studies • 45 Hours in-classroom work• CS5070-S: Advanced Topics Data Science and AI (seminar, 1 SWS)• 15 Hours exam preparation				
Contents of teaching: • Current research results and app • Probabilistic Differential Program • Automated Planning and Acting • Quantum Computing • Stochastic Relational Modeling a	lications of data science and an nming nd Learning	rtificial intelligence techniqu	uesTopics are among:	
<ul> <li>Qualification-goals/Competencies:</li> <li>All current techniques taught in the module can be named and defined by the students and their functional proofs can be explained on the basis of applications.</li> <li>Students are able to identify advantages and disadvantages of Data Science- and Al-based system development approaches.</li> <li>Students are able to identify ethical aspects and assess their implications.</li> </ul>				
Grading through: • Oral examination				
Responsible for this module: • Prof. Dr. rer. nat. habil. Ralf Mölle Teacher: • Institute of Information Systems • Prof. Dr. rer. nat. habil. Ralf Mölle • PD Dr. Özgür Özçep • Prof. Dr. Sven Groppe	r r			
<ul> <li>Literature:</li> <li>Current conference papers for the topics of the course will be announced in lectures</li> </ul>				
Language: • German and English skills required				
Notes: Choose 1 out of 2: Students must a Prerequisites for attending the mod - None Prerequisites for the exam: - None	ttend one of the two courses. dule:			





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CS5075-KP06 - Trustworthy AI (TrustAI)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each summer semester		6	
Course of study, specific field • Master Computer Scienc • Master Medical Informat • Master IT-Security 2019	and term: ce 2019 (optional subject), Elective, Arbi tics 2019 (optional subject), ehealth / inf (optional subject), IT Security and Privad	trary semester fomatics, 1st or 2nd ser cy, 1st, 2nd, or 3rd seme	nester ester	
Classes and lectures:Workload:• CS5075-V: Trustworthy AI (lecture, 3 SWS)• 100 Hours private studies• CS5075-Ü: Trustworthy AI (exercise, 1 SWS)• 60 Hours in-classroom work• 20 Hours exam preparation			ivate studies lassroom work m preparation	
Contents of teaching:				
<ul> <li>Guiding principles of Tru</li> <li>Trustworthy Computing</li> <li>De-anonymization meth</li> <li>Mathematical notions for</li> <li>Privacy-preserving mach</li> <li>Analyse maschinell gele</li> <li>Verifikation maschinell gele</li> <li>Black-Box methods for e</li> <li>Attacks for manipulating</li> <li>Hardening of machine learn (Privacy-Preserving Feder</li> </ul>	ustworthy AI: lawful, ethical and robust basics: Security, Privacy, Dependability, nods using machine learning models or privacy-preserving machine learning m nine learning methods wrnter Modellen (Robustness Check, Expl gelernter Modellen ((Statistical Testing), extracting machine learning models (for g machine learning models (adversarial earning methods against manipulation ning methods against manipulation atta erated Learning)	Al , Safety, Transparency, I methods lainability) Model Checking) economical reasons, fc examples, backdoors) methods acksSecure and privacy-	Explainability, Traceability, Accountability or analysis, and for verification) preserving distributed learning methods	
<ul> <li>Qualification-goals/Competer</li> <li>All current techniques ta proofs can be explained</li> <li>The formal foundations</li> <li>Students are able to ide</li> <li>Understanding about po</li> <li>Understanding of harde</li> <li>Students can analyze co</li> </ul>	ncies: aught in the module and described abo I on the basis of applications. from the course can be precisely explai ntify advantages and disadvantages of otential vulnerabilities of machine learn ming methods compared to deanonymi omplex security requirements	ve can be named and c ned planning and acting ap ing methods w.r.t. priva ization and manipulatic	defined by the students and their functional proaches acy-violations and manipulation possibilities on methods	
Grading through: • Oral examination				
Is requisite for: • Privacy (CS4451-KP06)				
Responsible for this module:         • Prof. Dr. rer. nat. Esfandiar Mohammadi         Teacher:         • Institute of Software Technology and Programming Languages         • Institute for IT Security         • Prof. DrIng. Thomas Eisenbarth         • Prof. Dr. Martin Leucker         • Prof. Dr. rer. nat. Esfandiar Mohammadi				
Literature:				
C. Dwork, A. Roth: The A     Andrej Bogdanov: Lectu	lgorithmic Foundations of Differential F Ire notes by Andrei Bogdanov from Chir	Privacy - Now Publisher nese University of Honc	s Inc, 2014 I Kong	

• : Current conference and journal articles on the topics of the event will be announced at the beginning of the event in the case of the



seminar and at the discussion of the topic in the case of the lecture.

### Language:

#### offered only in English

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#### Notes:

Admission requirements for taking the module:

- None

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

Module Exam(s):

- CS5075-L1: Trustworthy AI, oral examination, 100% of module grade.

According to the decision of the examination board of computer science from 19.1.2022 this module can be chosen for Master SGO from WS 2019 in the area 5. elective.





CS5195-KP04 - Current Topics in IT Security (AktTheITS)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each semester		4	
Course of study, specific field and te • Master Computer Science 2019 • Master IT-Security 2019 (compu • Master Robotics and Autonome	<b>rm:</b> (optional subject), Elective, Arbit ulsory), IT-Security, 3rd semester ous Systems 2019 (optional subje	crary semester ct), Additionally recogniz	ed elective module, Arbitrary semester	
Classes and lectures:Workload:• Current Topics IT Security and Reliability (seminar-style• 45 Hourslectures, 2 SWS)• 45 Hours• Current Topics IT Security and Reliability (project work, 1 SWS)• 30 Hours		Workload: • 45 Hours work c • 45 Hours in-clas • 30 Hours private	on project sroom work e studies and exercises	
Contents of teaching: <ul> <li>new results in cyber security</li> <li>design and implementation of</li> </ul>	a secure system for a complex ap	oplication and its security	analysis	
Qualification-goals/Competencies: • deeper knowledge of current c • professional experience of con	levelopments in IT security structing and analyzing compute	r systems and networks v	vith respect to security issues	
Grading through: • Oral examination				
Responsible for this module: • Prof. DrIng. Thomas Eisenbart Teacher: • Institute for IT Security • Institute for Theoretical Compu • Prof. Dr. Maciej Liskiewicz • Prof. Dr. Rüdiger Reischuk • Prof. DrIng. Thomas Eisenbart • Prof. Dr. rer. nat. Esfandiar Moh	h iter Science h ammadi			
<ul> <li>Literature:</li> <li>papers to be discussed depend on specific topics: -</li> </ul>				
<ul> <li>English, except in case of only German-speaking participants</li> </ul>				
Notes: Admission requirements for takin - None Admission requirements for parti - alternates, will be announced at Module Exam(s): - CS5195-L1: Current Topics in IT	ig the module: cipation in module examination(s the beginning of the semester Security, oral exam, 100% of mod	s): lule grade.		

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

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





CS5400-KP08, CS5400 - Current Trends in Bioinformatics (WahlBioInf)						
Duration:	Turnus of offer:		Credit points:			
1 Semester	each semester		8			
<ul> <li>Course of study, specific field and term:</li> <li>Master Computer Science 2019 (optional subject), Elective, Arbitrary semester</li> <li>Master Computer Science 2019 (compulsory), Canonical Specialization Bioinformatics and Systems Biology, 2nd and/or 3rd semester</li> <li>Master Computer Science 2014 (compulsory), specialization field bioinformatics, 2nd and/or 3rd semester</li> </ul>						
<ul> <li>Classes and lectures:</li> <li>CS5410 T: Artificial Life (lecture with exercises, 3 SWS)</li> <li>CS5275 T: Selected Topics of Signal Analysis and Enhancement (lecture with exercises, 3 SWS)</li> <li>MA2600 T: Biostatistics 2 (lecture with exercises, 3 SWS)</li> <li>MA4400 T: Chaos and Complexity of Biological Systems (lecture with exercises, 3 SWS)</li> <li>CS5450 T: Machine Learning (lecture with exercises, 3 SWS)</li> <li>CS5440 T: Seminar Neuro- and Bioinformatics (seminar, 2 SWS)</li> <li>EW4170: Systems Biology (lecture with exercises, 3 SWS)</li> <li>LS1600-MI T: Organic Chemistry (lecture, 3 SWS)</li> <li>CS5549 T: Project Bioinformatics (practical course, 3 SWS)</li> </ul>			odule parts)			
Contents of teaching: • see module parts						
Qualification-goals/Competencies: • see module parts	Qualification-goals/Competencies: <ul> <li>see module parts</li> </ul>					
Grading through: • Oral examination						
Responsible for this module: • Prof. Dr. rer. nat. Thomas Mart Teacher: • Institute of Medical Biometry a • Institute for Mathematics • Institute for Robotics and Cog • Institute for Signal Processing • Institute for Neuro- and Bioinf	inetz and Statistics nitive Systems ormatics					
Literature: • : see module parts						
Language: • German and English skills requ	iired					
Notes: You must pick module parts tota	ling 8 ECTS.					
Prerequisites for attending the n - None	nodule:					
Prerequisites for the exam: - depending on the module part	S					



LS	53151-КР04, LS3151 - Мо	lecular Biology (Moli	
Duration:	Turnus of offer:		Credit points:
1 Semester	not available anymore		4
Course of study, specific field and ter Master Computer Science 2019 Master Computer Science 2019 Master Medical Informatics 2019 Master Computer Science 2014 Master Medical Informatics 2014 Master Computer Science 2012	m: (compulsory), Canonical Special (optional subject), Elective, Arbir 9 (optional subject), bioinformat (compulsory), specialization field 4 (optional subject), bioinformat (compulsory), specialization field	ization Bioinformatics and trary semester ics, 1st or 2nd semester d bioinformatics, 1st, 2nd, ics, 1st or 2nd semester d bioinformatics, 2nd seme	l Systems Biology, Arbitrary semester or 3rd semester ester
Classes and lectures:		Workload:	
<ul> <li>Molecular Biology (lecture, 2 SW</li> <li>Molecular Biology (seminar, 2 SW</li> </ul>	/S) WS)	<ul><li>60 Hours private</li><li>60 Hours in-class</li></ul>	studies sroom work
<ul> <li>Contents of teaching:</li> <li>Lecture: Molecular basis for provinfection biology, host genome</li> <li>Seminar: Scientific article readin</li> <li>understanding scientific context</li> <li>training in reading English in scientific</li> </ul>	cessing and analysis of biologica and virus infection, stem cell bio ig and oral presentation t ience	al data (nucleic acids, genc blogy)	ome sequencing, DNA polymorphism,
Qualification-goals/Competencies:			
<ul> <li>Students are able to present base</li> <li>They are able to explain the mo</li> <li>They acquire the competence to</li> </ul>	sic molecular biological requirer lecular biological terms genome o handle English literature and t	nents for processing and a e, transcriptome and prote o present it in a scientific o	analysis of biological data. come. oral presentation.
Grading through: • Oral examination			
<ul> <li>Responsible for this module:</li> <li>Prof. Dr. rer. nat. Norbert Tautz</li> <li>Teacher: <ul> <li>Institute of Virology and Cell Bio</li> <li>Dr. rer. nat. Olaf Isken</li> <li>Prof. Dr. rer. nat. Norbert Tautz</li> </ul> </li> </ul>	ology		
Literature: • Alberts et al.: Molecular Biology • Lodish et al.: Molecular Cell Biol	of Cells - Garland Science ogy - Freeman		
Language: • offered only in German			
Notes: Seminar-dates by appointment, pr Prerequisites for attending the mo - None Prerequisites for the exam: - attendance, >90%	rior registration is mandatory odule:		


CS4511-KP12, CS4511 - Learning Systems (LernSys)			
Duration:	Turnus of offer:		Credit points:
2 Semester	irregularly		12
<ul> <li>Course of study, specific field and term:</li> <li>Master Biophysics 2023 (advanced module), advanced curriculum, 1st or 2nd semester</li> <li>Master Computer Science 2019 (optional subject), Canonical Specialization Bioinformatics and Systems Biology, Arbitrary semester</li> <li>Master MES 2020 (advanced module), computer science / electrical engineering, Arbitrary semester</li> <li>Master Computer Science 2019 (optional subject), Canonical Specialization Data Science and AI, Arbitrary semester</li> <li>Master Entrepreneurship in Digital Technologies 2020 (advanced module), specific, Arbitrary semester</li> <li>Master Computer Science 2019 (optional subject), advanced module), specific, Arbitrary semester</li> <li>Master Biophysics 2019 (advanced module), advanced curriculum, 1st and 2nd semester</li> <li>Master IT-Security 2019 (advanced module), Elective Computer Science, 1st or 2nd semester</li> <li>Master MES 2014 (advanced module), computer science / electrical engineering, 1st and 2nd semester</li> <li>Master Entrepreneurship in Digital Technologies 2014 (advanced module), specific, 2nd and 3rd semester</li> <li>Master Computer Science 2014 (advanced module), advanced curriculum, 2nd and 3rd semester</li> </ul>			
Classes and lectures: • CS4405 T: Neuro Informatics (lectur • CS5450 T: Machine Learning (lectur • CS5430 T: Seminar Machine Learnin	res:Workload:leuro Informatics (lecture with exercises, 3 SWS)• 180 Hours private studiesAachine Learning (lecture with exercises, 3 SWS)• 120 Hours in-classroom workeminar Machine Learning (seminar, 2 SWS)• 40 Hours exam preparation• 20 Hours work on an individual topic with written and c presentation		e studies sroom work reparation n an individual topic with written and oral
Contents of teaching: • see module parts			
Qualification-goals/Competencies: <ul> <li>see module parts</li> </ul>			
Grading through: • Oral examination			
Responsible for this module: • Prof. Dr. rer. nat. Thomas Martinetz Teacher: • Institute for Neuro- and Bioinformatics • Prof. Dr. rer. nat. Thomas Martinetz • Prof. DrIng. Erhardt Barth			
Literature: • : see module parts			
Language: • German and English skills required			
Notes:			



Admission requirements for taking the module: - None

Admission requirements for participation in module examination(s):

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

Module Exam(s):

- CS4511-L1: Learning Systems, oral exam, 100% of module grade.

(Consists of CS4405 T, CS5450 T, CS5430 T)

Only for computer science students with the application subject Bioinformatics, the course CS4405 T Neuroinformatics is replaced by CS5204 T Artificial Intelligence 2, because this group of participants must already complete Neuroinformatics as part of a required module.



CS4516-KP12 - Bioinformatics and System Biology (BioinfVert)				
Duration:	Turnus of offer:	Credit points:		
1 Semester	each winter semester	12		
Course of study, specific field and term: • Master Computer Science 2019 (opt • Master Entrepreneurship in Digital T • Master Computer Science 2019 (opt	ional subject), Canonical Sp echnologies 2020 (advance ional subject), advanced mo	ecialization Bioinformatics and Systems Biology, Arbitrary semester d module), specific, Arbitrary semester odule, Arbitrary semester		
Classes and lectures:Workload:• CS4440 T Molecular Bioinformatics (lecture, 2 SWS)• 170 Hours private studies• CS4440 T Molecular Bioinformatics (exercise, 1 SWS)• 150 Hours in-classroom work• MA4450 T-INF Modeling Biological Systems (lecture, 2 SWS)• 40 Hours exam preparation• EW4170 T System Biology (lecture, 2 SWS)• EW4170 T System Biology (exercise, 2 SWS)				
Contents of teaching: • see module parts				
Qualification-goals/Competencies: • see module parts				
Grading through: • Oral examination				
Responsible for this module: • Prof. Dr. rer. nat. Thomas Martinetz Teacher: • LIED   Lübecker Institut für experime • Institute for Neuro- and Bioinformat • Prof. Dr. Hauke Busch • Prof. Dr. Hauke Busch • Prof. Dr. rer. nat. Thomas Martinetz • Dr. Axel Künstner • Nachfolge von Prof. Dr. rer. nat. Kars • Prof. Dr. Bernhard Haubold • Dr. rer. nat. Kurt Fellenberg	entelle Dermatologie (Lübec ics sten Keller	k Institute of Experimental Dermatology)		
Literature: • :				
Language: • German and English skills required				
Notes: (The module consists of CS4440 T, MA (Is equal to and is replaced by CS4442 Prerequisites for attending the module - None Prerequisites for the exam: - depending on the module parts	4450 T-INF and EW4170 T) -KP12) e:			



CS4514-KP12 - Intelligent Agents (IntAgents)				
Duration:	Turnus of offer:	Credit points:		
1 Semester	each winter semester	12		
Course of study, specific field and te Master Robotics and Autonome Certificate in Artificial Intelliger Master Entrepreneurship in Dig Master Computer Science 2019 Master IT-Security 2019 (advance Master Computer Science 2019	rm: ous Systems 2019 (optional subjo ce (compulsory), Artificial Intellio ital Technologies 2020 (advance (optional subject), Canonical Sp ced module), Elective Computer (optional subject), advanced mo	ect), Additionally recognized elective module, 1st to 3th semester gence, 1st semester ed module), specific, Arbitrary semester recialization Data Science and AI, 1st or 2nd semester Science, 1st or 2nd semester odule, Arbitrary semester		
Classes and lectures:		Workload:		
<ul> <li>CS4514-P: Lab course Intelliger SWS)</li> <li>CS4514-V: Intelligent Agents (let</li> </ul>	CS4514-P: Lab course Intelligent Agents (practical course, 2 SWS)• 195 Hours private studies • 120 Hours in-classroom work • 45 Hours exam preparation			
Contents of teaching:		2		
<ul> <li>Agents, Mechanisms, and Collaboration: Intelligent agents and artificial intelligence / Game theory and social choice / Mechanism design, algorithmic mechanism design / Agent collaboration, rules of encounter / Continuous Space / Epistemic logic / Knowledge and seeing / Knowledge and time / Dynamic epistemic logic / Knowledge-based programs</li> <li>Perception (Language and Vision): Information retrieval and web-mining agents / Probabilistic dimension reduction, latent content descriptions, topic models, LDA, LDA-HMM / Representation learning for sequential structures, embedding spaces, word2vec, CBOW, skip-gram, hierarchical softmax, negative sampling / Language models (1d-CNNs. RNNs, LSTMs, ELMo, Transformers, BERT, GPT-3/OPT, and beyond), Natural language inference and query answering / Computer Vision (2D-CNNs, Deep Architectures: AlexNet, ResNet) //Combining language and vision (CLIP (OpenAl) / LIT (Google) / data2vec (Facebook) / Flamingo (DeepMind), DALL-E and beyond) /Knowledge graph embedding with GNNs, combining embedding-based KG completion with probabilistic graphical models(ExpressGNN, pLogicNet), MLN inference and learning based on embedded knowledge graphs, GMNNs)</li> <li>Planning, Causality, and Reinforcement Learning: Planning and acting with deterministic models, temporal models, nondeterministic models / Standard decision making / Advanced decision making and reinforcement learning / Causal dependencies / Intervention / Instrumental variables / Counterfactuals / Causal planning / Causal reinforcement learning</li> <li>In the project lab students use the usual (open source) data science related programming languages and tools in order to transfer the function the project lab students use the usual (open source) data science related programming languages and tools in order to transfer the</li> </ul>				
<ul> <li>Qualification-goals/Competencies:</li> <li>The students can enumerate central ideas, define the relevant concepts and explain the functioning of algorithms with help of application scenarios for all the items listed in contents of teaching.</li> </ul>				
Grading through: • Oral examination				
Responsible for this module: • Prof. DrIng. Nele Rußwinkel Teacher: • Institute of Information Systems • Prof. DrIng. Nele Rußwinkel Literature: • J. Pearl, C. Glymour, and N.P. Jewell: Causal Inference in Statistics - A Primer - Wiley, 2016				
<ul> <li>Y. Shoham, K. Leyton-Brown: Multiagent-Systems: Algorithmic, Game-Theoretic, and Logical Foundations - Cambridge University Press, 2009</li> <li>S.J. Russell, P. Norvig: Artificial Intelligence: A Modern Approach - Pearson, 2020</li> <li>M. Ghallab, D. Nau, P. Traverso: Automated Planning and Acting - Cambridge University Press, 2016</li> </ul>				
Language: • offered only in English				



## Notes:

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s):

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

Module examination(s):

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

(Replaces CS4513-KP12).



CS4501-KP12, CS4501 - Algorithmics, Logic and Computational Complexity (ALK14)				
Duration: Turnus of offer:		Credit points:		
2 Semester	each summer semester		12	
Course of study, specific field and term: • Master Entrepreneurship in Digital T • Master Computer Science 2019 (opt • Master IT-Security 2019 (advanced r • Master Entrepreneurship in Digital T • Master Computer Science 2014 (adv	echnologies 2020 (advanced ional subject), advanced mo nodule), Elective Computer S echnologies 2014 (advanced ranced module), advanced co	d module), specific, Arbitra dule, Arbitrary semester Science, 1st or 2nd semest d module), specific, 2nd ar urriculum, 2nd and/or 3rd	ary semester er ad/or 3rd semester semester	
Classes and lectures:	Classes and lectures: Workload:			
<ul> <li>Algorithmics, Logic and Computational Complexity (lecture, 4 SWS)</li> <li>Algorithmics, Logic and Computational Complexity (exercise, 2 SWS)</li> <li>Seminar Algorithmics, Logic and Computational Complexity (seminar, 2 SWS)</li> <li>Interview of the second second</li></ul>		e studies and exercises sroom work reparation n an individual topic with written and oral		
Contents of teaching:				
<ul> <li>recent results in algorithmics and complexity theory</li> <li>communication and circuit complexity</li> <li>structural and descriptive complexity theory</li> <li>algorithmic game theory</li> <li>nonstandard computing models</li> <li>understanding logics as a tool</li> </ul>				
<ul> <li>the students can demonstrate a dee</li> <li>They are able to classify algorithmic</li> <li>They are able to model complex pro</li> <li>They can assess and explain the imp</li> </ul>	ep knowledge of concepts ar problems and to select app oblem settings appropriately portance of lower bounds for	nd methods for algorithm ropriate strategies for thei r applications.	design and complexity analysis. r solution	
Grading through:     Oral examination				
Requires:         • Algorithmics (CS4000-KP06, CS4000SJ14)				
Responsible for this module:				
Prof. Dr. Kim-Manuel Klein				
Teacher:				
Institute for Theoretical Computer S	cience			
<ul> <li>Prof. Dr. Rüdiger Reischuk</li> <li>Prof. Dr. rer. nat. Till Tantau</li> <li>Prof. Dr. Maciej Liskiewicz</li> <li>Prof. Dr. Kim-Manuel Klein</li> </ul>				
Literature:				
<ul> <li>R. Reischuk: Einführung in die Komp</li> <li>S. Arora, B. Barak: Computational Co</li> <li>C. Papadimitriou: Computational Co</li> <li>M. Huth, M. Ryan: Logic in Compute</li> <li>D. Kozen: Theory of Computation - 5</li> </ul>	olexitätstheorie - Teubner, 19 omplexity - Cambridge UP 20 omplexity - Addison-Wesley, er Science - Cambridge Unive Springer, 2006	90 009 1994 ersity. Press 2004		
Language:				



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# German and English skills required

## Notes:

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



CS4503-KP12, CS4503 - Ambient Computing and Applications (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 Robotics and Autonomous S Master Entrepreneurship in Digital Master Computer Science 2019 (opt Master IT-Security 2019 (advanced of Master Entrepreneurship in Digital Master Computer Science 2014 (adv	ystems 2019 (advanced mo Fechnologies 2020 (advance ional subject), advanced mo nodule), Elective Computer Fechnologies 2014 (advance vanced module), advanced c	dule), advanced curriculum d module), specific, Arbitra odule, Arbitrary semester Science, 1st or 2nd semest d module), specific, 2nd an curriculum, 2nd and/or 3rd	n, Arbitrary semester ry semester er ıd/or 3rd semester semester	
Classes and lectures:		Workload:		
<ul> <li>CS4670 T: Ambient Computing (lect</li> <li>Seminar Ambient Computing (seminer)</li> <li>Lab Course Ambient Computing (pressure)</li> </ul>	puting (lecture, 3 SWS)120 Hours group workuting (seminar, 2 SWS)120 Hours in-classroom workmputing (project work, 3 SWS)70 Hours private studies30 Hours oral presentation (including preparation)20 Hours exam preparation		work sroom work studies sentation (including preparation) reparation	
Contents of teaching:				
<ul> <li>Ambient Computing:</li> <li>Current paradigms in computer tec</li> <li>Smart components</li> <li>Software architectures</li> <li>Context-sensitive systems</li> <li>Ambient Intelligence</li> <li>Interactive ambient media systems</li> <li>Ambient Computing Applications (a</li> <li>Ethical, Legal and Social Implication</li> </ul>	hnology AAL) Is (ELSI)			
Qualification-goals/Competencies: <ul> <li>Ambient Computing:</li> <li>The students are able to evaluate p</li> <li>They have an overview about curre</li> <li>They are able to follow and judge s</li> </ul>	ossibilities, concepts and ch nt technologies and system: tate-of-the-art research in th	allenges of Ambient Syster 5 for developing Ambient S 1e area of Ambient Comput	ns ystems ting	
Grading through: • portfolio exam				
Responsible for this module: • Prof. DrIng. Andreas Schrader				
Teacher:     Institute of Telematics				
Prof. DrIng. Andreas Schrader				
Literature: • John Krumm: Ubiquitous Computin • Stefan Poslad: Ubiquitous Computin	g Fundamentals - CRC Press ng: Smart Devices, Environm	, 2009 Jents and Interactions - Wil	ey, 2009	
Language: • German and English skills required				
Notes:				



Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s):

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

Module Exam(s):

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

(Consists of CS4670 T)

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



CS4504-KP12, CS4504 - Cyber Physical Systems (CPS)			
Duration:	Turnus of offer:		Credit points:
2 Semester	each year, can be started in	winter or summer semester	12
Course of study, specific field and term Master Entrepreneurship in Digita Master Computer Science 2019 (o Master Robotics and Autonomous Master IT-Security 2019 (advanced Master Entrepreneurship in Digita Master Computer Science 2014 (a	: I Technologies 2020 (advance ptional subject), advanced mo Systems 2019 (advanced mo I module), Elective Computer I Technologies 2014 (advance dvanced module), advanced c	d module), specific, Arbitra odule, Arbitrary semester dule), advanced curriculum Science, 1st or 2nd semest d module), specific, 2nd ar curriculum, 2nd and/or 3rd	ary semester n, 1st or 2nd semester er nd/or 3rd semester semester
Classes and lectures: • CS5150 T: Organic Computing (lea	cture with exercises, 3 SWS)	Workload: • 220 Hours private	e studies
<ul> <li>CS5153 T: Wireless Sensor Networ SWS)</li> <li>CS4504-S: Cyber Physical Systems</li> </ul>	ks (lecture with exercises, 3 (seminar, 2 SWS)	<ul><li> 120 Hours in-clas</li><li> 20 Hours exam p</li></ul>	sroom work reparation
Contents of teaching:		J	
<ul> <li>basic principles of organic computing from motion to intelligent behavi</li> <li>design for self-organization, robu</li> <li>analyzing, reverse-engineering, diditional designing experiments and meas</li> <li>modeling system/machine behavion complexity, opacity, obscurity, true</li> <li>architecture of organic computing</li> <li>applications of self-x systems</li> <li>basics of wireless sensor networks</li> <li>hardware aspects of sensor nodes</li> <li>physics and protocols of wireless</li> <li>routing in wireless networks</li> <li>time synchronization and localiza</li> <li>data management and data proce</li> <li>applications of wireless sensor networks</li> </ul>	ting / self-x system properties or and system/machine behav stness, adaptivity, flexibility, tr ebugging machine behavior uring behavior ior ist of (AI) systems and explain g systems communication tion in wireless networks essing in wireless sensor netw tworks	i vior rust able Al	
Qualification-goals/Competencies: <ul> <li>Students are able to utilize the pr</li> <li>They are able to explain principle</li> <li>They are able to analyze system/r</li> <li>Students are able to present the p</li> <li>They are able to cope with analys</li> <li>They are able to interpret and put</li> </ul>	inciples of organic computing s of organic computing/self-x nachine behaviors in a structu pros and cons of sensor netwo is, design, and evaluation of p rsue current research activities	/self-x systems on exempla systems. Ired, sound approach. Irks. rotocols in sensor network s for sensor networks.	ary designs. .s.
Grading through: • Oral examination			
Responsible for this module: • Prof. DrIng. Mladen Berekovic Teacher: • Institute of Computer Engineering • Dr. rer. nat. Javad Ghofrani	)		
Literature: • C. Müller-Schloer, S. Tomforde: Or • H. Karl, A. Willig: Protocols and Ar	ganic Computing Technical chitectures of Wireless Sensor	Systems for Survival in the Networks - Wiley, 2005	Real World - Birkhäuser, 2017



## Language:

## • offered only in English

#### Notes:

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s):

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

### Module Exam(s):

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

(Consists of CS5150 T, CS5153 T)



CS4505-KP12, CS4505 - System Architecture (SysArch)				
Duration:	Turnus of offer:		Credit points:	
2 Semester	each year, can be started in	winter or summer semester	12	
Course of study, specific field and term: • Master Entrepreneurship in Digital • Master Computer Science 2019 (opt • Master IT-Security 2019 (advanced r • Master Entrepreneurship in Digital • Master Computer Science 2014 (adv	Technologies 2020 (advanced tional subject), advanced mo module), Elective Computer S Technologies 2014 (advanced vanced module), advanced cu	l module), specific, Arbitra dule, Arbitrary semester science, 1st or 2nd semeste module), specific, 2nd an urriculum, 2nd and/or 3rd	ry semester er d/or 3rd semester semester	
<ul> <li>Classes and lectures:</li> <li>Computer-Aided Design of Digital C with exercises, 3 SWS)</li> <li>Hardware/Software Co-Design (s. Cl exercises, 3 SWS)</li> <li>Lab course System Architecture or S Architecture (practical course, 3 SW</li> </ul>	<ul> <li>Asses and lectures:</li> <li>Computer-Aided Design of Digital Circuits (s. CS3110 T) (lecture with exercises, 3 SWS)</li> <li>Hardware/Software Co-Design (s. CS5170 T) (lecture with exercises, 3 SWS)</li> <li>Lab course System Architecture or Seminar System Architecture (practical course, 3 SWS)</li> <li>Workload: <ul> <li>195 Hours private studies</li> <li>135 Hours in-classroom work</li> <li>30 Hours exam preparation</li> </ul> </li> </ul>		e studies sroom work reparation	
Contents of teaching: • see module parts				
Qualification-goals/Competencies: <ul> <li>see module parts</li> </ul>				
Grading through: • Oral examination				
Responsible for this module: <ul> <li>Prof. DrIng. Mladen Berekovic</li> </ul> <li>Teacher: <ul> <li>Institute of Computer Engineering</li> <li>Prof. DrIng. Mladen Berekovic</li> </ul> </li>				
Literature: • :				
Language: • German and English skills required				
Notes: Admission requirements for taking the - None Admission requirements for participat - Successful completion of exercises a - Successful completion of the practic Module Exam(s): - CS4505-L1: System Architecture, oral	e module: tion in module examination(s s specified at the beginning o al tasks according to the requ l exam, 100% of the module o	.): of the semester. uirements at the beginning grade.	g of the semester.	
A seminar can also be offered instead of the internship.				



CS45	06-KP12, CS4506 - Informatior	n and Communication	Security (SDK)	
Duration:	Turnus of offer:		Credit points:	
2 Semester	each year, can be started ir	winter or summer semester	12	
Course of study, specific field a Master Entrepreneurship Master Computer Science Master Computer Science Master Entrepreneurship Master Computer Science	and term: in Digital Technologies 2020 (advance e 2019 (optional subject), advanced me e 2014 (compulsory), specialization fiel in Digital Technologies 2014 (advance e 2014 (advanced module), advanced o	ed module), specific, Arbitrar odule, Arbitrary semester d IT security and safety, 1st ed module), specific, 2nd and curriculum, 2nd and 3rd sem	y semester and 2nd semester d 3rd semester jester	
Classes and lectures:		Workload:		
<ul> <li>Cryptographic Protocols</li> <li>Cryptographic Protocols</li> <li>Modeling and Analysing</li> <li>Modeling and Analysing</li> <li>Modeling and Analysing</li> </ul>	(lecture, 3 SWS) (exercise, 1,5 SWS) Security (seminar, 3 SWS) Security (practical course, 1 SWS) Security (exercise, 1 SWS)	ure, 3 SWS)• 170 Hours private studiesrcise, 1,5 SWS)• 150 Hours in-classroom workurity (seminar, 3 SWS)• 40 Hours exam preparationurity (practical course, 1 SWS)urity (exercise, 1 SWS)		
Contents of teaching:				
<ul> <li>Modelling and formalizin</li> <li>Adversaries and models</li> <li>Symbolic methods and a</li> <li>Consistency and synchrom</li> </ul> Qualification-goals/Competen <ul> <li>The students can compresent</li> <li>They can reason about compresent</li> <li>The are able to select suited the select suited of the students can compresent</li> <li>They can designate the select scale they can report on secure</li> <li>They can recite complex</li> <li>They are able to specify,</li> <li>They can describe technic</li> </ul>	ng protocols and security properties of attacks, security pitfalls nutomatic verification of security proper onization <b>cies:</b> ehensively explain the security challen- ryptographic methods and their applic table security primitives for given app ity analysis of communication protocol weaknesses of real systems and evalua ehensively elaborate on algorithmic ba rity properties. methods for IT security and apply their analyse and verify protocols and secur iques for automatic verification of secu-	rties ges of of digital communica ation in communication sys lications and to implement t ls. te them. Isics for IT security. m. ity properties. Irity properties.	tion. tems. hem.	
Grading through:				
Oral examination				
Requires:				
<ul><li>Cryptology (CS4016)</li><li>Security in Networks and</li></ul>	Distributed Systems (CS4180-KP04, C	54180)		
Responsible for this module: • Prof. Dr. Rüdiger Reischu Teacher:	k			
Institute for Theoretical C	Computer Science			
<ul><li> Prof. Dr. Rüdiger Reischu</li><li> Prof. Dr. Maciej Liskiewic</li></ul>	k z			
Literature:				



- V. Cortier, S. Kremer (Ed.): Formal Models and Techniques for Analyzing Security Protocols Cryptology and Information Security Series 5, IOS Press, 2011
- C. Pfleeger, S. Pfleeger: Security in Computing Prentice-Hall 2007
- A. Joux: Algorithmic Cryptanalysis CRC Press 2009
- J. Katz, Y. Lindell: Introduction to Modern Cryptography CRC Press 2014
- S. Loepp, W. Wootters: Protecting Information Cambridge Univ. Press 2006
- Lindell: Tutorials on the Foundations of Cryptography Springer 2017
- Goldreich: Fundamentals of Cryptography Cambridge Univ. Press 2004
- I. Cox, M. Miller, J. Bloom, J. Fridrich, T. Kalkerm: Digital Watermarking and Steganography Morgan Kaufmann 2008
- Dwork, Roth: The Algorithmic Foundations of Differential Privacy 2014

## Language:

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

### Notes:

Prerequisites for attending the module:

- None

Prerequisites for the exam:

- Successful completion of homework and project assignments during the semester



CS4508-KP12, CS4508 - Data Management (DatManag)				
Duration:	Turnus of offer:		Credit points:	
1 Semester	each winter semester		12	
Course of study, specific field and to Master Entrepreneurship in Di Master Computer Science 201 Master IT-Security 2019 (advar Master Media Informatics 2014 Master Entrepreneurship in Di Master Computer Science 201	erm: gital Technologies 2020 (advanced 9 (optional subject), advanced mo nced module), Elective Computer S 4 (optional subject), computer scie gital Technologies 2014 (advanced 4 (advanced module), advanced co	d module), specific, Arbitr dule, Arbitrary semester Science, 1st or 2nd semes ence, Arbitrary semester d module), specific, 2nd o urriculum, 2nd or 3rd sem	ary semester ter r 3rd semester nester	
Classes and lectures: • CS4140 T: Mobile and distribu with exercises, 3 SWS)	ted information systems (lecture	Workload: • 130 Hours privat • 120 Hours in-cla	te studies ssroom work	
<ul> <li>CS5140 T: Semantic Web (lect)</li> <li>Seminar data management (set)</li> </ul>	ure with exercises, 3 SWS) eminar, 2 SWS)	<ul> <li>90 Hours work o presentation or</li> <li>20 Hours exam p</li> </ul>	on an individual topic with written and oral group work preparation	
Contents of teaching: • see module parts				
Qualification-goals/Competencies: • see module parts				
Grading through: • Oral examination				
Responsible for this module: <ul> <li>Prof. Dr. Sven Groppe</li> </ul> Teacher: <ul> <li>Institute of Information System</li> <li>Prof. Dr. Sven Groppe</li> </ul>	ns			
Literature: • : see module parts				
Language: • German and English skills requ	ıired			
Notes: Admission requirements for taki - None	ng the module:			
Admission requirements for part - Successful completion of the p - Seminar lecture with elaboration	icipation in module examination( roject assignment as specified at t on according to the requirements	s): he beginning of the seme at the beginning of the se	ester or emester.	
Module Exam(s): - CS4508-L1: Data Management, oral exam, 100% of the module grade.				
Instead of the seminar, an internship can also be offered.				
(Consists of CS4140 T, CS5140 T)				



CS4509-KP12, CS4509	9 - Internet Structures an	d Protocols / Interne	t Technologies (Internet)
Duration:	Turnus of offer:		Credit points:
2 Semester	not available anymore		12
Course of study, specific field and term Master Entrepreneurship in Digit. Master Computer Science 2019 (a Master IT-Security 2019 (advance Master Media Informatics 2014 (a Master Entrepreneurship in Digit Master Computer Science 2014 (a	n: al Technologies 2020 (advanced optional subject), advanced mo ed module), Elective Computer S optional subject), computer scie al Technologies 2014 (advanced advanced module), advanced c	d module), specific, Arbitra Idule, Arbitrary semester Science, 1st or 2nd semest ence, Arbitrary semester d module), specific, 2nd ar urriculum, 2nd and 3rd se	ıry semester er ıd 3rd semester nester
Classes and lectures:		Workload:	
<ul> <li>Architectures for Distributed Apprexercises, 3 SWS)</li> <li>Advanced Internet Technologies</li> <li>Software Architectures (project v</li> </ul>	olications (lecture with (lecture with exercises, 3 SWS) vork, 3 SWS)	<ul> <li>120 Hours in-classroom work</li> <li>105 Hours private studies</li> <li>45 Hours work on project</li> <li>45 Hours group work</li> <li>45 Hours exam preparation</li> </ul>	
Contents of teaching: • see module parts			
Qualification-goals/Competencies: <ul> <li>see module parts</li> </ul>			
Grading through: • Oral examination			
Responsible for this module: • Prof. Dr. Stefan Fischer Teacher: • Institute of Telematics			
<ul><li>Prof. DrIng Horst Hellbrück</li><li>Prof. DrIng. habil. Dennis Pfister</li></ul>	er		
Literature: • : see module parts			
Language: • German and English skills require	ed		
Notes:			
(Consists of CS5158 T, CS4151 T).			
As of winter semester 2019/20, the	module has been renamed from	m Internet Technologies t	o Internet Structures and Protocols.
As of winter semester 2020/21, the	module is no longer offered to	new students.	
Admission requirements for taking - None	the module:		
Admission requirements for taking - Successful participation in lab	module examination(s):		



CS4510-KP12, CS4510 - Signal Analysis (SignalAna)				
Duration:	Turnus of offer:		Credit points:	
2 Semester	each year, can be started in	winter or summer semester	12	
Course of study, specific field and term: Master Biophysics 2023 (advanced m Master MES 2020 (advanced module Master Entrepreneurship in Digital T Master Computer Science 2019 (opti Master Biophysics 2019 (advanced m Master IT-Security 2019 (advanced m Master MES 2014 (advanced module Master Entrepreneurship in Digital T Master Computer Science 2014 (advanced m	nodule), advanced curricului ), computer science / electri echnologies 2020 (advanced onal subject), advanced mo nodule), advanced curricului nodule), Elective Computer S ), computer science / electri echnologies 2014 (advanced anced module), advanced cu	m, 1st or 2nd semester ical engineering, Arbitrary d module), specific, Arbitra dule, Arbitrary semester m, 1st and 2nd semester Science, 1st or 2nd semest ical engineering, 1st and/c d module), specific, 2nd ar urriculum, 2nd and/or 3rd	semester ary semester er or 2nd semester nd/or 3rd semester semester	
Classes and lectures:		Workload:		
<ul> <li>CS5260SJ14 T: Speech and Audio Signith exercises, 3 SWS)</li> <li>CS5275 T: Selected Topics of Signal A (lecture with exercises, 3 SWS)</li> <li>CS5194 T: Lab course (project work,</li> </ul>	nal Processing (lecture Analysis and Enhancement 3 SWS)	<ul> <li>150 Hours private</li> <li>90 Hours in-class</li> <li>60 Hours group v</li> <li>40 Hours exam p</li> <li>20 Hours written</li> </ul>	e studies room work work reparation report	
Contents of teaching:				
<ul> <li>Introduction to statistical signal analysis</li> <li>Principles of feature extraction and pattern recognition</li> <li>Linear optimum filters</li> <li>Adaptive filters</li> <li>Spectrum analysis</li> <li>Basic concepts of multirate signal processing</li> <li>Applications in speech and image processing</li> <li>Realization of signal processing tasks for typical application scenarios in teamwork</li> </ul>				
Qualification-goals/Competencies:				
<ul> <li>Students are able to explain the basis</li> <li>They are able to describe and apply</li> <li>Students are able to describe the co</li> <li>They are able to explain the concepts</li> <li>They are able to analyze and design</li> <li>Students are able to explain various</li> <li>They are able to create and implement</li> </ul>	c elements of stochastic sig linear estimation theory. ncepts of adaptive signal pr s of feature extraction and p multirate systems. practical applications of sig ent signal processing system	nal processing and optime ocessing. battern recognition. nal processing algorithms. ns on their own and in tear	um filtering. mwork.	
Grading through: • Oral examination				
Responsible for this module: <ul> <li>Prof. DrIng. Markus Kallinger</li> </ul> <li>Teacher: <ul> <li>Institute for Signal Processing</li> <li>Prof. DrIng. Markus Kallinger</li> </ul> </li>				
Literature: • : See description of module parts	Literature:			
Language:     German and English skills required				



## UNIVERSITÄT ZU LÜBECK

# Module Guide

## Notes:

Examination prerequisites can be defined at the beginning of the semester. If preliminary work is defined, it must have been completed and positively evaluated before the first examination.

Admission requirements for taking the module:

- None

Admission requirements for participation in module examination(s):

- CS4510-L3 (all exept Master Biophysics since 2023): Successful completion of the project assignment, seminar presentation and exercise assignments as specified at the beginning of the semester

- CS4510-L1 (only Master Biophysics since 2023): Successful completion of the exercise assignments as specified at the beginning of the semester

- CS4510-L2 (only Master Biophysics since 2023): Successful completion of the project assignment as specified at the beginning of the semester

Module Exam(s):

- CS4510-L3 (all exept Master Biophysics since 2023): Signal Analysis, oral exam, 100% of module grade

- CS4510-L1 (only Master Biophysics since 2023): partial exam Signal Analyse, oral exam, 100% of module grade
- CS4510-L2 (only Master Biophysics since 2023): partial exam Lab course Signal- and image processing, project, ungraded

(Consists of CS4220 T, CS5275 T, CS5194 T)



CS451	5-KP12 - Computer a	nd System Security (Co	mSysSec)
Duration:	Turnus of offer:		Credit points:
2 Semester	each year, can be started	l in winter or summer semester	r 12
Course of study, specific field and term • Master Entrepreneurship in Digita • Master Entrepreneurship in Digita • Master Computer Science 2019 (o	ı <b>:</b> I Technologies 2020 (advan I Technologies 2014 (advan ptional subject), advanced	nced module), specific, Arbitra nced module), specific, 2nd ar module, Arbitrary semester	ary semester nd 3rd semester
Classes and lectures: Communication and System Secu Communication and System Secu Communication and System Secu Computer Security (lecture, 2 SWS Computer Security (practical cour	rity (lecture, 2 SWS) rity (exercise, 1 SWS) rity (seminar, 1 SWS) S) rse, 3 SWS)	Workload: • 170 Hours privat • 150 Hours in-clas • 40 Hours exam p	e studies ssroom work oreparation
<ul> <li>Contents of teaching:</li> <li>Applied cryptography in systems</li> <li>Efficient and secure implementation in tracks a attacks, modern inference method</li> <li>Virtualization security and microa attacks such as cache attacks, spee</li> <li>Trusted Computing and Hardward basics and cryptographic techniq</li> <li>Cryptographic procedures and pr</li> <li>IT security at system level, security</li> <li>Security, privacy and trust of spec</li> <li>Operating system security</li> <li>Security problems in IT systems</li> </ul>	and protocols: Overview of on of common crypto proc and countermeasures: Error ds and associated cryptanal rchitecture attacks: security ctre, etc., measures to resto e-Assisted System Security: ues, design basics for secur otocols, security analyses y mechanisms ial systems like Cloud and I ework conditions	common methods and their edures: multiple-precision ar injection attacks, passive phy lysis methods, classes of prot concepts in the operating sy pre system security Functionality TPMs, Secure E e systems oT	applications ithmetic, efficient exponentiation, constant ysical attacks such as SPA/DPA and timing ective measures /stem and hypervisor, microarchitecture lements and Trusted Execution Environments,
Qualification-goals/Competencies: • The students can demonstrate a c • They can construct secure and eff • They can explain methods and alg • They can perform basic side-chan • They can implement protection a • They can evaluate the security of • Students can explain the basic me • They can demonstrate a deeper u • They can analyze the entire spect • They can explain modelling techr • They can apply a variety of standa	leep understanding of cryp icient cryptographic primiti gorithms for efficient multip nel attacks on systems with gainst specific physical atta existing primitives. ethods in the field of cybers inderstanding of cryptograp rum of the security of a syst hiques and describe experie ard techniques to increase t	otographic methods and their ives and implement them sec ole-precision arithmetic. In physical access or shared sy tecks for cryptographic primition security and apply them to can ohic methods and their applic tem. Inces with their use. The security of a system.	applications in communication systems. Eurely in computer systems. stems with code execution rights. ves. ase studies. cations in communication systems.
Grading through: • Written or oral exam as announce • written homework	d by the examiner		
Requires: • Cybersecurity (CS2250-KP04) • Cryptology (CS3420-KP04, CS3420 Responsible for this module:	))		
<ul> <li>Prof. DrIng. Thomas Eisenbarth</li> </ul>			

Teacher:



- Institute for IT Security
- Prof. Dr.-Ing. Thomas Eisenbarth
- Prof. Dr. Rüdiger Reischuk

### Literature:

• S. Mangard, E. Oswald & T. Popp: Power analysis attacks: Revealing the secrets of smart cards - Vol. 31, Springer Science & Business Media, 2008

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- D. Stinson: Cryptography: Theory and Practice 4th ed., CRC Press, 2018
- Stallings, Brown: Computer Security: Principles and Practice 4th ed., Pearson, 2018
- Katz, Lindell: Introduction to Modern Cryptography 2nd ed., CRC Press, 2014
- : Recent literature

#### Language:

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

## Notes:

Prerequisites for attending the module:

- None

Prerequisites for the exam:

- Successful completion of homework and project assignments during the semester.



CS4517-KP12 - Architectures for Distributed Communication Systems (ArchVeK)			
Duration:	Turnus of offer:		Credit points:
2 Semester	each semester 12		12
Course of study, specific field and term: • Master IT-Security 2019 (optional sub • Master Entrepreneurship in Digital To • Master Computer Science 2019 (opti	oject), Elective Computer Sci echnologies 2020 (optional s onal subject), advanced moc	ence, 1st or 2nd semester subject), specific, 2nd or 3i dule, Arbitrary semester	rd semester
<ul> <li>Classes and lectures:</li> <li>Architectures for distributed communication systems (lecture, 2 SWS)</li> <li>Architectures for distributed communication systems (exercise, 1 SWS)</li> <li>Mobil communication systems (lecture, 2 SWS)</li> <li>Mobil communication systems (exercise, 1 SWS)</li> <li>Architectures for distributed communication systems (practical course, 3 SWS)</li> </ul>		Workload: • 120 Hours in-classroom work • 105 Hours private studies • 45 Hours work on project • 45 Hours exam preparation • 45 Hours group work	
<ul> <li>Contents of teaching:</li> <li>Introduction to Communication Syst</li> <li>Wireless Data Link Layer, Network La Satellite Systems)</li> <li>Security in wireless Networks</li> <li>Applications of wireless Networks</li> <li>Software Architectures</li> <li>Basics of communication in distribute</li> <li>N-Tier Applications</li> <li>Architectures of distributed systems (Web 2.0), Overlay Networks, Peer-to</li> </ul>	ems and overview of the sta yer and Technologies (802.1 ed networks (Service-Oriented and Event -Peer, Grid and Cloud Comp	te-of-the-art technologies 5.4, WLAN, GSM, Bluetoot -Driven Architectures (SO/ uting, Internet of Things)	s .h, RFID, LowPowerWANs, Broadcast and A and EDA), Web-Oriented Architectures
<ul> <li>Qualification-goals/Competencies:</li> <li>Students can highlight the particular</li> <li>They interpret and follow current res</li> <li>They can systematically design and e</li> <li>They can design, implement, and op</li> <li>They can analyze technical requirem</li> <li>They can carry out diagnoses, tests a</li> <li>The students are able to name the mother.</li> <li>For each architecture, they know the</li> <li>For a given problem, they can analyze realization.</li> </ul>	rities of wireless mobile com search activities and technole evaluate protocols for mobile erate real-time applications ents for mobile radio system nd optimizations of wireless sost important archiectures f e most prominent and impor ze which architecture is best	munication systems and t ogy trends. e communication systems based on wireless commu is and components and ch is networked mobile comm for distributed systems, ex tant implementation platf suited to solve it, and the	he challenges and concepts. and their applications. inication networks. hoose solutions. hunication systems. plain them, and compare them to each forms and basically know how to use them. y can design a plan for the solution's
Grading through: <ul> <li>Oral examination</li> </ul>			
Responsible for this module: • Prof. Dr. Stefan Fischer Teacher: • Institute of Telematics • Prof. DrIng Horst Hellbrück • Dr. Mohamed Hail			
<ul> <li>Literature:</li> <li>Jochen Schiller: Mobile Communications - 2nd Edition, Addison-Wesley, 2004, Signature: VK 2650 2005 A 302</li> </ul>			



- Andrew S. Tanenbaum: Computer Networks 4th Edition, Prentice-Hall, 2003, Signature: VK 1670 2004 A 823
- Charles E. Perkins: Ad Hoc Networking 1st Edition, Addison Wesley Professional, December 2000, Signature: VK 1670 2002 A 640
- J. Dunkel, A. Eberhart, S. Fischer, C. Kleiner, A. Koschel: Systemarchitekturen für verteilte Anwendungen Hanser-Verlag 2008
- I. Melzer et.al.: Service-Orientierte Architekturen mit Web Services Spektrum-Verlag 2010

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### Language:

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

#### Notes:

Admission requirements for taking the module: - None

Admission requirements for participation in module examination(s): - Successful completion of the project internship

Module Examination(s):

- CS4517-L1: Architectures for Distributed Communication Systems, oral exam, 100% of module grade.

According to the decision of the Examination Board for Computer Science of 17.7.2020, this module can be chosen as a specialization module for Master Computer Science.



CS4518-KP12 - Current and Future Network Technologies (AzuNet)			
Duration:	Turnus of offer:		Credit points:
2 Semester	each semester		12
Course of study, specific field and to • Master Computer Science 207 • Master IT-Security 2019 (optic • Master Entrepreneurship in D	<b>term:</b> 19 (optional subject), advanced mo onal subject), Elective Computer So igital Technologies 2020 (optional	odule, Arbitrary semester cience, 1st or 2nd semeste l subject), specific, Arbitrar	r y semester
<ul> <li>Classes and lectures:         <ul> <li>Advanced Internet Technolog</li> <li>Advanced Internet Technolog</li> <li>Nano communication networe</li> <li>Nano communication networe</li> <li>Seminar Internet of Things or networks (seminar, 2 SWS)</li> </ul> </li> <li>Contents of teaching:         <ul> <li>Fundamental Internet design</li> <li>Problems of today's Internet</li> <li>Backbone Technologies</li> <li>Mobile Internet</li> <li>IPv6 und related topics</li> <li>Delay Tolerant Networks (DTI</li> <li>Internet of Services / Internet</li> <li>Peer-To-Peer networks</li> <li>Big Data</li> <li>Goals, architectures, algorithm</li> </ul> </li> </ul>	gies (lecture, 2 SWS) gies (exercise, 1 SWS) rks (lecture, 2 SWS) rks (project work, 1 SWS) Seminar Nano communication principles architecture	Workload: 165 Hours privat 105 Hours in-clas 45 Hours exam p 30 Hours work o presentation 15 Hours work o	e studies ssroom work oreparation n an individual topic with written and oral n project
<ul> <li>Reductions and compilation</li> <li>Definitions &amp; associations of i</li> <li>Simulation tools for nanonety</li> <li>Deployment in medical appli</li> </ul>	nanonetworks works cation scenarios		
Qualification-goals/Competencies: • Understand the fundamental	design decisions that have led to	today's Internet architectu	Ire
<ul> <li>Understand the original designetworks</li> <li>Learn about essential, universetc.)</li> <li>Know technological as well a innovations, mobile commun</li> <li>Identify problems of the Inter</li> <li>Become acquainted with the future</li> <li>They can design, implement of the result of the</li></ul>	gn goals of the Internet and realized sally valid criteria for the design of s societal developments that have nications, ) rnet's architecture and understand Future Internet research field and and test basic IoT applications. nalyze and interpret data from IoT d use cases and be able to develop ends and future developments in nd the basic concepts of nanonetwo cepts of nanoscale computational nd self-assembly systems and crys nd the constraints and peculiaritie or falsify a model using simulatior neoretical concepts to related quest	e the implications that the networks and application led to massive changes in potential solutions by cor learn about novel approad systems. o solutions for specific indu the IoT area and can evalu works. models. tal formation. s at the nanoscale. n tools. stions.	emphasis on certain of them has on today's s (e.g., end-to-end argument, fate sharing, the Internet's infrastructure (growth, mparing different approaches ches to research and shape the Internet of the istries. ate them critically.
Grading through: • Oral examination			



Responsible for this module:         • Prof. Dr. Stefan Fischer
Teacher:
Institute of Telematics
<ul> <li>Dr. Mohamed Hail</li> <li>Dr. rer. nat. Florian-Lennert Lau</li> </ul>
Literature:
Olivier Hersent, David Boswarthick, Omar Elloumi: The Internet of Things: Key Applications and Protocols - Wiley, 2012
Language:
English, except in case of only German-speaking participants
Notes:
Admission requirements for taking the module: - None
Admission requirements for participation in module examination(s): - Successful participation in the seminar
Module Exam(s): - CS4518-L1: Current and Future Network Technologies, oral exam, 100% of module grade.



CS4520-KP12, CS4520 - Case study in professional product development (Fallstudie)				
Duration:	Turnus of offer:	Credit points:	Max. group size:	
2 Semester	each semester	12	12	
Course of study, spe • Master Artificia • Master Entrep • Master Compu • Master Entrep • Master Compu	cific field and term: al Intelligence 2023 (optional subject), for ec reneurship in Digital Technologies 2020 (ad Iter Science 2019 (optional subject), advanc reneurship in Digital Technologies 2014 (ad Iter Science 2014 (advanced module), advar	quivalence check, Arbitrary semest vanced module), specific, Arbitrary ed module, Arbitrary semester vanced module), specific, 2nd and nced curriculum, 2nd and 3rd seme	er semester 3rd semester ister	
Classes and lectures	:	Workload:		
Basics for proc     Product devel	duct development (exercise, 2 SWS) opment (practical course, 6 SWS)	<ul> <li>120 Hours in-classre</li> <li>120 Hours group w</li> <li>70 Hours private str</li> <li>30 Hours oral prese</li> <li>20 Hours exam prese</li> </ul>	oom work ork udies ntation (including preparation) oaration	
Contents of teaching generating ide developing a l planning and techniques for product cycles economic stud licences	g: eas for product development ousiness plan developing a prototype r management and planning s dies			
Qualification-goals/ • Students can s • They can orga • They can asses • They are able	<b>Competencies:</b> start working in or leading a team for produ nize and conduct the different phases of pro- ss legal and economic restrictions of produc to play different roles in a developing team.	ct development in informatics. oduct development. t development.		
Grading through: • Oral examination	ion			
Responsible for this <ul> <li>Studiengange</li> </ul> Teacher: <ul> <li>Institutes of th</li> <li>Alle prüfungs</li> </ul>	<b>module:</b> sleitung Informatik le Department of Computer Science/ Engine sberechtigten Dozentinnen/Dozenten des St	eering :udienganges		
Language:	· _ · · · · · · · · · · · · · · · · · ·			
• English, excep	t in case of only German-speaking participa	nts		

Notes:



Basics for product development can be taught by various appropriate forms of instruction other than exercises.

Prerequisites for attending the module:

- None

Prerequisites for the exam:

- continuous, successful participation in course
- presentation
- successful addressing of the project goals
- documentation
- grading by the reviewer





CS4521-KP12 - Constructive Cognitive Science (CCS)				
Duration:	Turnus of offer:		Credit points:	
2 Semester	each semester		12	
Course of study, specific field a	nd term:			
<ul><li>Master Computer Science</li><li>Master Robotics and Auto</li></ul>	2019 (optional subject), advanced n onomous Systems 2019 (optional sub	nodule, Arbitrary semester oject), Additionally recognize	ed elective module, 1st to 3th semester	
Classes and lectures:	Classes and lectures: Workload:			
<ul> <li>Human-Aware AI (lecture</li> <li>Models for human intellig</li> <li>Human-Aware AI (Excerci</li> </ul>	<ul> <li>Human-Aware AI (lecture, 3 SWS)</li> <li>Models for human intelligent Assistance (lecture, 3 SWS)</li> <li>Human-Aware AI (Excercises with project, 3 SWS)</li> <li>90 Hor</li> <li>30 Hor</li> </ul>		<ul> <li>135 Hours in-classroom work</li> <li>105 Hours private studies</li> <li>90 Hours work on project</li> <li>30 Hours exam preparation</li> </ul>	
Contents of teaching:				
<ul> <li>Definition and Examples for Human-Centered and Human-Aware Arsystems</li> <li>Constructive Cognitive Science, Situation understanding and mental models</li> <li>Explainable Human-Al Interaction</li> <li>Cognitive Modelling especially cognitive architectures</li> <li>Human-Robot Collaboration</li> <li>Digital cognitive Twins and Physical Human Models</li> <li>Intention recognition and Theory of Mind</li> <li>Interactive task learning</li> <li>Situated cognitive agents</li> <li>Tracing the cognitive state of the human-in-the-loop</li> </ul>				
Qualification-goals/Competend • The students can enumer application scenarios as v	c <b>ies:</b> rate central ideas, define the relevant vell as apply the algorithms for all th	t concepts and explain the f e items listed in contents of	unctioning of algorithms with help of teaching.	
Grading through:				
<ul><li>exercises and project assignments</li><li>Oral examination</li></ul>				
Responsible for this module:				
<ul> <li>Prof. DrIng. Nele Rußwin</li> </ul>	kel			
Institute of Information Systems				
Prof. DrIng. Nele Rußwinkel				
l iterature:				
<ul> <li>S.J. Russell: Human Comp</li> <li>C.S. Nam, JY. Jung, S. Lee</li> <li>J.R. Anderson: How Can to</li> <li>B. Sneiderman: Human-Comp</li> </ul>	atible: Artificial Intelligence and the e (Eds.): Human-Centered Artificial In he Human Mind Occur in the Physica entered AI - Oxford University Press,	Problem of Control - Pengu telligence: Research and Ap al Universe? - Oxford Univers 2022	in Books, 2020 pplications - Elsevier, 2022 sity Press, 2007	
Language:				
offered only in English				
Notes:				



Admission requirements for taking the module: - None

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

Module Exam(s):

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



CS4522-KP12 - Com	mon Sense Reasoning and	d Natural Language	Understanding (CSRNLU)	
Duration:	Turnus of offer:		Credit points:	
2 Semester	starts every winter semest	er	12	
Course of study, specific field and ter • Master Computer Science 2019	r <b>m:</b> (optional subject), advanced mo	dule, Arbitrary semester		
<ul> <li>Classes and lectures:</li> <li>Knowledge Representation and (lecture, 3 SWS)</li> <li>Knowledge Representation and (exercise, 1 SWS)</li> <li>Reasoning in Natural Language</li> <li>Lab course Common Sense Rea Understanding (practical course)</li> </ul>	Workload:Common Sense Reasoning135 HoursCommon Sense Reasoning95 HoursCommon Sense Reasoning90 HoursUnderstanding (lecture, 2 SWS)40 Hoursoning and Natural Language3 SWS)		s in-classroom work private studies group work exam preparation	
<ul> <li>This module provides an introd artificial intelligence in particula encountered before and solve r knowledge. As main area of app context and background inform</li> <li>fundamental concepts: knowled</li> <li>reasoning techniques (analogic</li> <li>qualitative algebras and calculi</li> <li>constraint-based reasoning</li> <li>qualitative reasoning</li> <li>spatial logics</li> <li>complexity of reasoning</li> </ul>	uction to the area of knowledge ar. Knowledge representation and new problems. The focus of this r plication, we consider natural lan nation. dge, abstraction, reasoning, unce al, deductive, inductive)	representation, a sub-dise d reasoning enable intellio nodule are techniques to guage understanding tha ertainty, context	cipline of computer science in general and gent agents to act in situations not represent and exploit common sense at hinges on the ability to reason about	
Qualification-goals/Competencies: • The students can describe fund • They can overview formalisms f • They can apply knowledge repr • They can implement and evalua • They can analyse and explain cl • They can identify computationa • They can present scientific resu • They can implement reasoning • They can implement selected a	amental concepts of knowledge or representing everyday knowle resentation and reasoning techni ate approaches to common sense hallenges in common sense reaso al properties of common sense re lts. techniques for common sense re pproaches to natural language u	representation and comm edge. ques to problems of natu e reasoning. oning and natural language easoning problems. easoning tasks. nderstanding.	non sense reasoning. ral language understanding. ge understanding.	
Grading through: • Oral examination				
Responsible for this module: • Prof. Dr. Diedrich Wolter Teacher: • Institute of Software Technolog • Prof. Dr. Diedrich Wolter	y and Programming Languages			
Literature: • Gary Marcus, Ernest Davis: Rebo • Kenneth D. Forbus: Qualitative • Ronald Brachman, Hector Leves • Frank van Harmelen, Vladimir L • Ernest Davis: Benchmarks for A	poting AI: Building Artificial Intelli Representations: How People Re- sque: Knowledge Representation ifschitz, Bruce Porter (editors): Ha	igence We Can Trust - Par ason and Learn about the and Reasoning - Elsevier andbook of Knowledge Re	ntheon 2019 Continuous World - MIT Press 2019 2004 epresentation - Elsevier 2007 2023 ACM Computing Surveys DOL	



10.1145/3615355, 2007

- Frank Dylla, Jae Hee Lee, Till Mossakowski, Thomas Schneider, André Van Delden, Jasper Van De Ven, Diedrich Wolter: A Survey of Qualitative Spatial and Temporal Calculi: Algebraic and Computational Properties ACM Computing Surveys, 50:1, Article 7, DOI 10.1145/3038927, 2017
- James Allen: Natural Language Understanding Addison Wesley 1995
- Alexander Clark, Chris Fox, Shalom Lappin (editors): The Handbook of Computational Linguistics and Natural Language Processing -Wiley 2010
- Ernest Davis: Benchmarks for Automated Commonsense Reasoning: A Survey February 2023. ACM Computing Surveys, DOI 10.1145/3615355, 2007
- Nitin Indurkhya, Fred J. Damerau (editors): Handbook of Natural Language Processing Routledge 2010
- Gerhard Paaß, Sven Giesselbach: Foundation Models for Natural Language Processing, Pre-trained Language Models Integrating Media, - Springer 2023

### Language:

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

## Notes:

Admission requirements for taking the module:

### - None

Admission requirements for participation in module examination(s):

- Successful completion of the project internship

## Module Examination(s):

- CS4522-L1: Common Sense Reasoning and Natural Language Understanding, oral exam, 100% of module grade.

According to the decision of the Examination Board for Computer Science of October 2023, this module can be chosen as a specialization module for Master Computer Science.