Module Handbook

for the

Master Programme "Computer Science"

at

Rheinischen Friedrich-Wilhelms-Universität Bonn

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The curriculum of the master programme is divided into four sub-curricula, each corresponding to one of the four main areas of competence in research of the Bonn Institute of Computer Science:

- 1. Algorithmics
- 2. Graphics, Vision, Audio
- 3. Information and Communication Management
- 4. Intelligent Systems

Module numbers **MA-INF ASXY** have been assigned according to the following key: vergeben:

- \bullet **A** = number of the area of competence
- \mathbf{S} = semester within the master curriculum
- XY = sequential number within the semester and the respective area of competence (two digits)

According to the curriculum, all modules ought to be taken between the first and the third semester. The fourth semester is reserved for preparing the master thesis.

Contents

1	Algorithmics	2
2	Graphics, Vision, Audio	37
3	Information and Communication Management	66
4	Intelligent Systems	98
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1 Algorithmics

MA-INF 1102	L4E2	9 CP	Combinatorial Optimization	. 3
MA-INF 1103	L4E2	9 CP	Cryptography	. 4
MA-INF 1105	L2E2	6 CP	Algorithms for Data Analysis	. 5
MA-INF 1106	L2	4 CP	HPC modern Architectures and Trends	. 6
MA-INF 1107	L2E2	6 CP	Foundations of Quantum Computing	. 7
MA-INF 1201	L4E2	9 CP	Approximation Algorithms	. 8
MA-INF 1202	L4E2	9 CP	Chip Design	. 9
MA-INF 1203	L4E2	9 CP	Discrete and Computational Geometry	10
MA-INF 1205		6 CP	Graduate Seminar Discrete Optimization	11
MA-INF 1206	Sem2	4 CP	Seminar Randomized and Approximation Algorithms	12
MA-INF 1207	Lab4	9 CP	Lab Combinatorial Algorithms	13
MA-INF 1209	Sem2	4 CP	Seminar Advanced Topics in Cryptography	14
MA-INF 1213	L4E2	9 CP	Randomized Algorithms and Probabilistic Analysis	
MA-INF 1217	Sem2	4 CP	Seminar Theoretical Foundations of Data Science	16
MA-INF 1218	L4E2	9 CP	Algorithms and Uncertainty	17
MA-INF 1219	Sem2	4 CP	Seminar Algorithmic Game Theory	18
MA-INF 1220	Sem2	4 CP	Seminar Algorithms for Computational Analytics	19
MA-INF 1221	Lab4	9 CP	Lab Computational Analytics	20
MA-INF 1222	Lab4	9 CP	Lab High Performance Optimization	21
MA-INF 1223	L4E2	9 CP	Privacy Enhancing Technologies	22
MA-INF 1224	L2E2	5 CP	Quantum Computing Algorithms	23
MA-INF 1301	L4E2	9 CP	Algorithmic Game Theory	24
MA-INF 1304	Sem2	4 CP	Seminar Computational Geometry	25
MA-INF 1305	•	6 CP	Graduate Seminar on Applied Combinatorial	
			Optimization	26
MA-INF 1307	Sem2	4 CP	Seminar Advanced Algorithms	27
MA-INF 1308	Lab4	9 CP	Lab Algorithms for Chip Design	28
MA-INF 1309	Lab4	9 CP	Lab Efficient Algorithms: Design, Analysis and	
			Implementation	29
MA-INF 1314	L4E2	9 CP	Online Motion Planning	30
MA-INF 1315	Lab4	9 CP	Lab Computational Geometry	31
MA-INF 1316	Lab4	9 CP	Lab Cryptography	32
MA-INF 1320	Lab4	9 CP	Lab Advanced Algorithms	33
MA-INF 1321	L2E2	6 CP	Binary Linear and Quadratic Optimization	34
MA-INF 1322			Seminar Focus Topics in High Performance Computing .	
MA-INF 1323	L4E2	9 CP	Computational Topology	36

Module	Combinatorial Optimization								
MA-INF 1102									
Workload	Credit points	Duration	n Frequency						
270 h	9 CP	1 semester	at leas	st every y	ear				
Module	Prof. Dr. Jens	s Vygen							
coordinator									
Lecturer(s)	All lecturers o	f Discrete M	athemati	.cs					
Classification	Programme		Mode	Seme	ster				
Classification	M. Sc. Compu	iter Science	Option	al 1. or	2.				
Technical skills	Advanced know	wledge of co	mbinator	ial optimi	ization. Modelli	ng			
	and developme	ent of solution	n strateg	gies for co	mbinatorial				
	optimization p	$_{ m roblems}$							
Soft skills	Mathematical	_	•	-	,				
		thinking, presentation of solutions to exercises							
Contents	Matchings, b-1	Matchings, b-matchings and T-joins, optimization over							
	matroids, sub	nodular fund	tion min	imization	, travelling				
	salesman prob	lem, polyhed	lral comb	inatorics,	NP-hard probl	ems			
Prerequisites	none								
	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP			
Format	Lecture			4	60 T / 105 S	5.5			
	Exercises			2	30 T / 75 S	3.5			
	T = face-to-fa	ce teaching;	S = inde	pendent s	study				
Exam achievements	Oral exam				(gra	ded)			
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)			
Forms of media									
	• B. Korte, J.	Vygen: Con	binatoria	al Optimi	zation: Theory	and			
	Algorithms. Springer, 6th edition, 2018								
	• A. Schrijver: Combinatorial Optimization: Polyhedra and								
Literature	Efficiency. Springer, 2003								
Literature	• W. Cook, W	. Cunningha	ım, W. P	ulleyblan	k, A. Schrijver:				
	Combinatorial	_	-						
	• A. Frank: C	onnections in	n Combin	natorial O	ptimization. Ox	xford			
	University Press, 2011								

Module MA-INF 1103	Cryptography									
Workload	Credit points Duration Frequency									
270 h	9 CP	1 semeste								
Module	Dr. Michael N		3.323	J						
coordinator	21. PHOLOGIA TUDION									
Lecturer(s)	Dr. Michael N	üsken								
	Programme		Mode	Seme	ster					
Classification	M. Sc. Compu	ter Science	Option	al 1. or	2.					
Technical skills	interplay betw	Understanding of security concerns and measures, and of the interplay between computing power and security requirements. Mastery of the basic techniques for cryptosystems and								
Soft skills	Oral presentation (in tutorial groups), written presentation (of exercise solutions), team collaboration in solving homework problems, critical assessment									
Contents	_				ms: AES, RSA,					
		· ·		· ·	nge, cryptograp					
		, –		,	toring integers a	and				
	discrete logari	thms; lower	bounds 1	n structur	red models.					
Prerequisites	none			.,.						
	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP				
Format	Lecture			4	60 T / 105 S	5.5				
	Exercises			2	30 T / 75 S	3.5				
	T = face-to-fa	ce teaching;	S = inde	ependent s	study					
Exam achievements	Written exam				(gra	ded)				
Study achievements	Successful exe	rcise partici	oation		(not gra	ded)				
Forms of media										
Literature	Jonathan KaModern CryptCourse notes	ography, Cl		(2015/20	08). Introduction	on to				

Module MA-INF 1105	Algorithms	for Data	Analysis	1				
Workload	Credit points	Duration	Freque	nev				
180 h	6 CP	$\frac{1}{1}$ semeste	_	t every 2 j	vears			
Module			at Icas	CVCIY 2,	ycars			
coordinator	Prof. Dr. Petra Mutzel							
Lecturer(s)	Prof. Dr. Petr	n Mutzol						
Lecturer(s)		a wiutzei	Mode	Semes	.			
Classification	Programme M. Co. Communication	tan Caianaa						
T 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	M. Sc. Compu		_			1		
Technical skills					chniques of mod	iern		
					analytics tasks			
Soft skills				ds, critica	d discussion of			
	applied metho		_					
Contents					ructures relevai			
	analytic tasks	for big data	a, i.e., algo	rithms for	graph similari	ity,		
	parallel algorit	thms, I/O -d	lata structi	ires, and	streaming			
	algorithms.							
Prerequisites	Required:							
	none							
	Recommended	:						
			f foundation	ns of algo	orithms and da	ta		
	structures is e	_	1 TO GIT GOVIE	.113 01 01-80				
	Teaching forms	at C	Group size	h/week	Workload[h]	CP		
Format	Lecture			2	30 T / 45 S	2.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-fa	ce teaching	S = inder	endent st		ı		
Exam achievements	Oral exam					ded)		
Study achievements	Successful exe	rcise partici	pation		(not gra	ded)		
Forms of media						-		
Literature								

26.1.1	HPC modern Architectures and Trends								
Module MA-INF 1106	HPC modern Architectures and Trends								
Workload	Credit points Duration Frequency								
120 h	4 CP 1 semester every year								
Module	Prof. Dr. Estela Suarez								
coordinator	1 101. D1. Estela Sualez								
Lecturer(s)	Prof. Dr. Estela Suarez								
. ,	Programme Mode Semester								
Classification	M. Sc. Computer Science Optional 1-3.								
Technical skills	Understanding principles of computer architecture of modern								
	HPC systems at component (processor, accelerators) and system								
	level (system architecture, network, memory hierarchy) and								
	their implication for application programming.								
Soft skills	Ability to select an specific HPC topic and present it in a clear								
	and comprehensive manner suitable for a lightning talk (10min)								
Contents	Computer architectures, system components (CPU, memory,								
	network) and their interrelation.								
	Software environment								
	Parallel architectures and parallel programming paradigms								
	(MPI, OpenMP, CUDA)								
	High Performance Computing								
	Current challenges								
Prerequisites	Required:								
	Knowledge of a modern programming language (like C, C++, Python,?).								
	Interest in High Performance Computing								
	Recommended:								
	Bachelor Lecture "Computerarchitektur"								
E 4	Teaching format Group size h/week Workload[h] CP								
Format	Lecture 2 30 T / 90 S 4								
	T = face-to-face teaching; S = independent study								
Exam achievements	Oral exam (graded)								
Study achievements	none (not graded)								
Forms of media									
	- John L. Hennessy, David A. Patterson: Computer Architecture								
	- A Quantitative Approach. Morgan Kaufmann Publishers, 2012								
	- David A. Patterson, John L. Hennessy: Computer								
	Organization and Design - The Hardware / Software Interface.								
Literature	Morgan Kaufmann Publishers, 2013								
	- Message Passing Interface Forum: MPI: A Message-Passing								
	Interface Standard, Version 3.1								
	- OpenMP Application Programming Interface, Version 4.5,								
	November 2015								

Module MA-INF 1107	Foundations of Quantum Computing									
Workload	Credit points	Credit points Duration Frequency								
180 h	6 CP	1 semes	ster	every y	ear					
Module	Prof. Dr. Chr.	istian Baı	uckh	age						
coordinator										
Lecturer(s)	Prof. Dr. Chr.	istian Baı	uckh	age						
Classification	Programme			Mode	Semest	ter				
Classification	M. Sc. Compu	iter Scien	ce	Optiona	l 1-3.					
Technical skills			,							
Soft skills										
Contents										
Prerequisites	none									
	Teaching forms	at	Gr	oup size	h/week	Workload[h]	CP			
Format	Lecture				2	30 T / 45 S	2.5			
	Exercises				2	30 T / 75 S	3.5			
	T = face-to-fa	ce teachir	ng; S	S = indep	endent st	udy				
Exam achievements	Schriftliche Pr	Schriftliche Prüfung (graded)								
Study achievements	Erfolgreiche Ü	bungsteil	nahı	me		(not gra	$\overline{\operatorname{ded}}$			
Forms of media										
Literature										

Module	Approximat	tion Algori	$\overline{ ext{thms}}$							
MA-INF 1201										
Workload	Credit points	Duration	Freque	ency						
270 h	9 CP 1 semester at least every year									
Module	Prof. Dr. Jens Vygen									
coordinator		v O								
Lecturer(s)	All lecturers o	All lecturers of Discrete Mathematics,								
	Senior Prof. D	r. Marek Ka	rpinski							
CI 10 II	Programme		Mode	Seme	ster					
Classification	M. Sc. Compu	ter Science	Option	al 2. or	3.					
Technical skills	Introduction t	o design and	analysis	of most i	important					
	approximation	algorithms	or NP-h	ard comb	inatorial					
	optimization p	oroblems, and	l various	techniqu	es for proving lower					
	and upper bou	ınds, probabi	listic me	thods and	d applications					
Soft skills	Presentation o	f solutions a	nd metho	ods, critic	al discussion of					
	applied metho	ds and techn	iques							
Contents	Approximation	n Algorithms	and Ap	proximati	on Schemes. Design					
	and Analysis of	of Approxima	tion algo	orithms fo	or selected NP-hard					
	problems, like	Set-Cover, a	nd Verte	x-Cover p	oroblems,					
	MAXSAT, TS	P, Knapsack	Bin Pac	cking, Ne	twork Design,					
	Facility Locati	on. Introduc	tion to v	arious ap	proximation					
	techniques (lik									
	Search, randor		_							
	MCMC-Metho	* *			nalysis of					
	approximation	hardness an	d PCP-S	Systems.						
Prerequisites	Recommended									
	Introductory k			ons of alg	gorithms and					
	complexity the									
	Teaching forms	at Gro	up size	h/week	Workload[h] CP					
Format	Lecture			4	60 T / 105 S 5.5					
	Exercises			2	30 T / 75 S 3.5					
	T = face-to-fa	ce teaching;	S = inde	pendent s	study					
Exam achievements	Oral exam				(graded)					
Study achievements	Successful exe	rcise particip	ation		(not graded)					
Forms of media										
	• S. Arora, C.	Lund: Hard	ness of A	pproxima	ations. In:					
	Approximation	n Algorithms	for NP-	Hard Pro	blems (D. S.					
	Hochbaum, ed.), PWS, 1996									
	• M. Karpinski: Randomisierte und approximative Algorithmen									
	für harte Berechnungsprobleme, Lecture Notes (5th edition),									
Literature	Universität Bo									
	· ·			_	zation: Theory and					
	Algorithms (6t				-					
					s, Springer, 2001					
	• D. P. Willian									
	Approximation Algorithms, Cambridge University Press, 2011									

Module MA-INF 1202	Chip Design	1								
Workload	Credit points	Duration	Freque	ency						
270 h	9 CP	9 CP 1 semester every year								
Module	Prof. Dr. Jens	Prof. Dr. Jens Vygen								
coordinator										
Lecturer(s)	All lecturers o	f Discrete Ma	athemati	cs						
Classification	Programme		\mathbf{Mode}	Seme	ster					
Classification	M. Sc. Compu									
Technical skills	Knowledge of	the central p	roblems	and algor	ithms in chip					
	_		_		gorithms for so	_				
	_	,	_		hnical constraii					
	_	_	impleme	ent efficier	nt algorithms for	or				
	very large inst									
Soft skills		_	-		ng in chip desig	gn,				
	development o	_	,		thinking,					
	_	presentation of solutions to exercises								
Contents	Problem form		_	_	0 , 0					
	synthesis, plac	ement, routii	ng, timin	g analysi	s and optimiza	tion				
Prerequisites	none				T					
	Teaching forma	at Gro	up size	h/week		CP				
Format	Lecture			4	60 T / 105 S	5.5				
	Exercises			2	30 T / 75 S	3.5				
	T = face-to-fa	ce teaching;	S = inde	pendent s	study					
Exam achievements	Oral exam				(gra	aded)				
Study achievements	Successful exer	rcise particip	ation		(not gra	aded)				
Forms of media										
		,	_		The Handbook					
	Algorithms for VLSI Physical Design Automation. CRC Press,									
	New York, 2008.									
	• S. Held, B. Korte, D. Rautenbach, J. Vygen: Combinatorial									
	optimization in VLSI design. In: "Combinatorial Optimization:									
Literature	Methods and Applications" (V. Chvátal, ed.), IOS Press,									
Divortabulo	Amsterdam 2011, pp. 33-96									
	· ·		Design. I	Lecture N	otes (distribute	ed				
	during the cou	,	a		~ - ~	_				
					.K. Scheffer, ed					
		0			nentation, Circu					
	Design, and Process Technology. CRC Press, 2nd edition, 2016									

Module	Discrete an	d Comput	ational (Geome	try								
MA-INF 1203													
Workload	Credit points	Duration	Freque	-									
270 h	9 CP	1 semester	every y	ear									
Module	Prof. Dr. Ann	ne Driemel											
coordinator													
Lecturer(s)		Prof. Dr. Anne Driemel, PD Dr. Elmar Langetepe,											
		Dr. Herman Haverkort											
Classification	Programme		Mode	Seme	ster								
	M. Sc. Compu		Optiona										
Technical skills					acepts in the are								
		-		, ,	and analysis of								
				-	of the complex	ity							
	of geometric c	_			owledge								
	autonomously												
Soft skills	Social compet	`		-	_								
	solutions, goal			/	,								
	competence (a	. ,	, -	, ,									
	`	commitment	and willin	gness to	learn, creativity	y,							
	endurance).												
Contents			,	_	ms, hyperplane								
	arrangements, well-separated pair decomposition, spanners,												
	_				n, VC-dimension	n,							
	epsilon-nets, v	0 / 2		, –	٠,								
	randomized in			. –	tric distance								
	problems in di	mension two	and high	er.									
Prerequisites	Recommended												
	BA-INF 114 –		der algor	ithmisch									
	Teaching forms	at Gro	oup size	h/week	Workload[h]	CP							
Format	Lecture			4	60 T / 105 S	5.5							
	Exercises			2	30 T / 75 S	3.5							
	T = face-to-fa	ce teaching;	S = indep	endent s	study								
Exam achievements	Oral exam					ded)							
Study achievements	Successful exe	rcise particip	ation		(not gra	$\frac{\widetilde{\mathrm{ded}}}{\mathrm{ded}}$							
Forms of media					, ,								
	• Jiri Matousek. Lectures on Discrete Geometry. Springer												
	Graduate Texts in Mathematics. ISBN 0-387-95374-4.												
	• Mark de Bei	rg, Otfried C	heong, Ma	arc van I	Kreveld, and Ma	ark							
	Overmars. Co	<u> </u>	٠,		,								
Literature	Applications (-		_									
	978-3-540-779		,	-									
			netric Spa	nner Net	works								
			_			 Narasimhan/Smid, Geometric Spanner Networks Klein, Concrete and Abstract Voronoi Diagrams 							

Module MA-INF 1205	Graduate S	eminar D	iscrete (Optimiz	ation			
Workload	Credit points	Duration	Freque	ency				
180 h	6 CP	1 semeste	r every	year				
Module	Prof. Dr. Jens	Prof. Dr. Jens Vygen						
coordinator								
Lecturer(s)	All lecturers o	f Discrete N	[athemati	ics				
Classification	Programme		Mode	Seme	ester			
Classification	M. Sc. Compu	iter Science	Option	al 2 .				
Technical skills	Competence to	o understan	d new res	earch res	ults based on			
	original literat	ure, to put	such resu	lts in a b	roader context a	and		
	present such re	present such results and relations.						
Soft skills	Ability to read	d and under	stand rese	earch pap	ers, abstract			
	thinking, prese	entation of	nathemat	ical resul	ts in a talk			
Contents	A current rese	arch topic i	n discrete	optimiza	tion will be cho	sen		
	each semester	and discuss	ed based	on origina	al literature.			
Prerequisites	Recommended	:						
	MA-INF 1102	– Combina	torial Opt	timization	1			
Format	Teaching forms	at G	oup size	h/week	Workload[h]	CP		
rormat	Seminar		10	4	60 T / 120 S	6		
	T = face-to-fa	ce teaching	S = inde	ependent	study			
Exam achievements	Oral presentat	ion, writter	report		(gra	ded)		
Study achievements					(not gra	ded)		
Forms of media								
Literature	The topics and the end of the			ıre will be	e announced tow	ards		

Module MA-INF 1206	Seminar Ra Algorithms	Seminar Randomized and Approximation Algorithms						
Workload	Credit points Duration Frequency							
120 h	4 CP	1 semest	_	•				
Module	Prof. Dr. Heik	o Röglin		<u>'</u>				
coordinator		J						
Lecturer(s)	Prof. Dr. Ann	e Driemel,	Prof. Dr.	Thomas K	Kesselheim,			
, ,	Prof. Dr. Heik	o Röglin, l	PD Dr. Elı	nar Lange	etepe,			
	Dr. Herman H	averkort, S	Senior Prof	. Dr. Mar	ek Karpinski			
C1 10 11	Programme	· · · · · · · · · · · · · · · · · · ·	Mode	Semes				
Classification	M. Sc. Compu	ter Science	Optiona	nal 2.				
Technical skills	Ability to perfe	Ability to perform individual literature search, critical reading,						
	understanding,	and clear	presentati	on.				
Soft skills	Presentation of	f solutions	and method	ds, critica	d discussion of			
	applied method	ds and tecl	nniques					
Contents	Current topics	in design	and analys	is of rando	omized and			
	approximation	algorithm	s based on	lastest res	search literatur	e		
Prerequisites	none							
Format	Teaching forma	ıt (Group size	h/week	Workload[h]	CP		
rormat	Seminar		10	2	30 T / 90 S	4		
	T = face-to-fac	ce teaching	S = inde	pendent st	udy			
Exam achievements	Oral presentati	ion, writte	n report		(gra	ded)		
Study achievements	(not graded)							
Forms of media								
Literature	The relevant li	terature w	ill be anno	unced in t	ime.			

Module	Lab Combin	natorial Al	gorithn	ns		
MA-INF 1207						
Workload	Credit points	Duration	Freque	ency		
270 h	9 CP	1 semester every year				
Module	Prof. Dr. Jens	s Vygen				
coordinator						
Lecturer(s)	All lecturers o	All lecturers of Discrete Mathematics				
Classification	Programme		Mode	Seme	ster	
Classification	M. Sc. Compu	iter Science	Optiona	al 2 .		
Technical skills	Competence to	o implement	advance	l combina	torial algorithn	ns,
	handling nonti	rivial data st	ructures,	testing,	documentation.	
	Advanced soft	ware techniq	ues.			
Soft skills	Efficient imple	ementation of	complex	algorith	ms, abstract	
	thinking, documentation of source code					
Contents	Certain combi	natorial algo	rithms w	ill be cho	sen each semest	er.
	The precise ta	sk will be ex	plained i	n a meeti	ng in the previo	ous
	semester.					
Prerequisites	Recommended	:				
	MA-INF 1102	- Combinate	orial Opt	imization		
Format	Teaching forms	at Gro	oup size	h/week	Workload[h]	CP
Format	Lab		8	4	60 T / 210 S	9
	T = face-to-fa	ce teaching;	S = inde	pendent s	study	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)
Study achievements					(not gra	$\overline{\operatorname{ded}}$
Forms of media						
Literature	The topics and	d the relevan	t literatu	re will be	announced tow	ards
Literature	the end of the	previous sen	nester			

Module	Seminar Ad	lvanced	Top	oics in (Cryptog	graphy	
MA-INF 1209							
Workload	Credit points	Duration	n	Frequer	ncy		
120 h	4 CP	1 semes	ster	every se	emester		
Module	Dr. Michael N	üsken					
coordinator							
Lecturer(s)	Dr. Michael N	Dr. Michael Nüsken					
Classification	Programme			Mode	Semest	ter	
Classification	M. Sc. Compu	iter Scienc	ce	Optional	2. or 3	3.	
Technical skills	Understanding	g research	pub	lications	, often wr	ritten tersely.	
	Distilling this	into a pre	esent	ation. D	eterminat	tion of relevant	vs.
	irrelevant mat fellow students		elop	ing a pre	esentation	that fascinate	es
Soft skills		Understanding and presenting material both orally and in visual				isual	
	_	media. Motivating other students to participate. Critical					
	assessment of	_			1 1		
Contents	A special topic	c within c	rypt	ography,	changing	from year to	year,
	is studied in d	epth, base	ed or	n current	research	literature	
Prerequisites	Required:						
	MA-INF 1103	- Crypto	grap	hy			
	and one further	er course i	in cr	yptograp	hy like T	he Art of	
	Cryptography	or eSecur	ity.				
Format	Teaching forms	at	Gro	oup size	h/week	Workload[h]	CP
rormat	Seminar			10	2	30 T / 90 S	4
	T = face-to-fa	ce teachir	ng; S	= indep	endent st	udy	
Exam achievements	Oral presentat	ion, writt	en r	eport		(gra	ded)
Study achievements						(not gra	ded
Forms of media							
Literature	Current crypto	ographic l	itera	ture.			

Module MA-INF 1213	Randomize	d Algorith	ms and	Probab	oilistic Analy	sis		
Workload	Credit points	Duration	Freque	encv				
270 h	9 CP	1 semester	every	-				
Module	Prof. Dr. Heil		cvery	Jear				
coordinator	1 101. D1. 11011	ko 1togiiii						
Lecturer(s)	Prof. Dr. Heil	zo Röglin						
Lecturer (s)	Programme	ko 1togiiii	Mode	Seme	stor			
Classification	M. Sc. Compu	iter Science	Optiona					
Technical skills					the probabilisti	$\overline{\mathbf{c}}$		
		orithms as w		•	gn and analysis			
Soft skills	Oral and write	<u> </u>	ion of so	lutions ar	nd methods.			
	abstract think	_			,			
Contents	Design and an	0	domized	algorithm	ıs			
	• complexity of			O				
	Markov chai		m walke					
	• tail inequalit		m wang					
	• probabilistic							
	1	smoothed and average-case analysis						
	smoothed and	average-case	analysis	3				
	• simplex algo	rithm						
	• local search	_						
	• clustering al	gorithms						
	• combinatoria	-	-	ems				
	• multi-object	ive optimizat	ion					
Prerequisites	none							
	Teaching forms	at Gro	oup size	h/week	Workload[h]	CP		
Format	Lecture			4	60 T / 105 S	5.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-fa	ce teaching;	S = inde	pendent s	study			
Exam achievements	Oral exam				(gra	ded)		
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)		
Forms of media								
	• lecture notes	5						
	• research arti	icles						
T:tonotuno	• Motwani, Ra	aghavan, Rar	domized	Algorith	ms, Cambridge			
Literature	University Pre							
	• Mitzenmach	er, Upfal, Pr	obability	and Con	nputing, Cambr	idge		
	University Pre	ess, 2nd editi	on, 2017					

Module MA-INF 1217	Seminar Th	Seminar Theoretical Foundations of Data Science				
Workload	C	Duration	Th			
	Credit points					
120 h	4 CP					
Module	Prof. Dr. Heil	Prof. Dr. Heiko Röglin				
coordinator						
Lecturer(s)	Prof. Dr. Ann	Prof. Dr. Anne Driemel, Prof. Dr. Thomas Kesselheim,				
	Prof. Dr. Heil	ko Röglin, Pl	Dr. Elm	ar Lange	tepe,	
	Dr. Herman H	Iaverkort		J	- /	
CI IO II	Programme		Mode	Semest	ter	
Classification	M. Sc. Compu	M. Sc. Computer Science Optional 2. or 3.			3.	
Technical skills	Ability to understand new research results presented in original					
	scientific pape	rs.		_	_	
Soft skills	Ability to pres		ritically di	scuss the	se results in th	ie
	framework of		-			
Contents	Current confer	rence and joi	ırnal pape	rs		
Prerequisites	none					
To 4	Teaching forms	at G	roup size	h/week	Workload[h]	CP
Format	Seminar		10	2	30 T / 90 S	4
	T = face-to-fa	ce teaching;	S = indep	endent st	udy	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
Literature						

Module MA-INF 1218	Algorithms	and Unc	ertainty			
Workload	Credit points	Duration	Frequ	encv		
270 h	9 CP	1 semeste	_	st every 2	years	
Module	Prof. Dr. Tho	mas Kessel	heim			
coordinator						
Lecturer(s)	Prof. Dr. Tho	mas Kessel	neim			
Classification	Programme		Mode	Seme	ster	
Classification	M. Sc. Compu	iter Science	Option	al 2. or	3.	
Technical skills	Understanding	g approache	s for mod	eling unce	ertainty in	
	algorithmic th	eory. Desig	ning and	analyzing	algorithms with	ı
	performance g	uarantees i	n the cont	ext of unc	certainty.	
Soft skills	Oral and writt	Oral and written presentation of solutions and methods				
Contents	• Advanced Online Algorithms					
	Markov Dec:	isions Proc	esses			
	• Stochastic a	nd Robust	Optimizat	ion		
	Online Learn	ning Algori	hms and	Online Co	onvex Optimizat	tion
Prerequisites	Recommended	:				
	Solid backgrou	ınd in algor	ithms, cal	lculus, and	d probability the	eory.
	Specialized kn	owledge ab	out certai	n algorith	ms is not necess	sary.
	Teaching forms	at G	roup size	h/week	Workload[h]	CP
Format	Lecture			4	60 T / 105 S	5.5
	Exercises			2	30 T / 75 S	3.5
	T = face-to-fa	ce teaching	S = inde	ependent s	study	
Exam achievements	Oral exam				(gra	ded)
Study achievements	Successful exe	rcise partic	pation		(not gra	ded)
Forms of media						
Literature	lecture notes,	research ar	icles			

Module MA-INF 1219	Seminar Al	Seminar Algorithmic Game Theory				
Workload	Credit points	Duration	Frequen	ıcy		
120 h	4 CP	1 semeste	r every ye	ear		
Module	Prof. Dr. Tho	Prof. Dr. Thomas Kesselheim				
coordinator						
Lecturer(s)	Prof. Dr. Tho	Prof. Dr. Thomas Kesselheim				
CI :C .:	Programme		Mode	Semest	ter	
Classification	M. Sc. Compu	iter Science	Optional	2. or 3	3.	
Technical skills	Ability to und	erstand nev	research r	esults pre	esented in orig	inal
	scientific pape	scientific papers.				
Soft skills	Ability to perf	Ability to perform individual literature search, critical reading,				
	and clear dida	ctic present	ation			
Contents	Advanced topi	ics in Algori	thmic Gam	e Theory	and Algorithi	mic
	Mechanism De	esign based	on current	conference	ce and journal	
	papers					
Prerequisites	none					
Format	Teaching forms	at C	roup size	h/week	Workload[h]	CP
Format	Seminar		10	2	30 T / 90 S	4
	T = face-to-fa	ce teaching	S = indep	endent st	udy	
Exam achievements	Oral presentat	tion, written	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
Literature						

Module	Seminar Al	Seminar Algorithms for Computational Analytics				
MA-INF 1220						
Workload	Credit points	Duration	Frequen	cy		
120 h	4 CP	1 semester	at least	every ye	ar	
Module	Prof. Dr. Petra Mutzel					
coordinator						
Lecturer(s)	Prof. Dr. Petr	Prof. Dr. Petra Mutzel				
Classification	Programme		Mode	Semest	ter	
Classification	M. Sc. Compu	M. Sc. Computer Science Optional 2. or 3.				
Technical skills	Ability to perf	Ability to perform individual literature search, critical reading,				
	understanding	understanding, and clear didactic presentation.				
Soft skills	Ability to present and to critically discuss these results in the					
	framework of	the correspo	nding area.			
Contents	Current topics	in algorithr	ns for com	putationa	al analytics bas	sed
	on recent resea	arch literatu	re.			
Prerequisites	Recommended	:				
	Interest in Alg	m gorithms				
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP
Format	Seminar		10	2	30 T / 90 S	4
	T = face-to-fa	ce teaching;	S = indep	endent st	tudy	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
Literature	The relevant l	iterature wil	l be annou	nced in t	ime.	

Module MA-INF 1221	Lab Compu	itational A	nalytics	5		
Workload	Credit points	Duration	Freque	ncy		
270 h	9 CP	1 semester	1 -	•		
Module	Prof. Dr. Peti	Prof. Dr. Petra Mutzel				
coordinator						
Lecturer(s)	Prof. Dr. Peti	Prof. Dr. Petra Mutzel				
Classification	Programme		Mode	Seme	ster	
Classification	M. Sc. Compu	iter Science	Optiona	d 2. or	3.	
Technical skills		0 /			cient algorithm	s for
	computational					
	_	evaluation ar	nd docum	entation	of the implemen	nted
	software.					
Soft skills		Ability to properly present and defend design decisions, to				
	prepare readal			,		
			_		nall teams over	
		,		siry ones	own results into	o tne
<u> </u>	state-of-the-ar			imata ala	sanithmaa and da	+
Contents	structures for			_	gorithms and da	ııa
Prerequisites	Recommended		iai anaiyu	ics proble	:1115.	
Frerequisites	Interests in alg	· -				
	Teaching forms		oup size	h/week	Workload[h]	СР
Format	Lab	at G1	8	4	60 T / 210 S	9
			-		,	
	T = face-to-fa			pendent s		1 1\
Exam achievements	Oral presentat	non, written	report		(0	ded)
Study achievements					(not gra	iaea)
Forms of media	/ml1		1 1	1 •	4:	
Literature	The relevant literature will be announced in time.					

Module MA-INF 1222	Lab High P	erforman	ce Opti	mization	1
Workload	Credit points	Duration	Frequ	ency	
270 h	9 CP	1 semest	er every	year	
Module	Prof. Dr. Petr	a Mutzel	1		
coordinator					
Lecturer(s)	Prof. Dr. Petr	a Mutzel,	Or. Sven 1	Mallach	
Classification	Programme		Mode	Seme	ster
Classification	M. Sc. Compu	iter Science	Option	al 2. or	3.
Technical skills	Ability to desi	gn, analyze	and impl	ement alg	orithms for
	computational	analytics	and optim	ization pr	oblems. The lab
	also includes e	experimenta	l evaluati	on and do	cumentation of the
	implemented s	software.			
Soft skills	Ability to properly present and defend design decisions, to				
	prepare readal	ole docume	ntation of	software;	skills in
	constructively	collaborati	ng with o	thers in sr	nall teams over a
	longer period	of time; ab	lity to cla	ssify ones	own results into the
	state-of-the-ar	t of the res	p. area		
Contents					
Prerequisites	none				
Format	Teaching forms	at G	roup size	h/week	L J
Format	Lab		8	4	60 T / 210 S 9
	T = face-to-fa	ce teaching	S = inde	ependent s	study
Exam achievements	Oral presentat	ion, writte	n report		(graded)
Study achievements					(not graded)
Forms of media					
Literature	The relevant l	iterature w	ill be anno	ounced in	time.

Module	Privacy Enl	nancing Te	chnolo	gies		
MA-INF 1223	l IIVacy Lin	naneing re	cimolo	51CB		
Workload	Credit points	Duration	Freque	encv		
270 h	9 CP	1 semester	every	-		
Module	Dr. Michael N			J		
coordinator						
Lecturer(s)	Dr. Michael N	Tüsken				
	Programme		Mode	Semes	ster	
Classification	M. Sc. Compu	iter Science	Optiona	al 2. or	3.	
Technical skills	Knowledge: C	La contraction de la contracti			ncing privacy,	
	underlying sec	urity notions	, applica	tions and	restrictions.	
	Skills: Secure	application o	f sophist	icated cry	yntographic	
			-		ciency and secu	rity
	in an applicati				<i>y</i>	,
Soft skills	Competences:		sess sche	emes and	their use in	
	applications.	-				
Contents	With more an	d more data	available	a clear s	eparation of	
	sensitive data	is necessary	and need	ls to be p	rotected. Some	of
	that data mus	t stay within	strict er	nvironmer	nts, for example	es
	hospitals must	store certain	highly	sensitive i	medical informa	ation
	_				ore it outside i	
					collected in a c	
					m a medical de	vice
	or a smart hor			_		
	important conclusions from it, for example to send immediate help to a patient suffering a heart attack.					
		_				
					of tension. The	
				ome high	ly sophisticated	_
	tools for solving	ng the like pr	oblems.			
	• Fully homon	norphic encry	ption (F	THE).		
			, .	rticular:	Non-interactive	:
	zero-knowledg					
	• Secure multi			` /		
	• Anonymisat:		-		_	
	• Weaker priva		ike diffe	rential pri	vacy.	
Prerequisites	Recommended			1-:1-1		
	Basic knowled			0 0		,
	_		_		nelp. In particu	
					ing are importa	ant,
	but also topics				•	
	mathematics, Teaching forms		up size	h/week	Workload[h]	СР
Format	Lecture	Gro	up size	11/ week	60 T / 105 S	5.5
10111100	Exercises			2	30 T / 75 S	3.5
		eo topahina: (inda			1 3.0
Even cabiarres	T = face-to-fa Schriftliche Pr		$\mathfrak{z} = \mathrm{mae}$	репаент 8		, deq.)
Exam achievements	Erfolgreiche Ü		mo			ided)
Study achievements Forms of media	Errorgreiche U	bungstellitäll	1116		(not gra	ided)
Literature						
Literature						

Module MA-INF 1224	Quantum C	omputir	ng .	Algoritl	nms		
Workload	Credit points	Duration	ı	Frequer	ıcy		
150 h	5 CP	1 semes	ter	every y	ear		
Module	Prof. Dr. Chr.	Prof. Dr. Christian Bauckhage					
coordinator							
Lecturer(s)	Prof. Dr. Chr.	istian Bau	ıckh	age			
Classification	Programme			Mode	Semest	ter	
Classification	M. Sc. Compu	iter Scienc	ce	Optional	2. or 3	3.	
Technical skills							
Soft skills							
Contents							
Prerequisites	none						
	Teaching forms	at	Gro	oup size	h/week	Workload[h]	CP
Format	Lecture				2	30 T / 45 S	2.5
	Exercises				1	15 T / 60 S	2.5
	T = face-to-fa	ce teachin	ıg; S	S = indep	endent st	udy	
Exam achievements	Schriftliche Pr	üfung				(gra	ded)
Study achievements	Erfolgreiche Ü	bungsteilr	nahr	ne		(not gra	ded)
Forms of media							
Literature							

Module	Algorithmic	Game T	neory			
MA-INF 1301						
Workload	Credit points	Duration	Freque	ency		
270 h	9 CP	1 semester	_	2 years		
Module	Prof. Dr. Tho	mas Kesselh				
coordinator						
Lecturer(s)	Prof. Dr. Tho	mas Kesselh	eim,			
` ,	Senior Prof. D					
~	Programme		Mode	Seme	ster	
Classification	M. Sc. Compu	iter Science	Option	al 2. or	3.	
Technical skills	Knowledge of	fundamenta	results i	n (algorit	hmic) game theory	
	and (algorithm	nic) mechani	sm desig	n. Techni	ques and methods	
	related to mat	hematical m	odeling o	of strategi	c agents. Analyzing	
	and designing	systems of s	trategic a	agents, wi	th a focus on	
	computational	efficiency a	nd perfor	mance gu	arantees.	
Soft skills	Presentation o	f solutions a	nd meth	ods, critic	al discussion of	
	applied metho	ds and tech	niques			
Contents	• basic game t	heory				
	• computabilit	y and hardr	ess of eq	uilibria		
	• convergence	of dynamics	of selfish	agents		
	• (bounds on t	the) loss of p	erformai	nce due to	selfish behavior	
	• designing inc	• designing incentive-compatible auctions				
		• maximizing revenue				
	• designing me	echanisms fo	r stable a	and fair al	llocations without	
	money					
Prerequisites	Recommended					
	Introductory k			ons of alg	gorithms and	
	complexity the					
	Teaching forms	at Gr	oup size	h/week	Workload[h] CP	
Format	Lecture			4	60 T / 105 S 5.5	
	Exercises			2	30 T / 75 S 3.5	
	T = face-to-fa	ce teaching;	S = inde	ependent s	study	
Exam achievements	Written exam				(graded)	
Study achievements	Successful exer	rcise particij	oation		(not graded)	
Forms of media						
	• N. Nisan, T. Algorithmic G				Vazirani (ed.):	
	• T. Roughgarden, Twenty Lectures on Algorithmic Game					
					Tronnine Game	
	Theory, Camb	ridge Univ.	Press, 20	16		
Literature	Theory, Camb • A. Karlin, Y	ridge Univ. 7. Peres, Gar	Press, 20 ne Theor	16 y, Alive, <i>I</i>	AMS, 2017	
Literature	Theory, Camb • A. Karlin, Y • Y. Shoham,	ridge Univ. 7. Peres, Gar K. Leyton-F	Press, 20 ne Theor Brown, M	16 y, Alive, <i>I</i>	AMS, 2017	
Literature	Theory, Camb • A. Karlin, Y • Y. Shoham, Cambridge Un	ridge Univ. C. Peres, Gar K. Leyton-Faiv. Press, 20	Press, 20 ne Theor Brown, M 009	16 y, Alive, A ultiagent	AMS, 2017 Systems,	
Literature	Theory, Camb • A. Karlin, Y • Y. Shoham, Cambridge Un • D. M. Kreps	ridge Univ. f. Peres, Gar K. Leyton-H iv. Press, 20 : A Course	Press, 20 ne Theor Brown, M 009	16 y, Alive, A ultiagent	AMS, 2017	
Literature	Theory, Camb • A. Karlin, Y • Y. Shoham, Cambridge Un • D. M. Kreps Univ. Press, 1	ridge Univ. T. Peres, Gar K. Leyton-H Liv. Press, 20 T. A Course 1990	Press, 20 ne Theor Brown, M 009 in Micros	y, Alive, Aultiagent	AMS, 2017 Systems,	

Module	Seminar Co	mputati	iona	al Geon	netry		
MA-INF 1304				ı			
Workload	Credit points	Duration	1	Frequer	\mathbf{cy}		
120 h	4 CP	1 semes	ter	every y	ear		
Module	Prof. Dr. Ann	e Driemel	-				
coordinator							
Lecturer(s)	Prof. Dr. Ann	e Driemel	, PI	Dr. Elı	nar Lang	etepe,	
	Dr. Herman H	Dr. Herman Haverkort					
Classification	Programme			Mode	Semest	ter	
Classification	M. Sc. Compu	iter Scienc	ce	Optional	2-4.		
Technical skills	To independer	To independently study problems at research level, based on					L
	research public	cations, to	pre	epare a co	oncise sur	mmary, to pres	ent
	the summary	in a scient	ific	talk, to l	ead a crit	ical discussion	
	with other sen	ninar part	icipa	ants.			
Soft skills							
Contents	Current topics	in compu	ıtati	onal geor	metry.		
Prerequisites	Recommended	:					
	BA-INF 114 –	Grundlag	gen o	der algor	ithmische	n Geometrie	
	MA-INF 1203	- Discrete	e an	d Compu	itational	Geometry	
Б	Teaching forms	at	Gro	oup size	h/week	Workload[h]	CP
Format	Seminar			10	2	30 T / 90 S	4
	T = face-to-fa	ce teachin	ıg; S	= indep	endent st	sudy	
Exam achievements	Oral presentat	ion, writt	en r	eport		(gra	ded)
Study achievements						(not gra	ded)
Forms of media	Multimedia pr	ojector, b	lack	board.			
Literature	The relevant l	iterature v	vill	be annou	nced.		

Module	Graduate S	eminar on	Applie	d Comb	oinatorial	
MA-INF 1305	Optimization	n				
Workload	Credit points	Duration	Freque	ency		
180 h	6 CP	1 semester	every y	year		
Module	Prof. Dr. Jens	s Vygen				
coordinator						
Lecturer(s)	All lecturers o	f Discrete M	athematic	cs		
Classification	Programme		Mode	Seme	ster	
Classification	M. Sc. Compu	iter Science	Optiona	al 3.		
Technical skills	Competence to	Competence to understand new theoretical results and practical				
	solutions in V	solutions in VLSI design and related applications, as well as				
	presentation o	presentation of such results				
Soft skills	Ability to read					
	thinking, prese					
Contents	Current topics	in chip desi	gn and re	elated app	olications	
Prerequisites	Recommended	:				
	At least 1 of t	he following:				
	MA-INF 1102	- Combinat	orial Opt	imization		
	MA-INF 1202	- Chip Desi	gn			
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP
Format	Seminar		10	4	60 T / 120 S	6
	T = face-to-fa	ce teaching;	S = inde	pendent s	study	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
Literature	The topics and	d the relevan	t literatu	re will be	announced tow	vards
Diterature	the end of the	previous ser	nester			

Module MA-INF 1307	Seminar Ad	lvanced A	lgorithm	S		
Workload	Credit points	Duration	Frequer	ncv		
120 h	4 CP	1 semester	_	•		
Module	Prof. Dr. Tho		0 0			
coordinator						
Lecturer(s)	Prof. Dr. Ann	e Driemel, I	Prof. Dr.	Chomas Κ	Tesselheim,	
		Prof. Dr. Heiko Röglin, PD Dr. Elmar Langetepe,				
	Dr. Herman H	Dr. Herman Haverkort				
CI 'C '	Programme		Mode	Semest	ter	
Classification	M. Sc. Compu	M. Sc. Computer Science Optional 3.				
Technical skills	Presentation of	Presentation of selected advanced topics in algorithm design and				
	various applica	ations				
Soft skills	Ability to perf	form individ	ual literatı	ıre search	, critical readi	ng,
	understanding	, and clear o	lidactic pr	esentation	1	
Contents	Advanced topi	cs in algorit	hm design	based on	newest research	ch
	literature					
Prerequisites	none					
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP
Tormat	Seminar		10	2	30 T / 90 S	4
	T = face-to-fa	ce teaching;	S = indep	endent st	udy	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
Literature	The relevant l	iterature wil	l be annou	inced in t	ime.	

Module MA-INF 1308	Lab Algorit	hms for (Chip De	sign		
Workload	Credit points	Duration	Freque	encv		
270 h	9 CP	1 semeste				
Module	Prof. Dr. Jens		-	J		
coordinator						
Lecturer(s)	All lecturers o	f Discrete N	Iathemati	ics		
	Programme		Mode	Seme	ster	
Classification	M. Sc. Compu	iter Science	Option	al 3.		
Technical skills	Competence to	o implemen	algorith	ns for VL	SI design, efficien	nt
	handling of ve	handling of very large instances, testing, documentation.				
	Advanced soft	Advanced software techniques.				
Soft skills	Efficient imple	Efficient implementation of complex algorithms, abstract				
	thinking, mod	thinking, modelling of optimization problem in VLSI design,				
	documentation	documentation of source code				
Contents	A currently ch	allenging p	oblem wi	ll be chos	en each semester.	
	The precise ta	sk will be e	xplained i	n a meeti	ng in the previous	.S
	semester.					
Prerequisites	Recommended					
	At least 3 of the	he following	:			
	MA-INF 1102	- Combina	torial Opt	imization		
	MA-INF 1202	- Chip Des	ign			
	MA-INF 1205			Discrete	Optimization	
.	Teaching forms		oup size	h/week		CP
Format	Lab		8	4	60 T / 210 S	9
	T = face-to-fa	ce teaching	S = inde	ependent s	study	
Exam achievements	Oral presentat				(grade	ed)
Study achievements	_	·			(not grade	$\overrightarrow{\text{ed}}$
Forms of media					-	
T:tonotumo	The topics and the relevant literature will be announced towards					
Literature	the end of the	previous se	mester			

Module	Lab Efficien	t Algorith	ms: De	sign, A	nalysis and	
MA-INF 1309	Implementa	tion				
Workload	Credit points	Duration	Freque	ency		
270 h	9 CP	1 semester	at leas	st every y	ear	
Module	Prof. Dr. Heil	ko Röglin				
coordinator						
Lecturer(s)	Prof. Dr. Ann	Prof. Dr. Anne Driemel, Prof. Dr. Thomas Kesselheim,				
	Prof. Dr. Heil	Prof. Dr. Heiko Röglin, PD Dr. Elmar Langetepe,				
	Dr. Herman H	Dr. Herman Haverkort				
Classification	Programme		Mode	Seme	ster	
Classification	M. Sc. Compu	iter Science	Optiona	al 3.		
Technical skills	Ability to desi	Ability to design, analyze and implement efficient algorithms for				
	selected comp	utational pro	blems.			
Soft skills	ability to work	c on advance	d algoritl	hmic imp	lementation	
	projects, to we	ork in small	teams, cle	ear didact	tic presentation	and
	critical discuss	sion of result	S			
Contents	Design of effic	ient exact ar	ıd approx	imate alg	gorithms and da	ta
	structures for	selected con	putation	al probler	ns.	
Prerequisites	none					
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP
rormat	Lab		8	4	60 T / 210 S	9
	T = face-to-fa	ce teaching;	S = inde	pendent s	study	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
Literature	The relevant l	iterature wil	l be anno	unced in	time.	

Module	Online Mot	ion Planni	ng			
MA-INF 1314						
Workload	Credit points	Duration	Freque	ency		
270 h	9 CP	1 semester	every	year		
Module	PD Dr. Elmar	Langetepe				
coordinator						
Lecturer(s)	Prof. Dr. Rolf	Klein, PD D	r. Elma	r Langete	epe	
Classification	Programme		Mode	Seme	ster	
Classification	M. Sc. Compu	I. Sc. Computer Science Optional 1-4.				
Technical skills	To acquire fun	To acquire fundamental knowledge on topics and methods in				
	online motion	online motion planning				
Soft skills						
Contents	Search and ex	ploration in u	ınknown	environn	nents (e.g., grap	hs,
	cellular enviro	nmwents, pol	ygons, s	trets), onl	line algorithms,	
	competitive ar	nalysis, comp	etitive co	omplexity	functional,	
	optimization,	shortest watc	hman ro	ute, tethe	ered robots, man	rker
	algorithms, sp	iral search, a	pproxima	ation of o	ptimal search pa	aths.
Prerequisites	Recommended	:				
	BA-INF 114 –	Grundlagen	der algo	rithmisch	en Geometrie	
	Teaching forms	at Gro	up size	h/week	Workload[h]	CP
Format	Lecture			4	60 T / 105 S	5.5
	Exercises			2	30 T / 75 S	3.5
	T = face-to-fa	ce teaching; S	S = inde	pendent s	study	
Exam achievements	Oral exam				(gra	ded)
Study achievements	Successful exe	rcise participa	ation		(not gra	ded
Forms of media	Java applets o	f geometry la	b			
Literature	Scientific resea	arch articles v	vill be re	ecommend	led in the lectur	re.

Module MA-INF 1315	Lab Compu	tational G	eometry	7		
Workload	Credit points	Duration	Freque	ıcy		
270 h	9 CP	1 semester	every y	ear		
Module	Prof. Dr. Ann	e Driemel				
coordinator						
Lecturer(s)	Prof. Dr. Ann	e Driemel, F	Dr. Eli	mar Lang	getepe,	
	Dr. Herman H	laverkort				
Classification	Programme		Mode	Seme	ster	
Classification	M. Sc. Compu	iter Science	Optiona	l 2.		
Technical skills	Ability to design, analyze, implement and document efficient					
	algorithms for	selected pro	blems in o	computat	tional geometry	
Soft skills	Ability to prop	perly present	, defend a	nd discu	ss design and	
	implementatio	n decisions,	to docume	ent softw	are according to	О
	given rules and	d to collabor	ate with o	ther stu	dents in small	
	groups.					
Contents	Various proble	ms in comp	ıtational g	geometry		
Prerequisites	none					
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP
rormat	Lab		8	4	60 T / 210 S	9
	T = face-to-fa	ce teaching;	S = indep	endent s	study	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
Literature	The relevant li	iterature wil	be annou	inced in	time.	

Module	Lab Crypto	graphy					
MA-INF 1316	G 114 1 4	D 41	- ID				
Workload	Credit points	Duration	Freque	-			
270 h	9 CP	1 semeste	r every	year			
Module	Dr. Michael N	usken					
coordinator							
Lecturer(s)	Dr. Michael N	[üsken					
Classification	Programme		Mode	Semes	ster		
Classification	M. Sc. Compu	iter Science	Options	al 2. or	3.		
Technical skills	The students	will carry or	it a pract	ical task ((project) in the		
	context of Cry	ontext of Cryptography, including test and documentation of					
	the implement	the implemented software/system.					
Soft skills	Ability to prop	perly presen	t and defe	end			
	design decision	ns, to prepa	re readabl	e docume	entation of softw	vare;	
	skills in constr	ructively col	laborating	g with oth	ners in small tea	ams	
	over a longer p	period of tir	ne; ability	to classif	fy ones own rest	ults	
	into the state-	of-the-art o	the resp.	area			
Contents							
Prerequisites	none						
Format	Teaching forms	at G	oup size	h/week	Workload[h]	CP	
Format	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching	S = inde	pendent s	study		
Exam achievements	Oral presentat	ion, written	report		(gra	ided)	
Study achievements					(not gra	ided)	
Forms of media							
Literature							

Module MA-INF 1320	Lab Advanc	ced Algori	thms				
Workload	Credit points	Duration	Freque	ncy			
270 h	9 CP	1 semester	_	every 2	years		
Module	Prof. Dr. Tho	mas Kesselh					
coordinator							
Lecturer(s)	Prof. Dr. Tho	mas Kesselh	eim, Prof.	Dr. Hei	ko Röglin		
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	I. Sc. Computer Science Optional 2. or 3.					
Technical skills	Implementation	inplementation of algorithms from advanced algorithmic theory,					
	evaluating the	evaluating these algorithm on suitably chosen instances, and					
	discussing how	theoretical	results tra	ansfer to	practice.		
Soft skills	Ability to prop	perly present	, defend a	nd discu	ss design and		
	implementatio	n decisions a	and observ	red concl	usions, and to		
	collaborate wi	th other stud	dents in sr	nall grou	ips.		
Contents	Various proble	ems from cur	rent resea	rch and	courses on		
	algorithmic th	eory.					
Prerequisites	none						
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP	
rormat	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching;	S = indep	endent s	study		
Exam achievements	Oral presentat	ion, written	report		(gra	ided)	
Study achievements					(not gra	ided)	
Forms of media							
Literature	The relevant l	iterature wil	l be annou	inced in	time.		

Module MA-INF 1321	Binary Line	ear and Q	uadratic	Optimi	zation	
Workload	Credit points	Duration	Freque	ncy		
180 h	6 CP	1 semeste	_	every 2	years	
Module	Dr. Sven Mall	ach			-	
coordinator						
Lecturer(s)	Dr. Sven Mall	ach				
C1 10 11	Programme		Mode	Semes	ter	
Classification	M. Sc. Compu	iter Science	Optiona	l 2. or 3	3.	
Technical skills	Deeper unders	standing of	computation	nal meth	ods to solve	
	potentially lar	ge-scale mi	ked-integer	programs	s in practice.	
	Application-specific modelling and reformulation of					
	combinatorial	optimizatio	n problems	s, handlin	g quadratic	
	objective func	tions, algori	thm design	1.		
Soft skills	Social, method	dological, ai	nd analytic	al compet	ences via	
	communication	n, own deve	lopment, p	resentatio	on, and critical	
	assessment of problem formulations, algorithms, and solutions					
	covered in the course or the excercises. Learning to abstra also learning the limitations of abstraction.					
Contents	Computationa	l methods i	n (mixed-)	integer pr	ogramming suc	ch as
	cutting plane separation and branch-and-bound along with a					
	short and acce	essible intro	duction int	o their th	eoretical basis	
	Study of practically relevant binary linear and binary quadratic					
	optimization p	oroblems, e.	g., Maximu	ım Cut, I	inear Ordering	ŗ
	and variants o	f the Trave	ing Salesm	an proble	em, along with	the
	particular sepa	aration prol	olems arisir	ng there.	If there is time	·,
	linearizations	of quadration	objective	functions	and more	
	_	formulation	s of binary	quadratio	c problems are	
	discussed.					
Prerequisites	none					
	Teaching forms	at (Froup size	h/week	Workload[h]	CP
Format	Lecture			2	30 T / 45 S	2.5
	Exercises			2	30 T / 75 S	3.5
	T = face-to-fa	ce teaching	S = indep	endent st	udy	
Exam achievements	Oral exam		1			ded)
Study achievements	Successful exe	rcise partici	pation		(not gra	
Forms of media		<u> </u>			·	
Literature						

Module	Seminar Foo	cus Topic	s in High	n Perfor	mance	
MA-INF 1322	Computing					
Workload	Credit points	Duration	Freque	ncy		
120 h	4 CP	1 semeste	r every y	ear		
Module	Prof. Dr. Este	la Suarez				
coordinator						
Lecturer(s)	Prof. Dr. Este	la Suarez				
Classification	Programme		Mode	Semes	ter	
Classification	M. Sc. Compu	I. Sc. Computer Science Optional 2. or 3.				
Technical skills	Ability to perf	Ability to perform individual literature search, critical reading,				
	understanding	understanding, prepare a concise summary, and clear didactic				
	presentation	presentation				
Soft skills	Ability to pres	ent and crit	ically disc	uss these	results in the	
	framework of t	he correspo	nding area	ı		
Contents	General topics	and trends	in high pe	erformanc	e computing, b	ased
	on recent revie	ew and resea	arch literat	ture		
Prerequisites	Recommended	:				
	Interest in Hig	h Performa	nce Comp	uting		
To 4	Teaching forma	at G	roup size	h/week	Workload[h]	CP
Format	Seminar		10	2	30 T / 90 S	4
	T = face-to-face	ce teaching;	S = indep	endent st	udy	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
T	Literature and	further infe	ormation a	bout this	seminar will b	e
Literature	announced in	time in the	website of	lecturer.		
		mounced in time in the website of feeturer.				

Module	Computation	nal Topolo)gv				
MA-INF 1323	Comparation	nar ropon	783				
Workload	Credit points	Duration	Freque	ncy			
270 h	9 CP	1 semester		t every 2	years		
Module	Prof. Dr. Ann			J	<i>y</i>		
coordinator							
Lecturer(s)	Prof. Dr. Ann	e Driemel, D	r. Bened	ikt Kolbe	2		
· · · · · · · · · · · · · · · · · · ·	Programme	,	Mode	Seme			
Classification	M. Sc. Compu	iter Science	Optiona	al 2. or	3.		
Technical skills	-				cepts in the are	ea of	
					ent homology a		
	topological da	ta analysis; d	lesign and	d analysis	s of combinator	ial	
	algorithms in	topological c	ontexts; a	analysis o	of the complexit	y; to	
	apply this kno	wledge autor	omously	to solvin	g new problems	and	
	analysing new	data sets.					
Soft skills	Social compete	ence (commu	nication,	presentii	ng one's own		
	solutions, goal			,	,		
	competence (analysis, abstraction, proofs), individual						
	competence (commitment and willingness to learn, creativity,						
	perseverance).						
Contents	Fundamental concepts of relative homology and cohomology						
	theory and persistence theory in computational settings,						
	category theory in this context, algorithms for the computation						
	of (persistent) homology, (extended) persistence modules and						
	their decompositions, Morse theory, duality theorems, quiver						
	representation theory, stability of persistence diagrams and						
	barcodes, algebraic stability, topological filtrations,						
	multiparameter persistence, invariants of persistence, topological						
	data analysis, applications to shape pattern recognition, machine learning, identification of geometric objects.						
	machine learni		tion of a	comotrio	objects	0	
Duanaguisitas			ation of g	eometric	objects.	<u></u>	
Prerequisites	none	ing, identifica					
-	none Teaching forms	ing, identifica	oup size	h/week	Workload[h]	СР	
Prerequisites Format	none Teaching forma Lecture	ing, identifica		h/week	Workload[h] 60 T / 105 S	CP 5.5	
-	none Teaching forma Lecture Exercises	at Gro	oup size	h/week 4 2	Workload[h] 60 T / 105 S 30 T / 75 S	СР	
Format		at Gro	oup size	h/week 4 2	Workload[h] 60 T / 105 S 30 T / 75 S	5.5 3.5	
Format Exam achievements		at Groce teaching;	oup size	h/week 4 2	Workload[h] 60 T / 105 S 30 T / 75 S study (gra	CP 5.5 3.5	
Format Exam achievements Study achievements		at Groce teaching;	oup size	h/week 4 2	Workload[h] 60 T / 105 S 30 T / 75 S	CP 5.5 3.5	
Format Exam achievements	none Teaching formate Lecture Exercises T = face-to-fate Schriftliche Prescriber Ü	at Groce teaching; üfung bungsteilnah	oup size S = indep	h/week 4 2 pendent s	Workload[h] 60 T / 105 S 30 T / 75 S study (gra (not gra	CP 5.5 3.5 dedd)	
Format Exam achievements Study achievements	none Teaching forms Lecture Exercises T = face-to-fa Schriftliche Pr Erfolgreiche Ü • Herbert Ede	at Groce teaching; üfung bungsteilnah	S = indep	h/week 4 2 pendent s	Workload[h] 60 T / 105 S 30 T / 75 S study (gra (not gra	CP 5.5 3.5 ded) ded)	
Format Exam achievements Study achievements	none Teaching formate Lecture Exercises T = face-to-fa Schriftliche Pr Erfolgreiche Ü Herbert Eder Topology: An	ce teaching; üfung bungsteilnah	S = inder	h/week 4 2 pendent s r (2010). an Mathe	Workload[h] 60 T / 105 S 30 T / 75 S study (gra (not gra Computational ematical Society	CP 5.5 3.5 ded) ded)	
Format Exam achievements Study achievements	none Teaching formate Lecture Exercises T = face-to-fate Schriftliche Prediction Erfolgreiche Ü • Herbert Eder Topology: An • Steve Oudot	ce teaching; üfung bungsteilnah lsbrunner, Jo Introduction (2015). Pers	S = indepoint Haren. Americal Sistence T	h/week 4 2 pendent s r (2010). an Mathe	Workload[h] 60 T / 105 S 30 T / 75 S study (gra (not gra Computational ematical Society rom Quiver	CP 5.5 3.5 ded) ded)	
Format Exam achievements Study achievements Forms of media	none Teaching forms Lecture Exercises T = face-to-fa Schriftliche Pr Erfolgreiche Ü Herbert Ede Topology: An Steve Oudot Representation	ce teaching; üfung bungsteilnah lsbrunner, Jo Introduction (2015). Persons to Data A	S = indepoint Haren. Americal Sistence T	h/week 4 2 pendent s r (2010). an Mathe	Workload[h] 60 T / 105 S 30 T / 75 S study (gra (not gra Computational ematical Society rom Quiver	CP 5.5 3.5 ded) ded)	
Format Exam achievements Study achievements	none Teaching formate Lecture Exercises T = face-to-fa Schriftliche Pr Erfolgreiche Ü Herbert Eder Topology: An Steve Oudot Representation Mathematical	ce teaching; üfung bungsteilnah lsbrunner, Jo Introduction (2015). Pers	S = inder me ohn Haren America sistence T nalysis (V	h/week 4 2 pendent s r (2010). can Mather Theory: F Vol. 209).	Workload[h] 60 T / 105 S 30 T / 75 S study (gra (not gra Computational ematical Society rom Quiver American	CP 5.5 3.5 ded) ded)	
Format Exam achievements Study achievements Forms of media	none Teaching forms Lecture Exercises T = face-to-fa Schriftliche Pr Erfolgreiche Ü • Herbert Ede Topology: An • Steve Oudot Representation Mathematical • Magnus Bak	ce teaching; üfung bungsteilnah lsbrunner, Jo Introduction (2015). Pers as to Data A Society. ke Botnan, N	S = indepoint Haren American Sistence Talysis (Validael L	h/week 4 2 pendent s r (2010). can Mather Theory: F Vol. 209). cesnick (2	Workload[h] 60 T / 105 S 30 T / 75 S study (gra (not gra Computational ematical Society rom Quiver American	CP 5.5 3.5 ded) ded)	
Format Exam achievements Study achievements Forms of media	none Teaching formate Lecture Exercises T = face-to-fa Schriftliche Pr Erfolgreiche Ü Herbert Eder Topology: An Steve Oudot Representation Mathematical	ce teaching; üfung bungsteilnah lsbrunner, Jo Introduction (2015). Pers as to Data A Society. ke Botnan, M o Multiparar	S = indepoint Haren American Sistence Tonalysis (Volumeter Per	h/week 4 2 pendent s r (2010). can Mather Theory: F Vol. 209). esnick (2 sistence.	Workload[h] 60 T / 105 S 30 T / 75 S study (gra (not gra Computational ematical Society rom Quiver American 022). An	CP 5.5 3.5 ded) ded)	

2 Graphics, Vision, Audio

MA-INF 2113	L2E2	6 CP	Foundations of Audio Signal Processing	38
MA-INF 2201	L4E2	9 CP	Computer Vision	39
MA-INF 2203	L4E2	9 CP	Selected Topics in Signal Processing	40
MA-INF 2206	Sem2	4 CP	Seminar Vision	41
MA-INF 2207	Sem2	4 CP	Seminar Graphics	42
MA-INF 2208	Sem2	4 CP	Seminar Audio	43
MA-INF 2209	L4E2	9 CP	Advanced Topics in Computer Graphics I	44
MA-INF 2212	L2E2	6 CP	Pattern Matching and Machine Learning for Audio Signal	l
			Processing	45
MA-INF 2213	L3E1	6 CP	Advanced Computer Vision	46
MA-INF 2214	L2E2	6 CP	Computational Photography	47
MA-INF 2215	Sem2	4 CP	Seminar Digital Material Appearance	48
MA-INF 2216	Lab4	9 CP	Lab Visual Computing	49
MA-INF 2217	L2E2	6 CP	Advanced Deep Learning for Graphics	50
MA-INF 2218	L2E2	6 CP	Video Analytics	51
MA-INF 2219	Sem2	4 CP	Seminar Visualization and Medical Image Analysis	52
MA-INF 2220	Lab4	9 CP	Lab Visualization and Medical Image Analysis	53
MA-INF 2221	Sem2	4 CP	Seminar Visual Computing	54
MA-INF 2222	L4E2	9 CP	Visual Data Analysis	55
MA-INF 2307	Lab4	9 CP	Lab Vision	56
MA-INF 2308	Lab4	9 CP	Lab Graphics	57
MA-INF 2309	Lab4	9 CP	Lab Audio	58
MA-INF 2310	L4E2	9 CP	Advanced Topics in Computer Graphics II	59
MA-INF 2312	L3E1	6 CP	Image Acquisition and Analysis in Neuroscience	60
MA-INF 2313	L2E2	6 CP	Deep Learning for Visual Recognition	61
MA-INF 2314	L4E2	9 CP	Image Processing, Search and Analysis I	62
MA-INF 2315	L4E2	9 CP	Seminar Computational Photography	63
MA-INF 2316	L4E2	9 CP	Lab Digital Material Appearance	64
MA-INF 2317	L2E2	6 CP	Numerical Algorithms for Visual Computing and Machine	3
			Learning	65

Module	Foundations of Audio Signal Processing							
MA-INF 2113	roundations	o or Aud.	o bigii	ai i .	1000331	11g		
Workload	Credit points	Duration	Free	quenc	• W			
180 h	6 CP	1 semest		-	•			
Module	6 CP 1 semester every year apl. Prof. Dr. Frank Kurth							
coordinator	api. 1101. Di. 11ank Ruion							
Lecturer(s)	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen							
Decoration (b)	Programme	*						
Classification	•	M. Sc. Computer Science Optional			1.			
Technical skills	• Introduction					l digital signal		
Teemirear skins	processing;	to babie e	опсеры	or an	aros arre	angivar bigilar		
	1 0,	• Applications in the field of Audio Signal Processing;						
		• Signal Processing Algorithms;						
		• Implementing basic Signal Processing Algorithms						
Soft skills	•	Solving basic Signal Processing Problems; Implementing Signal						
	Processing Alg	_	_		, -			
	frameworks; C	frameworks; Capability to analyze; Time management;						
	Presentation s	kills; Discu	ssing ow	n sol	lutions a	and solutions o	f	
	others, and wo	orking in g	roups.					
Contents	Theoretical int	troduction	to analo	g and	d digital	Signal Proces	sing;	
	Fourier Transf	orms; Ana	log to di	gital	Convers	sion; Digital		
	Filters; Audio	Signal Pro	cessing	Appli	ications;	Filter banks;		
	Windowed For	ırier Trans	form; 2L)-Sign	nal Proc	essing		
Prerequisites	none							
	Teaching forma	at	Group si	ze l	h/week	Workload[h]	CP	
Format	Lecture				2	30 T / 45 S	2.5	
	Exercises				2	30 T / 75 S	3.5	
	T = face-to-fa	ce teaching	g; S = in	depe	ndent st	udy		
Exam achievements	Written exam					(gra	ded)	
Study achievements	Successful exer	rcise partic	cipation			(not gra	ded)	
Forms of media	Slides, Blackboard, Whiteboard							
Literature								

Module	Computer V	Vision						
MA-INF 2201								
Workload	Credit points	Duration	Freque	ency				
270 h	9 CP	1 semester	r every year					
Module	Prof. Dr. Jürg	gen Gall						
coordinator								
Lecturer(s)	Prof. Dr. Jürg	gen Gall						
Classification	Programme		\mathbf{Mode}	Semes				
Classification	M. Sc. Computer Science Optional 1. or 2.							
Technical skills	Students will learn about various mathematical methods and							
	their applicati	their applications to computer vision problems.						
Soft skills	Productive wo	ork in small to	eams, de	velopmen	t and realization	n of		
	individual app	roaches and	solutions	s, critical	reflection of			
	competing methods, discussion in groups.							
Contents		The class will cover a number of mathematical methods and						
		_			ample, linear fil			
					tation, graph cu	ıts,		
	mean shift, ac		*	,	_			
	· · · · · · · · · · · · · · · · · · ·	_			oral filtering, a			
		, -	_	,	cracking, camera	· ·		
	· '			,	pose estimation	′		
	_		, deform	able mesh	nes, RGBD visio	on.		
Prerequisites	Recommended							
		_	lgebra, a	nalysis, p	probability theor	ry,		
	C++ program							
	Teaching forms	at Gro	up size	h/week	Workload[h]	CP		
Format	Lecture			4	60 T / 105 S	5.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-fa	ce teaching;	S = inde	pendent s	study			
Exam achievements	Written exam				(gra	ded)		
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)		
Forms of media								
	• R. Hartley, A. Zisserman: Multiple View Geometry in							
T it anatuma	Computer Vis	ion						
Literature	• R. Szeliski:	Computer Vi	sion: Alg	gorithms a	and Application	ns		
	• S. Prince: C	omputer Visi	on: Mod	lels, Learı	ning, and Infere	nce		

Module	Selected To	pics in Sign	nal Pro	cessing					
MA-INF 2203									
Workload	Credit points	Duration	Freque	ency					
270 h	9 CP	1 semester	every	year					
Module	apl. Prof. Dr.	Frank Kurth							
coordinator									
Lecturer(s)	apl. Prof. Dr.	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen							
Classification	Programme		Mode	Seme	ster				
Classification	M. Sc. Compu		Optiona						
Technical skills	Learning adva	nced as well a	as state	of the art	topics and				
	•	techniques in digital signal processing. Study examples from the							
	0		-	_	focus on music				
		audio. Develop skills for analysing audio signals and designing							
		audio features for selected application scenarios. Mathematical							
	_	modelling of signal processing problems in practical applications.							
	0	Design and implementation of corresponding algorithms and data structures solving those problems. Efficiency issues.							
Soft skills		Capability to analyze. Time management. Strength of purpose. Discussing own solutions and solutions of others.							
						C			
Contents		Advanced techniques for filter design, design and extraction of features describing multimedia signals, efficient DSP algorithms,							
		_	_		_	nms,			
	general concep			-					
	_		_		ns, for example				
	source separat		s, signa	compres	sion, denoising,				
Prerequisites	none	1011.							
Frerequisites	Teaching forms	ot Cros	up size	h/week	Workload[h]	CP			
Format	Lecture	at Gro	up size	4	60 T / 105 S	5.5			
Format	Exercises			2	30 T / 75 S	3.5			
					,	5.5			
	T = face-to-fa	ce teaching; S	s = inde	pendent s		1 1\			
Exam achievements	Written exam	. ,	1.		· -	aded)			
Study achievements	Successful exe	rcise participa	tion		(not gra	aded)			
Forms of media	т , .	4 1 1 4	1	1 11.	· ·				
	• Lecture script and selected research publications								
	• Hayes: Statistical Digital Signal Processing and Modelling,								
T:44	John Wiley, 1996 • Prophic Manalakia, Digital Signal Processing, Prophica Hall								
Literature	• Proakis, Manolakis: Digital Signal Processing, Prentice Hall,								
	1996 • Klapuri Dayry Signal Processing Mathods for Music								
	• Klapuri, Davy: Signal Processing, Methods for Music								
	Transcription, Springer, 2006								

Module MA-INF 2206	Seminar Vision							
Workload	Credit points	Duration	Frequer	ncy				
120 h	4 CP	1 semester	ter every semester					
Module	Prof. Dr. Jürg	Prof. Dr. Jürgen Gall						
coordinator								
Lecturer(s)	Prof. Dr. Jürg	gen Gall						
Classification	Programme		Mode	Semest	ter			
Classification	M. Sc. Compu	iter Science	Optional	$\lfloor 2 \rfloor$ 2. or 3	3.			
Technical skills	Ability to und	Ability to understand new research results presented in original						
	scientific papers.							
Soft skills	Ability to pres	Ability to present and to critically discuss these results in the						
	framework of	framework of the corresponding area.						
Contents	Current confer	rence and jou	ırnal pape	rs.				
Prerequisites	Required:							
	MA-INF 2201	- Computer	Vision					
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP		
Format	Seminar		10	2	30 T / 90 S	4		
	T = face-to-fa	ce teaching;	S = indep	endent st	udy			
Exam achievements	Oral presentat	tion, written	report		(gra	ded)		
Study achievements					(not gra	ded)		
Forms of media								
Literature								

Module MA-INF 2207	Seminar Graphics							
Workload	Credit points	Duration		Freque	ncy			
120 h	4 CP	1 semes	ter	er every semester				
Module	Prof. Dr. Reir	hard Klei	n					
coordinator								
Lecturer(s)	Prof. Dr. Rein	nhard Klei	n					
Classification	Programme			Mode	Semest	ter		
Classification	M. Sc. Compu	iter Scienc	e	Optiona	l 2. or 3	3.		
Technical skills	Ability to und	Ability to understand new research results presented in original						
		scientific papers.						
Soft skills	Ability to present and to critically discuss these results in the							
		framework of the corresponding area.						
Contents	Current confer	rence and	jour	nal pape	ers.			
Prerequisites	Recommended	-						
	Mathematical	_	,		ensional	analysis and li	near	
	algebra, basic	numerical	met	thods)				
	Basic knowled	ge in Com	put	er Graph	nics			
Format	Teaching forms	at	Gro	up size	h/week	Workload[h]	CP	
Format	Seminar			10	2	30 T / 90 S	4	
	T = face-to-fa	ce teachin	g; S	= indep	endent st	udy		
Exam achievements	Oral presentat	ion, writte	en re	eport		(gra	ded)	
Study achievements						(not gra	ded)	
Forms of media								
Literature								

Module MA-INF 2208	Seminar Au	dio						
Workload	Credit points	Duration	Frequen	cy				
120 h	4 CP 1 semester every semester							
Module	apl. Prof. Dr. Frank Kurth							
coordinator								
Lecturer(s)	apl. Prof. Dr.	apl. Prof. Dr. Frank Kurth, Dr. Michael Clausen						
Classification	Programme		Mode	Semest	ter			
Classification	M. Sc. Computer Science Optional 2.							
Technical skills	Ability to understand new research results presented in original							
	scientific papers.							
Soft skills	Ability to prese	ent and to c	ritically di	scuss the	se results in th	ıe		
	framework of the	he correspor	iding area.					
Contents	Current confere	ence and jou	rnal paper	s.				
Prerequisites	none							
Format	Teaching forma	t Gı	oup size	h/week	Workload[h]	CP		
Format	Seminar		10	2	30 T / 90 S	4		
	T = face-to-face	ce teaching;	S = independent	endent st	udy			
Exam achievements	Oral presentati	on, written	report		(gra	ded)		
Study achievements					(not gra	\overline{ded}		
Forms of media								
Literature								

26.11	A d d T		<u></u>	-4 0		T				
Module MA-INF 2209	Advanced T	opics in	Comp	iter G	rapn	iics i				
Workload	Credit points	Duration	Frequ	onav						
270 h	9 CP	1 semester	every	-						
Module	Prof. Dr. Reinha		cvery	ycai						
coordinator	Troi. Dr. Itemna	ra mem								
Lecturer(s)	Prof. Dr. Reinha	rd Klein								
		Programme Mode Semester								
Classification	M. Sc. Computer Science Optional 2. or 3.									
Technical skills	Analytical formul principles, technic	_			enderin	g. Knowledge of				
	• recognize and u				ties of	light transport				
		explain a range of surface and volumetric material modelsexplain the rendering and radiative transfer equations								
	• design and implement methods to solve these equations, especially McCarlo methods									
	· ·	• Assess / Evaluate the performance and conceptual limits of the implemented simulation code								
Soft skills	Based on the kno		kills acqu	ired stu	dents s	hould be able to				
	• read and judge	current scie	tific liter	ature in	the are	ea of rendering				
	• identify the ma					_	and			
	gain an overview	of the curren	nt state of	f the art						
	• discuss problems concerning rendering with researchers from different									
	application fields			~						
	• present, propos		ınicate di	fferent se	olution	s and work in a t	eam			
		to solve a rendering problem								
Contents	This course introduces the basic physical quantities as well as the									
	mathematical and algorithmic tools required to understand and simulate the light interaction with objects and different materials in a 3D scene. We will									
	light interaction with objects and different materials in a 3D scene. We will discuss how to solve the mathematical problem numerically in order to									
	create realistic im			_		-				
	material models f	_	_		_		nte			
	Carlo Methods.									
	• rendering and r	adiative trai	sfer equa	tion						
	• methods and al		_		ons, ra	diosity, Monte Ca	ırlo,			
	photon mapping			•	,	0 /	,			
	• analytical and o	data driven s	urface an	d subsur	face m	aterial models,				
	especially BRDF,		odels							
	• differentiable re	endering								
	In addition, result	ts from state	-of-the-ar	t researc	h will	be presented.				
Prerequisites	Recommended:									
	Recommended by				ge in c	omputer graphics	,			
	(numerical) analy					*** 11 101	GD			
TD 4	Teaching forma	ıt (Group si	ze h/	week	Workload[h]	CP			
Format	Lecture Exercises				$\frac{4}{2}$	60 T / 105 S	5.5			
						30 T / 75 S	3.5			
To 1.	T = face-to-face			dent stu	dy		1 2			
Exam achievements	Oral presentation					,-	aded)			
Study achievements	Successful exercis	e participati	on			(not gra	aded)			
Forms of media	• M. Pharr, W. J	akob and C	Humnh.	ove Dh-	reicoll	Rasad Randanina	r•			
	From Theory to I					Dased Rendering	5 •			
	• L. Szirmay-Kale					llumination Insti	itute			
T	of Computer Gra									
Literature	https://cg.iit.bme					50,, 1000				
	• P. Dutre, K. Ba				bal Illu	mination, 2nd ed	٠.,			
	B&T, 2006	•				•				
	• D'Eon, Eugene.	A Hitchhik	er's Guide	e to Mul	tiple S	cattering, 2016				

Module	Pattern Matching and Machine Learning for Audio							
MA-INF 2212	Signal Processing							
Workload	Credit points Duration	n l	Frequenc	cy				
180 h	6 CP 1 seme	ester $ \epsilon $	ster every year					
Module	apl. Prof. Dr. Frank &	Curth						
coordinator								
Lecturer(s)	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen							
Classification	Programme	M	lode	Semest	er			
Classification	M. Sc. Computer Science			2.				
Technical skills	• Introduction into sele	• Introduction into selected topics of digital signal processing;						
	• Applications in the f	• Applications in the field of Audio Signal Processing;						
	• Methods of Automatic Pattern Recognition							
Soft skills		Audio Signal Processing Applications; Extended programming						
		skills for signal processing applications; Capability to analyze;						
	Time management; Pro			*	_	ions		
		and solutions of others, and working in groups.						
Contents	The lecture is presente			,				
	motivated from the ap	•			•	re:		
	Windowed Fourier tran		,		· /			
	Matching; Signal Class		n; Hidde	en Marko	ov Models;			
—	Support Vector Machin	nes						
Prerequisites	none	T ~						
-	Teaching format	Grou	p size	h/week	Workload[h]	CP		
Format	Lecture			2	30 T / 45 S	2.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-face teaching	ng; S =	= indepe	endent st				
Exam achievements	Written exam				,,,	ded)		
Study achievements	Successful exercise par				(not gra	ded)		
Forms of media	Slides, Blackboard, Whiteboard							
Literature								

Module	Advanced Computer Vision								
MA-INF 2213									
Workload	Credit points	Duration	Fre	quenc	y				
180 h	6 CP	1 semest	er eve	ry yea	ar				
Module	Prof. Dr. Jürgen Gall								
coordinator									
Lecturer(s)	Prof. Dr. Jürg	Prof. Dr. Jürgen Gall							
Classification	Programme		Mod	e	Semest	ter			
Classification	M. Sc. Compu	iter Scienc	e Opti	onal	2. or 3	3.			
Technical skills		Students will learn about various learning methods and their applications to computer vision problems.							
G 6: 1 111						1 1: /:	c		
Soft skills		Productive work in small teams, development and realization of							
	individual approaches and solutions, critical reflection of competing methods, discussion in groups.								
~					_	1 1 1,1 .			
Contents					0	hods and their			
						linear method			
		0	,	0,		n forests, neura	ıl		
	networks, SVN	,	-	,		0 /			
	_	,				d learning, ima	age		
	classification,	•	,		recognit	tion, pose			
	estimation, fac	ce analysis	, trackın	g.					
Prerequisites	Required:	~	T T						
	MA-INF 2201					T			
	Teaching forms	at	Group si	ize l	h/week	Workload[h]	CP		
Format	Lecture				3	45 T / 45 S	3		
	Exercises				1	15 T / 75 S	3		
	T = face-to-fa	ce teaching	g; S = ir	depe	ndent st				
Exam achievements	Oral exam					(0	ded)		
Study achievements	Successful exe	rcise partic	cipation			(not gra	ded)		
Forms of media									
Literature									

Module MA-INF 2214	Computation	onal Photo	graphy						
Workload	Credit points	Duration	Frequer	ncy					
180 h	6 CP	1 semester	every y	-					
Module	Prof. Dr. Mat	thias Hullin							
coordinator									
Lecturer(s)	Prof. Dr. Matthias Hullin								
	Programme		Mode	Semest	ter				
Classification	M. Sc. Computer Science Optional 2. or 3				3.				
Technical skills	_		image sen	sors. Sign	nal processing a	and			
	inverse problems in imaging. Color spaces and perception.								
	Image alignment and blending. High-dimensional								
					reflectance fiel	lds,			
	reflectance distributions). Computational illumination.								
Soft skills	• to read and understand current literature in the field								
	• to implemen	t standard co	omputatio	nal photo	ography technic	ques			
	• to propose and implement solutions to a given problem								
	• to follow goo	od scientific p	oractice by	y planning	g, documenting	S			
	and communic	cating their v	ork						
Contents	• Image sensor	rs							
	• Optics								
	• Panoramas								
	• Light fields								
	• Signal proce	ssing and inv	erse prob	lems					
	• Color, perce	ption and HI	OR						
	• Reflectance	fields and lig	ht transpo	ort matric	ees				
Prerequisites	Required:								
	Basic knowled	ge in comput	er graphi	cs, data s	tructures,				
	multidimension	nal analysis	ınd linear	algebra,	numerical anal	lysis			
	and numerical	linear algebra	ca, C++ c	or MATL	AB				
	Teaching forms	at G1	oup size	h/week	Workload[h]	CP			
Format	Lecture			2	30 T / 45 S	2.5			
	Exercises			2	30 T / 75 S	3.5			
	T = face-to-fa	ce teaching:	S = index	endent st	udy	-			
Exam achievements	Oral exam	-01				ded)			
Study achievements	Successful exer	rcise particip	ation		(not gra				
Forms of media		1 · · · · · · · · · · · · · · · · · · ·			(0	/			
forms of media									

Module MA-INF 2215	Seminar Digital Material Appearance						
Workload	Credit points	Duration	Frequen	ıcy			
120 h	4 CP	1 semester every year					
Module	Prof. Dr. Mat	thias Hullin	-				
coordinator							
Lecturer(s)	Prof. Dr. Matthias Hullin						
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	ter Science	ce Optional 2.				
Technical skills	Ability to understand new research results presented in original						
	scientific paper	scientific papers.					
Soft skills	Ability to pres	ent and to c	ritically di	scuss the	se results in th	ne e	
	framework of t	the correspon	nding area	•			
Contents	Current confer	ence and jou	rnal pape	rs			
Prerequisites	none						
Format	Teaching forma	at Gi	oup size	h/week	Workload[h]	CP	
rormat	Seminar		10	2	30 T / 90 S	4	
	T = face-to-fa	ce teaching;	S = indep	endent st	udy		
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature							

Module	Lab Visual	Computin	$\overline{\mathbf{g}}$				
MA-INF 2216							
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semester	every	year			
Module	JunProf. Dr.	Florian Ber	nard				
coordinator							
Lecturer(s)	JunProf. Dr.	JunProf. Dr. Florian Bernard					
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Optiona	al 1-3.			
Technical skills	Students will o	carry out a p	ractical t	task (proj	ect) in the cont	ext	
	of visual comp	outing, includ	ling test	and docu	mentation of th	ıe	
	implemented software/system.						
Soft skills	Ability to prop	Ability to properly present and defend design decisions, to					
	prepare readal	prepare readable documentation of software; skills in					
	constructively	collaboratin	g with ot	hers in sr	nall teams over	a	
	longer period of	of time; abili	ty to clas	sify ones	own results inte	o the	
	state-of-the-ar						
Contents			_	_	ds and applicati	ions.	
	You will get a						
				-	s. At the end of	the	
	semester, you	-		, –			
			a report	t describi	ng the method	and	
	experimental of	outcomes.					
Prerequisites	none						
Format	Teaching forma	at Gr	oup size	h/week	Workload[h]	CP	
I of may	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching;	S = inde	pendent s	study		
Exam achievements	Oral presentat	ion, written	report		(gra	ided)	
Study achievements					(not gra	ided)	
Forms of media							
Literature							

Module	Advanced I	Deep Lear	ning for	Graphic	es		
MA-INF 2217							
Workload	Credit points	Duration	Freque	ncy			
180 h	6 CP	1 semeste	r every year				
Module	Prof. Dr. Rein	hard Klein					
coordinator							
Lecturer(s)	Dr. Michael W	Veinmann					
Classification	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optional	l 1-4.			
Technical skills	Students will b	oe introduce	ed to adapt	and app	ly deep learnir	ıg	
	techniques to	echniques to various applications in computer graphics.					
Soft skills	Productive wo	rk in small	teams, dev	elopment	and realizatio	n of	
	individual app	roaches and	solutions,	critical r	effection of		
	competing me	ompeting methods, discussion in groups.					
Contents	This course for	This course focuses on cutting-edge Deep Learning techniques					
	for computer g	graphics. Af	ter a brief	review of	CNNs the foc	us	
	will be laid on	autoencode	ers, generat	tive mode	els and the		
	extension of the	nese method	s to $graph$	and mar	nifold-structur	$_{ m ed}$	
	data. Applicat	tions discuss	sed will inc	lude inve	rse problems ii	1	
	computer grap	phics and th	e synthesis	of model	ls including da	ta	
	completion and	d super-reso	lution.				
Prerequisites	Recommended						
	The course wil	-			_	well	
	as fundamenta						
	Therefore, it is	0 0			-		
	Learning for V	_					
	prerequisite. E	Exercises wil	l be a mix	of theory	and practical		
	(Python).						
	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
Format	Lecture			2	30 T / 45 S	2.5	
	Exercises			2	30 T / 75 S	3.5	
	T = face-to-fa	ce teaching;	S = indep	endent st	tudy		
Exam achievements	Written exam				(gra	ided)	
Study achievements	Successful exe	rcise partici	pation		(not gra	ided)	
Forms of media						*	
Literature	No required text, supplemental readings will be given in class.						

Module MA-INF 2218	Video Anal	ytics					
Workload	Credit points	Duration	Frequer	ncv			
180 h	6 CP	1 semester					
Module	Prof. Dr. Jürg	gen Gall			•		
coordinator							
Lecturer(s)	Prof. Dr. Jürg	Prof. Dr. Jürgen Gall					
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	iter Science	Optional	1 2-3.			
Technical skills	Students will l	earn advance	ed techniq	ues for an	alyzing video o	lata.	
Soft skills	Productive work in small teams, development and realization of						
		a state-of-the-art system for video analysis.					
Contents	The class will	The class will discuss state-of-the-art methods for several tasks					
	of video analys	sis. For exan	ple, video	clip class	sification, temp	oral	
	video segment	ation, spatio	-temporal	action de	etection, video		
	context, spatio	o-temporal m	odeling of	f humans	and objects,		
	anticipation, a segmentation.	ffordance, vi	deo summ	arization	, semantic vide	eo	
Prerequisites	Required:						
•	MA-INF 2201	- Computer	Vision				
	Teaching forms	at G	oup size	h/week	Workload[h]	CP	
Format	Lecture			2	30 T / 45 S	2.5	
	Exercises			2	30 T / 75 S	3.5	
	T = face-to-fa	ce teaching;	S = indep	endent st	udy		
Exam achievements	Oral exam				(gra	ded)	
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)	
Forms of media							
Literature							

Module	Seminar Vi	sualizatio	n and Me	edical In	mage Analys	sis	
MA-INF 2219		Г					
Workload	Credit points	Duration	Frequer	•			
120 h	4 CP	1 semeste	0.00	emester			
Module	Prof. Dr. Tho	mas Schultz					
coordinator							
Lecturer(s)	Prof. Dr. Tho	Prof. Dr. Thomas Schultz					
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	iter Science	Optional	$1 \mid 2$.			
Technical skills		Ability to understand new research results presented in original scientific papers.					
Soft skills	Ability to present and to critically discuss scientific results in the						
	context of the	context of the current state of the art. Ability to perform an					
	independent se	earch for rel	evant scien	tific litera	ature.		
Contents	Current confer	ence and jo	urnal pape	ers			
Prerequisites	Recommended	:					
	At least one of	f the followi	ng:				
	• MA-INF 222	22 – Visual I	Data Analy	vsis			
	• MA-INF 231		·		lysis in		
	Neuroscience	O	1				
TD 4	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
Format	Seminar		10	2	30 T / 90 S	4	
	T = face-to-fa	ce teaching;	S = indep	endent st	udy		
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra	$\overline{\operatorname{ded}}$	
Forms of media							
Literature							

Module MA-INF 2220	Lab Visuali	zation and	Medic	al Imag	e Analysis	
Workload	Credit points	Duration	Freque	encv		
270 h	9 CP	1 semester				
Module	Prof. Dr. Tho		J			
coordinator						
Lecturer(s)	Prof. Dr. Tho	mas Schultz				
	Programme		Mode	Seme	ster	
Classification	M. Sc. Computer Science		Option	al 2 .		
Technical skills	context of data	The students will carry out a practical task (project) in the context of data visualization and visual analytics or medical mage analysis, including test and documentation of the mplemented software/system.				
Soft skills	prepare readal constructively longer period	Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area				
Contents						
Prerequisites	At least one of MA-INF 222 • MA-INF 231 Neuroscience	f the followir 22 – Visual I	ata Ana	·	alysis in	
	Teaching forms	at Gre	oup size	h/week	Workload[h]	CP
Format	Lab		8	4	60 T / 210 S	9
	T = face-to-fa	ce teaching;	$S = ind\epsilon$	pendent s	,	I
Exam achievements	Oral presentat	ion, written	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media					· -	,
Literature						

Module	Seminar Visual Computing						
MA-INF 2221							
Workload	Credit points	Duration	Freque	ncy			
120 h	4 CP	1 semeste	ester at least every year				
Module	JunProf. Dr.	Florian Be	ernard				
coordinator							
Lecturer(s)	JunProf. Dr.	Florian Be	ernard				
Classification	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optiona	1 2. or 3	3.		
Technical skills	Ability to und	erstand nev	v research i	results pro	esented in origi	inal	
	scientific paper	scientific papers.					
Soft skills		Ability to present and to critically discuss these results in the					
		framework of the corresponding area.					
Contents	Current confer	ence and jo	urnal pape	ers.			
Prerequisites	Required:						
	No formal requestions previous expos		-	_	ected to have s ring:	some	
	- visual compushape analysis	0 , 0	-	,	nputer graphics	s, 3D	
	- mathematica convex/non-co	-	, ,	mbinator	ial/continuous,	,	
	- machine lear	ning.					
Format	Teaching forms	at C	Froup size	h/week	Workload[h]	CP	
rormat	Seminar		10	2	30 T / 90 S	4	
	T = face-to-fa	ce teaching	S = indep	endent st	cudy		
Exam achievements	Oral presentat	ion, writter	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature							

Module MA-INF 2222	Visual Data	a Analysis						
Workload	Credit points	Duration	Freque	ency				
270 h	9 CP	9 CP 1 semester every year						
Module	Prof. Dr. Tho	mas Schultz	1					
coordinator								
Lecturer(s)	Prof. Dr. Tho	mas Schultz						
Classification	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	iter Science	Optiona	al 1-4.				
Technical skills	Ability to desi	Ability to design, implement, and make proper use of systems						
	for visual data	or visual data analysis. Knowledge of algorithms and						
	techniques for	techniques for the visualization of multi-dimensional data,						
	graphs, as wel	graphs, as well as scalar, vector, and tensor fields.						
Soft skills	Productive wo	Productive work in small teams, self-dependent solution of						
	practical prob	practical problems in the area of visual data analysis, critical reflection on visualization design, presentation of solution						
	reflection on v							
	strategies and	trategies and implementations, self management						
Contents	This class pro	This class provides a broad overview of principles and						
	algorithms for	data analysis	s via inte	eractive v	isualization.			
	Specific topics	include perce	eptual p	rinciples,	luminance and			
	color, visualiza	ation analysis	and des	sign, integ	gration of visual			
	with statistica	l data analysi	is and m	achine lea	arning, as well a	as		
	specific algorit	thms and tech	niques f	or the dis	splay of			
				-	tion, graphs, dir	rect		
	and indirect v	olume visuali	zation, v	ector field	d and flow			
	visualization,	as well as ten	sor field	visualiza	tion.			
Prerequisites	Recommended							
					nowledge in line	ear		
	_				programming.			
	Teaching forms	at Gro	up size	h/week	Workload[h]	CP		
Format	Lecture			4	60 T / 105 S	5.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-fa	ce teaching; S	S = inde	pendent s	study			
Exam achievements	Written exam				(gra	ded)		
Study achievements	Successful exe	rcise participa	ation		(not gra	ded)		
Forms of media		-						
	A.C. Telea, Data Visualization: Principles and Practice. CRC Press, Second Edition, 2015							
Literature	M. Ward et al., Interactive Data Visualization: Foundations, Techniques, and Applications. CRC Press, 2010							
	T. Munzner, V 2015	Visualization .	Analysis	and Desi	gn, A K Peters	,		

Module MA-INF 2307	Lab Vision						
Workload	Credit points	Duratio	n	Freque	ency		
270 h	9 CP	$1 \text{ sem} \epsilon$	ester	every	semester		
Module	Prof. Dr. Jürg	gen Gall					
coordinator							
Lecturer(s)	Prof. Dr. Jürg	Prof. Dr. Jürgen Gall					
Classification	Programme			Mode	Semes	ster	
Classification	M. Sc. Computer Science		nce	Option	al 2. or	3.	
Technical skills	The students v	The students will carry out a practical task (project) in the					
		context of RGB-D cameras.					
Soft skills		Ability to properly present and defend design decisions, to					
	prepare readal				,		
			_			nall teams over	
		,			ssify ones	own results into	the the
	state-of-the-ar						
Contents	RGBD camera	s: resear	rch to	pics and	d applicat	ions	
Prerequisites	Required:						
	MA-INF 2201	- Comp	uter '	Vision			
	Good C++ pr	ogramm	ing sk	kills			
Format	Teaching forma	at	Grou	ıp size	h/week	Workload[h]	CP
roimat	Lab			8	4	60 T / 210 S	9
	T = face-to-fa	ce teachi	ing; S	= inde	pendent s	study	
Exam achievements	Oral presentat	ion, writ	ten r	eport		(gra	ded
Study achievements						(not gra	ded)
Forms of media							
	,	,		,	,	Konolige. Consu	ımer
Literature	Depth Cameras for Computer Vision: Research Topics and						
	Applications						

Module	Lab Graphi	cs					
MA-INF 2308							
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semeste	er every	every semester			
Module	Prof. Dr. Rein	hard Klein	•				
coordinator							
Lecturer(s)	Prof. Dr. Rein	Prof. Dr. Reinhard Klein					
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Option	al 3.			
Technical skills	The students	will carry o	ıt a pract	ical task	(project) in the		
	context of geo:	metry proce	essing, ren	dering, so	cientific visualiza	ation	
	or human com	puter inter	action, inc	luding te	st and		
		documentation of the implemented software/system.					
Soft skills	Ability to prop	Ability to properly present and defend design decisions, to					
	prepare readal			,			
	·		0		mall teams over		
		*		ssify ones	own results into	the the	
	state-of-the-ar						
Contents		•			arch in the area		
		0,	lering, sci	entific vis	ualization or hu	man	
	computer inter	raction.					
Prerequisites	none				T		
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching	S = inde	pendent s	study		
Exam achievements	Oral presentat	ion, writter	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature							

Module	Lab Audio						
MA-INF 2309							
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semeste	r every	year			
Module	apl. Prof. Dr.	Frank Kurt	h				
coordinator							
Lecturer(s)	apl. Prof. Dr.	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen					
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	ter Science	Option	al 3.			
Technical skills	The students v	The students will carry out a practical task (project) in the					
	context of aud	io and musi	c process	ing, inclu	ding test and		
	documentation of the implemented software/system.						
Soft skills	Ability to prop	Ability to properly present and defend design decisions, to					
	prepare readal	ole documer	tation of	software;	skills in		
	constructively	collaboratii	ng with of	thers in sr	nall teams over	a	
	longer period	of time; abil	ity to clas	ssify ones	own results into	o the	
	state-of-the-ar	t of the resp	area.				
Contents							
Prerequisites	none						
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP	
rormat	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching;	$S = ind\epsilon$	ependent s	study		
Exam achievements	Oral presentat	ion, written	report		(gra	ided)	
Study achievements					(not gra	ided)	
Forms of media							
Literature							

Module MA-INF 2310	Advanced T	opics in	Comput	er Graph	nics II			
Workload	Credit points	Duration	Freque	ncy				
270 h	9 CP	1 semeste	r every y	ear				
Module	Prof. Dr. Reinh	ard Klein						
coordinator								
Lecturer(s)	Prof. Dr. Reinh	ard Klein						
Classification	Programme		Mode	Semester				
	-	M. Sc. Computer Science Optional 3.						
Technical skills	Analytical form	ulation of p	roblems rel	ated to geor	metry processing	g:		
	apply basic coreal world appliDesign and in	 apply methods of geometry processing apply basic concepts of statistical shape analysis and shape spaces to real world applications Design and implement novel application software in this area 						
Soft skills	Based on the kr	Based on the knowledge and skills acquired students should be able to						
	 processing and g identify the m geometry proces present, proporteam to solve ge 	 read and judge current scientific literature in the area of geometry processing and gain an overview of the current state of the art identify the major literature relevant for solving a given problem in geometry processing present, propose and communicate different solutions and work in a team to solve geometry processing problems discuss geometry processing problems with researchers from different 						
Contents	This course will first introduce the mathematical and algorithmic tools required to represent, model, and process 3D geometric objects. The second part discusses the latest mathematical, algorithmic, and statistical tools required for the analysis and modeling of 3D shape variability, which can facilitate the creation of 3D models. Topics among others will be							
	 mesh data str Laplacian oper denoising, smoot geodesic distance parameterizate point cloud respondence 	 classical and discrete differential geometry of curves and surfaces mesh data structures and generation of meshes from point clouds Laplacian operator and optimization techniques with applications to denoising, smoothing, decimation, shape fitting, shape descriptors, geodesic distances parameterization and editing of surfaces point cloud registration correspondences shape spaces and statistical shape analysis 						
Prerequisites	none		01 0110 0		······ se presente			
_ 101044101000	Teaching forma	at	Group size	h/week	Workload[h]	CP		
Format	Lecture			4	60 T / 105 S	5.5		
	Exercises			2	30 T' / 75 S	3.5		
	T = face-to-face	e teaching:	S — indene	ndent study	,	'		
Exam achievements	Oral exam	, waeming, i	– maeper	nacm study		aded)		
Study achievements	Successful exerc	ise particip	ation		(not gr			
Forms of media	Successiui exerc	ne paracip			(1100 810	aucuj		
Literature	 M. Botsch, L. Processing, A K Laga, Hamid, Mohammed Ber and applications Solomon, Just Peters/CRC Processing 	Yulan Guo Yulan Guo nnamoun. 3 s. John Wil in. Numeri	10 , Hedi Tabi D Shape ar ey & Sons,	a, Robert B nalysis: fund 2018.	3. Fisher, and	ry,		

Module	Image Acqu	uisition and	d Analys	sis in N	euroscience				
MA-INF 2312		I							
Workload	Credit points	Duration	Freque	-					
180 h	6 CP 1 semester at least every 2 years								
Module	Prof. Dr. Tho	mas Schultz							
coordinator									
Lecturer(s)	Prof. Dr. Tho	mas Schultz							
Classification	Programme		Mode	Semest	ter				
	M. Sc. Compu		Optiona						
Technical skills	Students will	learn about i	mage acqu	uisition a	nd analysis				
	pipelines which	h are used in	neuroscie	ence. The	y will understa	and			
	algorithms for	image recon	struction,	artifact i	removal, image				
	registration ar	nd segmentat	ion, as we	ll as relev	vant statistical	and			
	machine learn	ing technique	es. A part	icular foc	us will be on d	lata			
	from Magnetic	rom Magnetic Resonance Imaging and on mathematical models							
	for functional	or functional and diffusion MRI data.							
Soft skills	Productive wo	ork in small t	eams, self	-depender	nt solution of				
	practical prob	practical problems in the area of biomedical image processing,							
	presentation o	f solution str	ategies ar	d implen	nentations, self				
	management,	critical reflec	tion of co	nclusions	drawn from				
	complex exper								
Contents	This course co	vers the full	image for	mation ar	nd analysis pip	eline			
	that is typical		_						
	acquisition to	-			_				
Prerequisites	Recommended				U				
•	Mathematical	background	(calculus,	linear alg	gebra, statistics	s);			
	imperative pro	_	,		,	//			
	Teaching forms		oup size	h/week	Workload[h]	CP			
Format	Lecture		-	3	45 T / 45 S	3			
	Exercises			1	15 T / 75 S	3			
	T = face-to-fa	ce teaching:	S = indep	endent st		1			
Exam achievements	Oral exam					ded)			
Study achievements	Successful exe	rcise particin	ation		(not gra				
Forms of media		1 1			, 0				
	• B. Preim, C	. Botha: Vis	ıal Comp	iting for	Medicine: The	ory,			
			_	_		0 /			
	Algorithms, and Applications. Morgan Kaufmann, 2014 • R.A. Poldrack, J.A. Mumford, T.E. Nichols: Handbook of								
Literature	Functional MRI Data Analysis. Cambridge University Press,								
	2011		J			,			
	• D.K. Jones: Diffusion MRI: Theory, Method, and								
	Applications,				,				

Module MA-INF 2313	Deep Learn	ing for V	'isual I	Rec	ognition	n	
Workload	Credit points	Duration	Fre	quer	ıcy		
180 h	6 CP	1 semest	er eve	er every year			
Module	Prof. Dr. Rein	hard Kleir	1				
coordinator							
Lecturer(s)	Dr. Michael Weinmann						
Classification	Programme		Mod	le	Semest	ter	
Classification	M. Sc. Compu	iter Science	e Opti	ional	1-4.		
Technical skills	Students will l	Students will be introduced to the theory of neural networks and					s and
	study various	application	s in con	nput	er vision	and other top	ics in
	AI.	AI.					
Soft skills	Productive wo	rk in smal	teams,	dev	elopment	and realizatio	n of
	individual app	individual approaches and solutions, critical reflection of					
	competing me	thods, disc	ussion i	n gre	oups.		
Contents	Deep learning has taken over the machine learning community						
	by storm, with	ı success b	oth in r	esea	ch and c	ommercially. I	Deep
	learning is app	olicable ove	r a rang	ge of	fields suc	ch as compute	r
	vision, speech	recognition	ı, natur	al la	nguage p	rocessing, robo	otics,
	etc. This cour	se will intr	oduce t	he fu	ındament	als of neural	
	networks and	then progr	ess to st	tate-	of-the-art	convolutional	and
	recurrent neur	al network	s as wel	ll as	their use	in application	s for
	visual recognit	ion. Stude	nts will	get	a chance	to learn how t	Ю
	implement and	d train the	r own n	etwo	ork for vis	sual recognitio	n
	tasks such as o	object reco	gnition,	ima	ge segme	ntation and	
	caption genera	tion.					
Prerequisites	Recommended	:					
	Students are r	ecommend	ed to ha	ave a	basic kn	owledge in	
	probability an	d statistics	and lin	near	algebra a	s well as	
	proficiency in	programm	ng (pyt	hon	or Matla	b or $C++$).	
	Teaching forms	at	Group s	ize	h/week	Workload[h]	CP
Format	Lecture				2	30 T / 45 S	2.5
	Exercises				2	30 T / 75 S	3.5
	T = face-to-face teaching; $S = $ independent study						
Exam achievements	Oral exam		• •	r			ided)
Study achievements	Successful exe	rcise partic	ipation			(not gra	
Forms of media						, 5	
	No required to	ext. Supple	mental	read	ings will	be provided in	the
Literature	lecture.						

Module MA-INF 2314	Image Proc	essing, Se	arch an	d Analy	rsis I			
Workload	Credit points	Duration	Freque	ency				
270 h	9 CP	9 CP 1 semester every year						
Module	Prof. Dr. Chr.	istian Bauck	hage					
coordinator			J					
Lecturer(s)	Prof. Dr. Chr.	istian Bauck	hage					
CI 10 11	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	M. Sc. Computer Science Optional 2. or 3.						
Technical skills	Upon complet		should	oe able to	ı			
	processing • implement a	 implement simple and advanced algorithms for image filtering implement algorithms for creating artistic image effects implement algorithms for image warping implement algorithms for image morphing implement algorithms for color and intensity manipulation design and implement their own algorithms for image 						
Soft skills	Students will I foundations of editing. They	Students will learn about the mathematical and algorithmic foundations of digital image processing and raster graphics editing. They will learn about the basic concepts and procedures in this area and to implement them on their own.						
Contents	photography mathematica coordinate s Fourier trans low- band-, a mean- and C median filter efficient imp interpolation artistic imag image warpi image morph	 technical foundations / hardware aspects of digital photography mathematical representations of digital images coordinate systems and coordinate transformations Fourier transforms and convolutions low- band-, and high pass filtering mean- and Gaussian filtering median filtering and morphological operations efficient implementations of various kinds of filters interpolation methods artistic image effects image warping image morphing physiological foundations of color perception 						
Prerequisites	none							
Format	Teaching formate Lecture Exercises $T = face-to-fa$		$\begin{array}{l} \textbf{oup size} \\ \\ \text{S} = \text{inde} \end{array}$	h/week 4 2 pendent s	Workload[h] 60 T / 105 S 30 T / 75 S study	5.5 3.5		
Exam achievements	Written exam					ded)		
Study achievements	Successful exe	rcise particir	ation		(not gra			
Forms of media	• lecture slides			online	(33 820	·)		
					are made availa	ble		
Literature	Gonzales andJähne, "Digi		_	_	essing"			

Module MA-INF 2315	Seminar Computational Photography							
Workload	Credit points	Duration	on Frequency					
270 h	9 CP	1 semester	every	year				
Module	Prof. Dr. Mat	Prof. Dr. Matthias Hullin						
coordinator								
Lecturer(s)	Prof. Dr. Mat	thias Hullin						
Classification	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	iter Science	Options	al 2. or	3.			
Technical skills	Ability to understand new research results presented in original							
	scientific pape	scientific papers.						
Soft skills	Ability to present and to critically discuss these results in the							
	framework of	framework of the corresponding area.						
Contents								
Prerequisites	none							
	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP		
Format	Lecture			4	60 T / 105 S	5.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-fa	ce teaching;	S = inde	pendent s	study			
Exam achievements	Oral presentat	ion, written	report		(gra	ded)		
Study achievements					(not gra	ded)		
Forms of media								
Literature								

Module	Lab Digital	Material A	Appeara	ance				
MA-INF 2316								
Workload	Credit points	Duration	Freque	Frequency				
270 h	9 CP	1 semester	every year					
Module	Prof. Dr. Matthias Hullin							
coordinator								
Lecturer(s)	Prof. Dr. Mat	thias Hullin						
Classification	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	iter Science	Optiona	l 2. or	3.			
Technical skills	The students	The students will carry out a practical task (project) in the						
	context of the	context of the corresponding area, including test and						
	documentation	n of the imple	emented s	software/	system.			
Soft skills	Ability to prop	perly present	and defe	nd design	n decisions, to			
	prepare readal	ble document	ation of s	software;	skills in			
	constructively	collaborating	g with ot	hers in sr	nall teams over	a		
	longer period	of time; abilit	ty to class	sify ones	own results into	the the		
	state-of-the-ar	t of the resp.	area					
Contents								
Prerequisites	none							
	Teaching forms	at Gro	oup size	h/week	Workload[h]	CP		
Format	Lecture			4	60 T / 105 S	5.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-fa	ce teaching;	S = inder	pendent s	study			
Exam achievements	Oral presentat	tion, written	report		(gra	ded)		
	(not graded)							
Study achievements					(not gra	acaj		
Study achievements Forms of media					(Hot gra	aca		

Module	Numerical A	_	ns for Vis	ual Cor	nputing and		
MA-INF 2317	Machine Lea						
Workload	Credit points	Duration	Frequer	-			
180 h	6 CP 1 semester at least every 2 years						
Module	JunProf. Dr.	Florian B	Sernard				
coordinator							
Lecturer(s)	JunProf. Dr.	Florian B	Sernard				
Classification	Programme		Mode	Semest	ter		
Classification		M. Sc. Computer Science Optional 2. or 3.					
Technical skills	• ability to imp			_			
	_	understanding their strengths and shortcomings					
			_	ational p	roblems in visual		
	computing and		_				
			0		plied for which		
	problem in visu	_	_		0,		
	practical proble						
Soft skills	_	_	-	-	d utilise analogies		
	_	between new problems and previously seen ones					
			0	-	general intuition of		
	computational	- '	_	to adopt	different		
	perspectives of						
Contents					at frequently occur		
		_	- \ ,		ine learning (ML).		
		_	,		so cover modelling		
				practical	problems in VC		
	and ML. The c	ontents in	ıclude:				
	• Error analysi	s and con-	ditioning of	problems			
	• Linear systen	ns (solvab	ility, algoritl	nms, stab	ility,		
	regularisation),	and appl	ications and	modellin	g in VC and ML		
	(e.g. linear reg	ression, in	nage alignme	ent, decor	nvolution)		
	• Spectral metl	hods (eige	nvalue deco	mposition	ı, singular value		
	decomposition,	respective	e algorithms	s), and th	eir applications		
	and modelling	in VC and	d ML (e.g. c	lustering,	Procrustes		
	analysis, point-	cloud alig	nment, prin	cipal com	ponents analysis)		
	_		(0		hods, second-order		
	methods, large-	scale opti	misation) ar	nd applica	ations and		
	modelling in V	C and ML	ı .				
Prerequisites	Required:						
	No formal prer	equisites.					
	Recommended:						
	Participants ar	e expected	d to have a l	nigh level	of mathematical		
	maturity (in pa	_		_			
	algebra and cal	culus is es	ssential). A	basic und	lerstanding of		
	mathematical of	ptimisatio	on is advant	ageous.			
	Teaching forma		Group size	h/week	Workload[h] CP		
Format	Lecture			2	30 T / 45 S 2.5		
	Exercises			2	30 T / 75 S 3.5		
	T = face-to-face	e teachine	$g \cdot S = indep$	endent st	, ,		
Exam achievements	Written exam		5, 5 — macp	21140110 50	(graded)		
Study achievements	Successful exer	cise partic	cipation		(not graded)		
Forms of media	Successful oxel	Partic			(1100 Simuon)		
Literature							

3 Information and Communication Management

MA-INF	3108	L2E2	6 CP	Secure Software Engineering 6	57
MA-INF	3109	L2E2	6 CP	Quantum Algorithms: Introduction and Data Fusion	
				Examples 6	8
MA-INF	3140	L2E2	6 CP	Advanced Computer Forensics 6	9
MA-INF	3202	L2E2	6 CP	Mobile Communication	' 0
MA-INF	3209	Sem2	4 CP	Seminar Selected Topics in Communication	
				Management	1
MA-INF	3215	Sem2	4 CP	Seminar Selected Topics in Malware Analysis and	
				Computer/Network Security 7	' 2
MA-INF	3216	Sem2	4 CP	Seminar Sensor Data Fusion	'3
MA-INF	3229	Lab4	9 CP	Lab IT-Security 7	' 4
MA-INF	3233	L2E2	6 CP	Advanced Sensor Data Fusion in Distributed Systems 7	' 5
MA-INF	3235	L2E2	6 CP	Usable Security and Privacy	' 6
MA-INF	3236	L2E2	6 CP	IT Security 7	7
MA-INF	3237	L2E2	6 CP	Array Signal and Multi-channel Processing 7	8
MA-INF	3238	L2E2	6 CP	Side Channel Attacks	'9
MA-INF	3239	L2E2	6 CP	Malware Analysis 8	30
MA-INF	3241	L3E1	6 CP	Practical Challenges in Human Factors of Security and	
				Privacy 8	31
MA-INF	3242	L2E2	6 CP	Security of Distributed and Resource-constrained	
				Systems 8	32
MA-INF	3243	Sem2P3	9 CP	Tutorenpraktikum Cyber Security 8	3
MA-INF	3244	Sem2	4 CP	Cyber Security Seminar 8	34
MA-INF	3245	Lab4	9 CP	Cyber Security Lab	35
MA-INF	3304	Lab4	9 CP	Lab Communication and Communicating Devices 8	36
MA-INF	3305	Lab4	9 CP	Lab Information Systems 8	37
MA-INF	3309	Lab4	9 CP	Lab Malware Analysis 8	38
MA-INF	3310	L2E2	6 CP	Introduction to Sensor Data Fusion - Methods and	
				Applications 8	39
MA-INF	3312	Lab4	9 CP	Lab Sensor Data Fusion	0
MA-INF	3317	Sem2	4 CP	Seminar Selected Topics in IT Security 9	1
MA-INF	3319	Lab4	9 CP	Lab Usable Security and Privacy 9)2
MA-INF	3320	Lab4	9 CP	Lab Security in Distributed Systems 9	13
MA-INF	3321	Sem2	4 CP	Seminar Usable Security and Privacy 9	14
MA-INF	3322	L2E2	6 CP	Applied Binary Exploitation 9	15
MA-INF	3323	Lab4	9 CP	Lab Fuzzing Bootcamp 9	16
MA-INF	3324	Lab4	9 CP	Lab Design of Usable Security Mechanisms 9	17

Module MA-INF 3108	Secure Software Engineering						
Workload	Credit points	Duration	Fre	quen	cy		
180 h	6 CP	1 semest	ter every year				
Module	Dr. Christian	Tiefenau					
coordinator							
Lecturer(s)	Dr. Christian	Tiefenau, I	Mischa I	Meier	r		
Classification	Programme		Mod	.e	Semest	ter	
Classification	M. Sc. Compu	iter Science	Opti	onal	2. or 3	3.	
Technical skills	software-engin including secu	The students are introduced to the security-relevant aspects of a software-engineering lifecycle. Therefore, the main ideas of including security throughout the development process will be presented and explained by examples.					
	By showing common vulnerabilities throughout this course, the students will get an understanding of common vulnerabilities and attacks and how to prevent them.						
Soft skills	strengthen the vectors. Throumanagement,	In groups, the students will conduct practical exercises to strengthen the understanding of vulnerabilities and attack vectors. Through this, the abilities teamwork, time management, organization and critical discussion of their own and others' results are strengthened.					
Contents	 Threat mode Risk analysis Architectura Secure codin Applied Cry Secure config Updates and 	s l security g ptography guration ar	_	oymer	nt		
Prerequisites	Recommended Fundamental l concepts.		n softw	are-e	engineerii	ng and IT-secu	rity
	Teaching forms	at	Group si	ize	h/week	Workload[h]	CP
Format	Lecture				2	30 T / 45 S	2.5
	Exercises				2	30 T / 75 S	3.5
	T = face-to-fa	ce teaching	S = ir	ndepe	endent st	udy	
Exam achievements	Written exam						ded)
Study achievements	Successful exe	rcise partic	ipation			(not gra	
Forms of media						, 3	
Literature	Software Security: Building Security In by Gary McGraw						

Module MA-INF 3109	Quantum Algorithms: Introduction and Data Fusion Examples							
Workload	Credit points	Duration	Frequency					
180 h	6 CP	1 semester	every year					
Module	Prof. Dr. Wol	fgang Koch						
coordinator								
Lecturer(s)	Prof. Dr. Wol	fgang Koch, l	Or. Felix Govaers	, Dr. Martin Ulmke				
Classification	Programme		Mode Seme					
Classification	-	M. Sc. Computer Science Optional 2. or 3.						
Technical skills	as soon as quaprocessing arc. While emerging physics, quant phenomena as of quantum phenomena as of qu	Quantum algorithms for data fusion may become game changers as soon as quantum processing kernels embedded in hybrid processing architectures with classical processors will exist. While emerging quantum technologies directly apply quantum physics, quantum algorithms do not exploit quantum physical phenomena as such, but rather use the sophisticated framework of quantum physics to deal with "uncertainty". Although the link between mathematical statistics and quantum physics has long been known, the potential of physics-inspired algorithms for						
		lata fusion has just begun to be realized. While the mplementation of quantum algorithms is to be considered on						
	_	-	tum computers, t					
		=	"analog compute					
			g data fusion and					
			ile the developme	-				
	_		for granted, their	-				
	information fu			the international				
Soft skills	• Problem solv		иу.					
Soft Skills	• Adaptability	_						
	• Critical thin							
Contents	• Introduction		les					
	• Short introd	uction to qua	ntum mechanics					
	• Introduction	_						
	• Quantum co							
	• Quantum ins	_	g ionic target tracl	zina				
	• The data ass	_	_	ang				
		-	or management					
			_	ing data association				
	-		resources manage					
			ystems and boson	n sampling				
.	Path Integra							
Prerequisites	Recommended One of the following							
		9	g in die Sensorda	tonfusion				
			-	ta Fusion - Method				
	and Application		I					
T	Teaching forms	at Gr	oup size h/week					
Format	Lecture Exercises		$\begin{bmatrix} 2 \\ 2 \end{bmatrix}$	30 T / 45 S 2.5 30 T / 75 S 3.5				
		ca tanching:	1	, ,				
Exam achievements	I = Iace-to-Ia Oral exam	ce teaching;	S = independent	stuay (graded				
Study achievements	Erfolgreiche Ü	bungsteilnah	ne	(not graded				
Forms of media		000011110111	-	(220 Stadou				
Literature								
	<u> </u>							

Module MA-INF 3140	Advanced C	Advanced Computer Forensics						
Workload	Credit points	Credit points Duration Frequency						
180 h	6 CP	1 semeste	r every y	ear				
Module	Dr. Christian	Dr. Christian Tiefenau						
coordinator								
Lecturer(s)	Dr. Christian	Tiefenau						
Classification	Programme		Mode	Semes	ter			
Classification	M. Sc. Compu	iter Science	Optional	$1 \mid 1., 2.$	or 3.			
Technical skills	The course co	The course covers advanced research topics in computer						
	forensics and s	forensics and secure software engineering.						
Soft skills								
Contents	Theoretical an	•	-	•	forensics and			
	secure softwar	e engineerin	g are cover	ed.				
Prerequisites	none							
	Teaching forms	at G	roup size	h/week	Workload[h]	CP		
Format	Lecture			2	30 T / 45 S	2.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-fa	ce teaching;	S = indep	endent st	tudy			
Exam achievements	Written exam				(gra	ded)		
Study achievements	Successful exerc	cise particip	ation		(not gra	ded)		
Forms of media								
Literature								

Module MA-INF 3202	Mobile Com	ımunicatio	\mathbf{n}				
	G 111						
Workload	Credit points	Duration	Freque	-			
180 h	6 CP	1 semester	every y	ear			
Module	Prof. Dr. Pete	r Martini					
coordinator							
Lecturer(s)		Prof. Dr. Peter Martini, Dr. Matthias Frank					
Classification	Programme		Mode	Semest			
	M. Sc. Compu		Optiona				
Technical skills	Knowledge abo						
	including mobi	v	`			nt	
	and technology	- ,		_			
	technologies ar			-			
	and/or other n			-		ssess	
	scenarios with				_		
	understanding		-	0	,		
	systems and no				_	_	
	strengthening skills on presentation and discussion of solutions						
	to current chal						
Soft skills	Theoretical exercises to support in-depth understanding of						
	lecture topics and to stimulate discussions, practical exercises in						
	teamwork to support time management, targeted organisation of practical work and critical discussion of own and others' results						
	_						
Contents	Mobility Mana	_		,		ion	
	Basics, Wireles		_	· ,	,		
	Communication			d data cor	nmunication),		
	Ad-hoc and Se		ks.				
Prerequisites	Recommended:				_		
	Bachelor level	_			-	\mathbf{S}	
	(e.g. BA-INF				•		
	(German Bach	elor Progran	nme Infor	matik, Er	nglish lecture s.	lides	
	available)				T		
	Teaching forma	ıt Gı	oup size	h/week	Workload[h]	CP	
Format	Lecture			$\frac{2}{2}$	30 T / 45 S	2.5	
	Exercises			2	30 T / 75 S	3.5	
	T = face-to-face	ce teaching;	S = indep	endent st	udy		
Exam achievements	Written exam				(gra	\overline{ded}	
Study achievements	Successful exer	cise particip	ation		(not gra	\overline{ded}	
Forms of media							
	• Jochen Schill	ler: Mobile (Communic	cations, A	ddison-Wesley,	ı	
	2003						
T:tomoto	• William Stal	lings: Wirele	ss Comm	unication	s and Network	ing,	
Literature	Prentice Hall,	2002					
	• Further up-to	o-date litera	ure will h	oe annour	nced in due cou	ırse	
	before the begi	inning of the	lecture				

Module	Seminar Selected Topics in Communication							
MA-INF 3209	Managemer	Management						
Workload	Credit points	Duration	Frequer	ncy				
120 h	4 CP	1 semeste	ster at least every year					
Module	Prof. Dr. Peter Martini							
coordinator								
Lecturer(s)	Prof. Dr. Pete	er Martini, I	Prof. Dr. N	Aichael M	[eier			
Classification	Programme		Mode	Semest	ter			
Classification	M. Sc. Compu	iter Science	Optional	l 2. or 3	3.			
Technical skills	Ability to und	erstand new	research i	esults pre	esented in original	inal		
	scientific pape	rs.						
Soft skills	Ability to pres	Ability to present and to critically discuss these results in the						
	framework of	framework of the corresponding area.						
Contents		rence and jo	urnal pape	ers, curren	nt standardizat	ion		
	drafts	drafts						
Prerequisites	Required:							
					llowing lecture	s:		
	Principles of I		- ,		* '			
	- '	, ,		nmunicati	ion (MA-INF3	202),		
	IT Security (N	1	<u>′ </u>		1			
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP		
Tormat	Seminar		10	2	30 T / 90 S	$\mid 4$		
	T = face-to-fa	ce teaching;	S = indep	endent st	udy			
Exam achievements	Oral presentat	ion, written	report		(gra	ded)		
Study achievements					(not gra	ded		
Forms of media								
Literature	The relevant language previous semes		l be annou	inced tow	ards the end o	f the		

Module	Seminar Selected Topics in Malware Analysis and						
MA-INF 3215	Computer/	Network S	Security				
Workload	Credit points	Duration	Frequer	ncy			
120 h	4 CP	1 semeste	r at least	at least every year			
Module	Prof. Dr. Peter Martini						
coordinator							
Lecturer(s)	Prof. Dr. Pete	er Martini, l	Prof. Dr. M	Iichael M	[eier		
Classification	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optional	2. or 3	3.		
Technical skills			research r	esults pro	esented in origi	inal	
	scientific pape	rs.					
Soft skills		Ability to present and to critically discuss these results in the					
	framework of						
Contents				,	nt standardizat	ion	
	drafts - with a			n Malware	e Analysis,		
	Computer and	Network S	ecurity				
Prerequisites	Required:						
		•			llowing lecture	s:	
	Principles of I		•		, ,		
	- '	, .		nmunicati	ion (MA-INF32	202),	
	IT Security (N		/		1		
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
	Seminar		10	2	30 T / 90 S	$\mid 4 \mid$	
	T = face-to-fa	ce teaching;	S = indep	endent st	cudy		
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature							

Module MA-INF 3216	Seminar Sensor Data Fusion						
Workload	Credit points	Duration	n Frequency				
120 h	4 CP	CP 1 semester every year					
Module	P.D. Dr. Wolfgang Koch						
coordinator							
Lecturer(s)	P.D. Dr. Wolf	gang Koch,	Dr. Felix (Govaers			
Classification	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optional	l 2.			
Technical skills	Ability to und	erstand new	research i	esults pro	esented in original	inal	
	scientific pape	rs.					
Soft skills	Ability to pres	sent and to	critically d	iscuss the	ese results in th	ne	
	framework of	the correspo	nding area	٠.			
Contents	Current confer	ence and jo	urnal pape	ers			
Prerequisites	none						
To 4	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
Format	Seminar		10	2	30 T / 90 S	4	
	T = face-to-fa	ce teaching;	S = indep	endent st	cudy	'	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media					-		
Literature	The relevant li seminar.	iterature wil	l be annou	inced at t	he beginning o	f the	

Module MA-INF 3229	Lab IT-Secu	urity					
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semeste	r every	semester			
Module	Prof. Dr. Mic	hael Meier	1				
coordinator							
Lecturer(s)	Prof. Dr. Mic	hael Meier					
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Option	al 2. or	3.		
Technical skills	The students	The students will carry out a practical task (project) in the					
	context of IT	context of IT Security, including test and documentation of the					
	implemented s	oftware/sys	tem.				
Soft skills	Ability to prop	perly presen	t and def	end design	n decisions, to		
	prepare readal	ole documer	tation of	software;	skills in		
	constructively	collaboration	ng with of	thers in si	mall teams over	a	
	longer period	of time; abil	ity to clas	ssify ones	own results into	o the	
	state-of-the-ar	t of the resp	o. area				
Contents							
Prerequisites	none						
Format	Teaching forms	at G	oup size	h/week	Workload[h]	CP	
rormat	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching	$S = ind\epsilon$	ependent s	study		
Exam achievements	Oral presentat	ion, writter	report		(gra	ided)	
Study achievements					(not gra	ided)	
Forms of media							
Literature							

Module	Advanced S	ensor Dat	a Fusion	in Dist	tributed		
MA-INF 3233	Systems	clisor Dat	a Lusion	111 12130	Induca		
Workload	Credit points	Duration	Frequer	ıcv			
180 h	6 CP	1 semester	_	-			
Module	PD Dr. Wolfgang Koch						
coordinator	12 21	220011					
Lecturer(s)	Dr. Felix Govaers						
	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	ter Science	Optional	2.			
Technical skills	For challenging	For challenging state estimation tasks, algorithms which enhance					
	the situational	awareness	by fusing s	ensor info	ormation are		
	inevitable. Nov	wadays it ha	s become	very pop	ular to improve	e the	
	performance of	-	_	_		_	
	some challenge				_		
	sensor registrat						
	estimation erro	_					
	limited bandwi	,		_		•	
	at the sensor si	*			-		
	Once recieved to reconstruct		`	, .			
	to a achieve a	_			, –	,165	
	Among these a						
	formula, the Fe				_		
	distributed Ka						
Soft skills	Mathematical						
	mathematical i	results on ea	timation t	heory.			
Contents	tracklet fusion,	the Bar-Sh	alom-Cam	po formu	ıla, the Federat	ed	
	Kalman Filter,		*			nd	
	the least squar	·			e Densities,		
	Decorrlated fus	· -	t represen	tation			
Prerequisites	Recommended:						
	At least 1 of th	_					
	BA-INF 137 –	_					
	MA-INF 3310		ion to Sens	sor Data	Fusion - Metho	ods	
	and Applicatio		. 1				
	Teaching forma	ıt G	roup size	h/week	Workload[h]	CP	
Format	Lecture Exercises			$\frac{2}{2}$	30 T / 45 S 30 T / 75 S	$\begin{vmatrix} 2.5 \\ 3.5 \end{vmatrix}$	
			G . 1			3.5	
D 11	T = face-to-face	ce teaching;	S = indep	endent st		1. 1\	
Exam achievements	Oral exam		.a.t.:			$\frac{\mathrm{ded}}{\mathrm{ded}}$	
Study achievements	Successful exer Power Point	cise particij	pation		(not gra	aea)	
Forms of media	W. Koch: "Tra	cking and	ongor Date	Fusion	Methodologics	<u>.</u> 1	
	Framework and	_			_	7.1	
Literature					-	7-4	
	D. Hall, CY.					Jata	
	Fusion for Network-Centric Operations", CRC Press, 2014.						

Module MA-INF 3235	Usable Secu	rity and P	rivacy						
Workload	Credit points	Duration	Freque	ncy					
180 h	6 CP	1 semester	every y	rear					
Module	Prof. Dr. Mat	thew Smith							
coordinator									
Lecturer(s)	Prof. Dr. Mat	Prof. Dr. Matthew Smith							
Classification	Programme								
	-	M. Sc. Computer Science Optional 1. Students will be familiar with usability problems of IT security							
Technical skills	and privacy m	echanisms, un security and	nderstand privacy i	l methods mechanisr					
Soft skills	• Working wit	h scientific lit	erature						
	Communicat	ion skills							
	• Team working								
Contents	The lecture on Usable Security and Privacy deals with many aspects of human factors and usability in the context of security and privacy. The lecture includes both the foundations of usable security and privacy as well as a selection of cutting edge international research in this area. Topics include:								
	 Evaluation of usability issues of existing security & privacy models or technology Design and evaluation of new usable security & privacy technology Impact of organizational policy on security and privacy interaction Lessons learned from designing, deploying, managing or evaluating security & privacy technologies Foundations of usable security & privacy Methodology for usable security & privacy research Ethical, psychological, sociological and economic aspects of 								
Prerequisites	Required: Knowledge about IT Security is advantageous but not mandatory.								
	Recommended:								
	At least 1 of the following:								
	BA-INF 138 – IT-Sicherheit								
	BA-INF 136 –	Reaktive Sic	herheit						
	MA-INF 1103	- Cryptogran	ohy						
	MA-INF 3229								
	Teaching forms		oup size	h/week	Workload[h]	CP			
Format	Lecture	31		2	30 T / 45 S	$\frac{3}{2.5}$			
	Exercises			2	30 T / 75 S	3.5			
	T = face-to-fa	ce teaching: S	S = inder	l					
Exam achievements	Written exam	oo waamiig, k	, — muep	ondent st		$\overline{\operatorname{ded}}$			
Study achievements	Successful exer	cise participa	ation		(not grad				
Forms of media	S S S S S S S S S S S S S S S S S S S	Participe			(225, 814)				
Literature									

Module	IT Security							
MA-INF 3236								
Workload	Credit points	Duration	Frequer	ncv				
180 h	6 CP	1 semester	_	-				
Module	Prof. Dr. Mic	hael Meier						
coordinator								
Lecturer(s)	Prof. Dr. Mic	Prof. Dr. Michael Meier						
Cl :c .:	Programme		Mode	Semest	ter			
Classification	M. Sc. Compu	iter Science	Optional	l 1. or 2	2.			
Technical skills	Students are in	ntroduced to	a variety	of active	research fields	in		
	IT security. St	tudents learn	about the	e motivat	ion, challenges	and		
	objectives in t	hese fields.	Additional	ly, they g	et to know sele	ected		
	fundamental k	fundamental knowledge and methods helping them to deeper						
	their knowledg	heir knowledge in their upcoming studies.						
Soft skills		working in small groups on exercises, critical discussion of own						
		and others' results, time management, transfering theoretical						
		knowledge to practical scenarios						
Contents	The contents vary but usually include							
	• Privacy							
	Cryptographic Protocols							
	• Network Security							
	• Supply Chain Attacks							
	• Management of Identity Data							
	• Low-level software analysis							
	• Software testing							
	• Side Channel Attacks							
	• Anomaly Detection							
	• Human Factor in Security							
Prerequisites	Required:							
	Fundamental l	_		ving areas	s: operating			
	systems, netwo				T			
	Teaching forms	at G	roup size		Workload[h]	CP		
Format	Lecture			2	30 T / 45 S	2.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-fa	ce teaching;	S = indep	endent st	udy			
Exam achievements	Written exam				(gra	ded)		
Study achievements	Successful exe	rcise partici _l	ation		(not gra	ded		
Forms of media								
Literature								

Module MA-INF 3237	Array Signa	al and Mul	ti-chann	el Proc	essing		
Workload	Credit points	Duration	Frequen	cy			
180 h	6 CP 1 semester every year						
Module	Prof. Dr. Wol	fgang Koch	'				
coordinator							
Lecturer(s)	Dr. Marc Oisp	ouu					
Classification	Programme Mode Semester			ter			
Classification	M. Sc. Compu	iter Science	Optional	2. or 3	3.		
Technical skills	Localization of	ocalization of multiple sources using passive sensors is a					
	fundamental t	fundamental task encountered in various fields like wireless					
	communication	n, radar, son	ar, and sei	smology.	In this lecture, a		
	unified framew	vork for elect	romagneti	c and acc	oustic signals and		
	signal processi	ng technique	s are prese	ented. Fu	irthermore, the		
	sensor calibrat	ion, direction	n finding,	and bear	ings-only		
	localization pr	oblem are co	nsidered.	Special a	pplications are		
	emphasized, li	ke small airb	orne array	s for unr	nanned aerial		
	vehicles (UAVs	vehicles (UAVs).					
Soft skills	Mathematical	derivation of	algorithm	s, applic	ations of		
	mathematical	results on es	timation t	heory			
Contents	Estimation the	eory, Sensor	model, Cra	amér-Rac	analysis,		
	conventional b	eamforming,	Multiple	Signal Cl	lassification		
	(MUSIC), sens	sor calibration	n, Bearing	s-only lo	calization, Direct		
	Position Deter	mination (D	PD), Appl	ications			
Prerequisites	Recommended	:					
	Recommended	l: F. Kurth:	"Foundati	ons of Au	ıdio Signal		
	Processing" (N						
	Teaching forms	at G1	oup size	h/week	Workload[h] CP		
Format	Lecture			2	30 T / 45 S 2.5		
	Exercises			2	30 T / 75 S 3.5		
	T = face-to-fa	ce teaching;	S = indep	endent st	cudy		
Exam achievements	Oral Exam				(graded)		
Study achievements	Successful exe	rcise particip	ation		(not graded)		
Forms of media	Power Point						
	H. L. van Tree	es, Optimum	Array Pro	cessing.	Part IV of		
Literature	Detection, Est	imation, and	Modulati	on Theor	ry. New York:		
	Wiley-Interscie	ence, 2002.					

Module MA-INF 3238	Side Chann	el Attacks	3				
Workload	Credit points	Duration	Freque	ncy			
180 h	6 CP	1 semeste					
Module	Dr. Felix Boes	3					
coordinator							
Lecturer(s)	Dr. Felix Boes						
C1 10 11	Programme Mode Semester						
Classification	M. Sc. Compu	iter Science	Optional	l 2. or 3	3.		
Technical skills	• Students are	introduced	to theoret	ical and p	oractical side		
	channel effects of modern hardware.						
	• Students learn techniques to utilize these effects to circumvent						
	security mechanisms.						
	• This includes covert channels as well as side channel attacks						
	and microarchitectural attacks on modern CPUs.						
Soft skills	Theoretical exercises to support in-depth understanding of						
	lecture topics and to stimulate discussions, practical exercises in						
	teamwork to support time management, targeted organization of						
	practical work and critical discussion of own and others' results.						
Contents	• Theoretical foundations of side channel effects and attacks as						
	well as						
	• covert channels,						
	• differential power analysis,						
	• padding orac	cle,					
	• RSA timing	attacks,					
	• cache based	side channe	l effects,				
	• microarchite	ctural attac	ks (Spectro	e)			
Prerequisites	Recommended	:					
	Fundamental l	knowledge a	bout IT Se	ecurity, or	perating system	ns	
	and statistics	is advantage	ous but no	ot mandat	tory.		
	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
Format	Lecture			2	30 T / 45 S	2.5	
	Exercises			2	30 T / 75 S	3.5	
	T = face-to-fa	ce teaching:	S = index	endent st	udv		
Exam achievements	Written Exam					ded)	
Study achievements	Successful exe		oation		(not gra		
Forms of media	(not graded)						
Literature							

Module MA-INF 3239 Workload 180 h Module	Malware Ar	3						
180 h Module	- 1							
Module	- 1	Duration	Freque	ncy				
	6 CP	1 semester						
	Prof. Dr. Peter	Martini						
coordinator								
Lecturer(s)	Prof. Dr. Elman	r Padilla						
Classification	Programme		Mode	Semester				
	M. Sc. Compute		Optional	2. or 3.				
Technical skills	The students sh				-			
	binary file indep				~ -			
	addition, the str							
C (4 1 11	given aspects ar							
Soft skills	Presentation of		a metnoas	, critical dis	cussion of appli	ea		
Contents	methods and tee In the course, the		ired so for	in hinamı a	malyraia will finat			
Contents	deepened and a	_				, be		
	Different malwa					d by		
	malware author				teeminques usee	1 0 <i>j</i>		
	• Characteristic	_						
		s of marwar	5					
	Persistence Network communication							
	Network communicationEncryption							
	Dynamic malware analysis							
	• Debugging							
	Behavioral obfuscation							
	• Virtual analysis environments							
	• Static malware analysis							
	Control flow obfuscation							
	• Automation of common analysis steps							
	• Reconstruction of binary algorithms							
	The event begins with several lectures that provide the basics for the							
	students to work independently later. In the course of this, the							
	students will work on practical topics from the field of malware							
	analysis during the semester. Since these subject areas can turn out to							
	be very specific, it is necessary to be willing to deal with the subject outside of the lecture and exercise times.							
Duamaguisitas	Required:	ecture and e	xercise tim	es.				
Prerequisites	none							
	Recommended: Basic knowledge of operating systems (kernel, threads, virtual							
	memory), netwo					rv		
	analysis (assemb					- J		
	development (pr				- /			
	Teaching forma		Group size		Workload[h]	CP		
Format	Lecture			2	30 T / 45 S	2.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-face	e teaching: S	= indeper	dent study				
Exam achievements	Oral exam		шасро	-acii bouuy	(ør:	aded)		
Study achievements	Successful exerc	ise participa	tion		(not gra			
Forms of media		. r	-		(820			
	The relevant lite	erature will	be announ	ced at the b	eginning of the			
Literature	lecture							

Module MA-INF 3241		Practical Challenges in Human Factors of Security and Privacy					
Workload	Credit points	Duration	Freque	ncv			
180 h	6 CP 1 semester every year						
Module	Prof. Dr. Mat	thew Smith	-				
coordinator							
Lecturer(s)	Prof. Dr. Mat	thew Smith					
CI IC II	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	ter Science	Optiona	1 2.			
Technical skills	After completi	After completing the unit students will be able to conduct					
	related work se	elated work searchers to get a deep understanding into the state					
	of the art. The	f the art. They will be able to design, run and evaluate					
	scientific studi	es in this ar	ea.				
Soft skills							
Contents	In this course	we will lear	n about ar	nd develop	solutions for a	a	
	specific challer	nge concerni	ng human	factors in	security and		
	privacy.						
Prerequisites	none						
	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
Format	Lecture			1	15 T / 45 S	2	
	Exercises			3	45 T / 75 S	4	
	T = face-to-fa	ce teaching;	S = indep	endent st	udy		
Exam achievements	Project work				(gra	ded)	
Study achievements	Successful exe	rcise partici	pation		(not gra	ded)	
Forms of media							
Literature							

Module	Security of Distributed and Resource-constrained						
MA-INF 3242	Systems						
Workload	Credit points	Duration	Frequency				
180 h	6 CP	1 semeste:	er every year				
Module	Prof. Dr. Michael Meier						
coordinator							
Lecturer(s)	Dr. Thorsten	Aurisch					
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	iter Science	Optional	$\lfloor \ $			
Technical skills	Ability to und	Ability to understand and analyse theoretical and practical					
	cyber security	cyber security challenges of distributed and					
	ressource-cons	trained system	ems, as we	ll as the a	ability to select	and	
	apply appropr	pply appropriate solutions.					
Soft skills							
Contents	• Group comn	nunication w	rith IP mu	lticast			
	• Group key n	• Group key management					
	• Broadcast ei	ncryption					
	• Public key in	nfrastructur	е				
	• Web of trust	-					
	• Multicast in	frastructure	protection	-			
	• Distributed	security med	hanisms				
	• Cyber resilie	ence in group	OS				
	• Security in t	actical radio	networks				
	• Security for IoT						
Prerequisites	none						
	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
Format	Lecture			2	30 T / 45 S	2.5	
	Exercises			2	30 T / 75 S	3.5	
	T = face-to-fa	ce teaching;	S = indep	endent st	udy		
Exam achievements	Written exam				(gra	ded)	
Study achievements	Successful exe	rcise partici	oation		(not gra	$\overline{\text{ded}}$	
Forms of media					· -		
Literature							

Module MA-INF 3243	Tutorenpra	ktikum (Cyber Se	curity				
Workload	Credit points	Duration	Freque	on av				
270 h	9 CP	1 semest	_	-				
Module	Prof. Dr. Micl		er every	year				
	1 101. D1. MIC	naer meier						
coordinator	D., -f D., M4	+1 C:+	l D., f D.	M:-1	1 M -:			
Lecturer(s)	Prof. Dr. Mat		,		i Meier,			
		Prof. Dr. Peter Martini, Dr. Felix Boes, Dr. Matthias Wübbeling, Dr. Marc Ohm,						
		_	,	,				
		Prof. Dr. Michael Meier, Dr. Christian Tiefenau,						
		Dr. Matthias Frank						
Classification	Programme		Mode	Seme	ster			
	-	M. Sc. Computer Science Optional 2.						
Technical skills	Ability to and	Ability to and experience in						
	• conveying ki	• conveying knowledge to students,						
	• presenting to	• presenting technica, conceptional and scientific content,						
	• evaluating a	nd assessin	g excercise	e solutions	s and			
	argumentation	ıs,						
	• development	, impleme	ntation and	d applicat	ion of teach and	l		
	learning tools.							
Soft skills								
Contents	Varying practi	cal tutorin	g tasks in	the conte	xt of cyber secu	rity		
	are carried out	t. This can	include tu	itoring of	exercise session	s for		
	a cyber securi	ty course (bachelor or	r master l	evel), correction	of		
	homework, eva	aluation of	students'	progress, j	participation in	the		
	regular tutor r	neetings, d	evelopmen	t of teach	ing material (e.	g.		
	exercise tasks)	and demo	nstrations	to illustra	ate and convey			
	technical as we	ell as scien	tific correla	ations.				
Prerequisites	none							
	Teaching forms	at C	roup size	h/week	Workload[h]	CP		
Format	Seminar		8	1	15 T / 45 S	2		
	Practical World	k	8	5	75 T / 135 S	7		
	T = face-to-fa	ce teaching	g: S = inde	ependent s	study	-		
Exam achievements	Project work		,, ·	1	•	ded)		
Study achievements	J				(not gra			
Forms of media					(9			
Literature								

Module	Cyber Security Seminar						
MA-INF 3244							
Workload	Credit points	Duration	Frequen	cy			
120 h	4 CP	1 semeste	every year				
Module	Prof. Dr. Mic.	hael Meier					
coordinator							
Lecturer(s)	Prof. Dr. Mat	thew Smith	Prof. Dr.	Peter M	artini,		
	Prof. Dr. Mich	hael Meier,	Dr. Felix B	Soes,			
	Dr. Matthias	Dr. Matthias Wübbeling, Dr. Christian Tiefenauf,					
	Dr. Matthias	Dr. Matthias Frank					
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	iter Science	Optional	2.			
Technical skills	Ability to study and discuss current research related to Cyber						
	Security. Didactic preparation of a written report and didactic						
	presentation a	presentation a talk for a selected topic.					
Soft skills	Ability to perf	form individ	ual literatu	re search	ı, critical readi	ng,	
	and clear dida	ctic present	ation				
Contents	Recent research	•	·	ity based	on cúrrent jou	ırnal	
	and conference	e publication	ıs.				
	In addition the	e seminar gr	oup analys	es and di	iscusses curren	t	
	societal and pe	olitical deve	lopments re	elated to	Cyber Security	y.	
	Participation of	of discussion	events tha	t are and	nounced in the		
	seminar.						
Prerequisites	none						
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
rormat	Seminar		10	2	30 T / 90 S	4	
	T = face-to-fa	ce teaching;	S = independent S	endent st	udy		
Exam achievements	Oral Exam		1			ded)	
Study achievements					(not gra	$\overline{\operatorname{ded}}$	
Forms of media					-		
Literature							

Module MA-INF 3245	Cyber Security Lab						
Workload	Credit points	Duration	Freque	ncy			
270 h	9 CP	1 semester	every y	rear			
Module	Prof. Dr. Mic	hael Meier					
coordinator							
Lecturer(s)	Prof. Dr. Mic	hael Meier, F	rof. Dr.	Matthew	Smith,		
	Prof. Dr. Pete	er Martini, D	r. Felix E	$\operatorname{Boes},$			
	Dr. Matthias	Dr. Matthias Wübbeling, Dr. Christian Tiefenau,					
	Dr. Matthias	Dr. Matthias Frank					
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Optiona	1 2.			
Technical skills	Ability to carry out a practical task in the context of Cyber						
	Security. This						
	_	, -		-	cuss achieved results		
	in the context	of the state-	of-the-art	of the r	espective area.		
Soft skills							
Contents	_	*		-	ation of a practical		
	task in the con	atext of Cyb	er Securit	y.			
	Participation of	of discussion	events th	at are ar	nnounced in the lab.		
Prerequisites	none						
Format	Teaching forms	at Gro	oup size	h/week	1 2 1		
rormat	Lab		8	4	60 T / 210 S 9		
	T = face-to-fa	ce teaching;	S = indep	endent s	study		
Exam achievements	Oral presentat				(graded)		
Study achievements	_	•	·		(not graded)		
Forms of media					· · · · · · · · · · · · · · · · · · ·		
Literature							

Module	Lab Commi	ınication	and Co	mmunic	ating Devices	\mathbf{s}	
MA-INF 3304							
Workload	Credit points	Duration	Frequ	ency			
270 h	9 CP	1 semest	er every	${\rm semester}$			
Module	Prof. Dr. Pete	er Martini					
coordinator							
Lecturer(s)	Prof. Dr. Pete	er Martini,	Prof. Dr.	Michael I	Meier		
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Option	al 2. or	3.		
Technical skills	The students	will carry o	ut a pract	ical task	(project) in the		
	context of con	nmunicatio	n systems,	including	g test and		
	documentation	of the im	plemented	software/	system.		
Soft skills	Work in small	teams and	cooperate	e with oth	er teams in a gr	oup;	
	ability to mak	e design de	cisions in	a practica	al task; present a	and	
	discuss (interim and final) results in the team/group and to						
		; prepare v	ritten do	cumentation cume	on of the work		
	carried out						
Contents	Selected topics						
	communication	-			obile		
	communication	n and com	nunicating	g devices.			
Prerequisites	Required:						
		-			ollowing lecture	s:	
	_				3105), Network		
				ommunica	tion (MA-INF32	202),	
	IT Security (N						
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
2 02 2220	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching	S = I = I = I = I = I = I = I = I = I =	ependent s	study		
Exam achievements	Oral presentat	ion, writte	n report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature	The relevant l	iterature w	ill be anno	ounced to	wards the end o	f the	
Literature	previous semes	ster.					

Module	Lab Information Systems							
MA-INF 3305								
Workload	Credit points	Duration	Freque	•				
270 h	9 CP	1 semeste	r at leas	st every y	ear			
Module	Dr. Thomas E	Bode						
coordinator								
Lecturer(s)	Dr. Thomas E	Dr. Thomas Bode						
Classification	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	iter Science	Option	al 2. or	3.			
Technical skills	The students	The students will carry out a practical task (project) in the						
	context of info	ontext of information systems, including test and						
	documentation	locumentation of the implemented software/system.						
Soft skills	Ability to prop	Ability to properly present and defend design decisions, to						
	prepare readal	ole documer	tation of	software;	skills in			
	constructively	collaboratin	g with of	thers in sr	nall teams over	a		
	longer period	of time; abil	ity to clas	ssify ones	own results into	o the		
	state-of-the-ar	t of the resp	. area					
Contents	Varying select	ed topics clo	se to cur	rent resea	rch in the area	of		
	database- and	information	systems.					
Prerequisites	none							
TD 4	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP		
Format	Lab		8	4	60 T / 210 S	9		
	T = face-to-fa	ce teaching;	S = inde	ependent s	study			
Exam achievements	Oral presentat	ion, written	report		(gra	ded)		
Study achievements					(not gra	$\overline{\operatorname{ded}}$		
Forms of media								
Literature	The relevant literature will be announced towards the end of the							
Literature	previous semes	ster.						

Module MA-INF 3309	Lab Malwai	re Analysi	S					
Workload	Credit points	Duration	Freque	ency				
270 h	9 CP	1 semester	every	semester				
Module	Prof. Dr. Pete	er Martini	'					
coordinator								
Lecturer(s)	Prof. Dr. Pete	er Martini, F	rof. Dr.	Michael I	Meier			
Classification	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	iter Science	Optiona	al 3.				
Technical skills	The students v	will carry ou	t a pract:	ical task ((project) in the			
	context of con	nmunication	systems	with a sp	ecific topic focu	s on		
	· `	*	- ,		ecurity, includin	_		
		est and documentation of the implemented software/system.						
Soft skills			•		er teams in a gr	• /		
		ability to make design decisions in a practical task; present and						
	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	,			n/group and to			
		; prepare wr	itten doc	umentati	on of the work			
	carried out			1				
Contents	Selected topics							
	communication		alware a	nalysis, co	omputer and			
—	network securi	ty.						
Prerequisites	Required:	1-4:£	. 14	C +1 C	-11			
		_			ollowing lecture	s:		
	Principles of I		` `		tion (MA-INF3:	202)		
	IT Security (MA-	, ,		mmumca	uon (MA-INF)	202),		
D	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP		
Format	Lab		8	4	60 T / 210 S	9		
	T = face-to-fa	ce teaching;	S = inde	pendent s	study	•		
Exam achievements	Oral presentat	ion, written	report		(gra	ded)		
Study achievements					(not gra	ded)		
Forms of media								
Literature								

Module	Introduction		r Data	Fusion -	Methods a	nd		
MA-INF 3310	Application							
Workload	Credit points	Duration	Freque	-				
180 h	6 CP	1 semester	every y	every year				
Module	Prof. Dr. Wol	fgang Koch						
coordinator								
Lecturer(s)	Prof. Dr. Wol	fgang Koch						
Classification	Programme		Mode	Semes	ter			
Classification	M. Sc. Compu	iter Science	Optiona	1 3.				
Technical skills	All participant	ts shall get l	nown to t	the basic t	theory of sense	r		
	data fusion. T	he lecture s	arts with	prelimina	ries on how to)		
	handle uncerta	ain data and	knowledg	ge within a	analytical calc	ulus.		
	Then, the fund	damental an	d well-kno	wn Kalm	an filter is deri	ived.		
	Based on this	tracking sch	eme, furth	ner approa	aches to a wide	9		
	spectrum of a	oplications v	rill be sho	wn. All a	lgorithms will	be		
	motivated by	examples fro	m ongoing	g research	projects,			
	industrial coop	_	_	_				
	demonstration		•					
	Doggues of inh	arant practi	aal jaanaa	OTTOWER GOV	gov mooguvog			
	Because of inh	_		-				
	certain proper	-						
	model and ove					cai		
	tools such as I	-						
	solutions to po				ions, maneuver	ring		
	phases, and m				· · · · · · · · · · · · · · · · · · ·			
Soft skills	Mathematical		_		eation of			
	mathematical							
Contents	Gaussian prob	·	·	,				
	Multi-Hypothe					er,		
	Retrodiction,	Smoothing,	Maneuver	Modeling	S			
Prerequisites	none							
	Teaching forms	at G	roup size	h/week	Workload[h]	CP		
Format	Lecture			2	30 T / 45 S	2.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-fa	ce teaching:	S = inder	oendent st	tudy			
Exam achievements	Written exam	- 61	7			aded)		
Study achievements	Successful exe	rcise particii	ation		(not gra			
Forms of media		r			(810			
	W. Koch: "Tra	acking and S	ensor Dat	a Fusion	Methodologic	al		
	Framework an					1		
Literature						,		
	Y. Bar-Shalon				s to Tracking	and		
	Navigation", V	${ m Viley-Interset}$	ience, 200	1.				

Module MA-INF 3312	Lab Sensor	Lab Sensor Data Fusion						
Workload	Credit points	Duratio	'n	Frogue	max	,		
270 h	9 CP			Frequency				
	9 CP 1 semester every year Prof. Dr. Wolfgang Koch							
Module	Prof. Dr. Wol	igang Ko	ocn					
coordinator								
Lecturer(s)	Prof. Dr. Wol	Prof. Dr. Wolfgang Koch						
Classification	Programme			\mathbf{Mode}		Semes	ster	
Classification	M. Sc. Compu	ıter Scier	nce	Optiona	al	3.		
Technical skills	The students	The students will work together on a data fusion project using						
	various sensor	various sensor hardware. Latest algorithms for fusing						
	information from several nodes will be implemented.							
Soft skills		The students shall work together in a team. Everyone is						
			-	-			of a main goal.	
	_	_	_				software interfa	aces.
Contents	Varying select	ed topics	on s	sensor da	ata 1	fusion		
Prerequisites	none							
TD 4	Teaching forms	at	Gro	up size	h/v	week	Workload[h]	CP
Format	Lab			8		4	60 T / 210 S	9
	T = face-to-fa	ce teachi	ng; S	S = inde	pen	dent s	tudy	'
Exam achievements	Oral presentat	ion, writ	ten 1	report			(gra	ded)
Study achievements							(not gra	ded)
Forms of media							•	
	The relevant literature will be announced at the beginning of the							
Literature	lab.						5 0	

Module MA-INF 3317	Seminar Sel	Seminar Selected Topics in IT Security						
Workload	Credit points	Duration	Frequen	cy				
120 h	4 CP	P 1 semester every year						
Module	Prof. Dr. Michael Meier							
coordinator								
Lecturer(s)	Prof. Dr. Mich	Prof. Dr. Michael Meier, Prof. Dr. Peter Martini						
Classification	Programme		Mode	Semest	ter			
Classification	M. Sc. Compu	ter Science	Optional	2.	$\mid 2.$			
Technical skills	Ability to understand new research results presented in original							
	scientific paper	scientific papers.						
Soft skills	Ability to present	ent and to c	ritically di	scuss the	se results in th	ne		
	framework of t	he correspond	nding area	•				
Contents	Current confer	ence and jou	rnal pape	rs				
Prerequisites	none							
Format	Teaching forma	ıt G	oup size	h/week	Workload[h]	CP		
rormat	Seminar		10	2	30 T / 90 S	4		
	T = face-to-face	ce teaching;	S = indep	endent st	udy			
Exam achievements	Oral presentati	ion, written	report		(gra	ded)		
Study achievements					(not gra	ded		
Forms of media								
Literature								

Module MA-INF 3319	Lab Usable Security and Privacy						
Workload	Credit points	Duration	n	Freque	ncy		
270 h	9 CP	1 semes	ster	every	year		
Module	Prof. Dr. Mat	thew Smi	ith				
coordinator							
Lecturer(s)	Prof. Dr. Mat	Prof. Dr. Matthew Smith					
Classification	Programme		N	Mode	Seme	ster	
Classification	M. Sc. Compu	iter Scien	ce C	Optiona	d 2.		
Technical skills	The students	will carry	out a	practi	cal task ((project) in the	
	context of usa	context of usable security and privacy, including user studies.					
Soft skills	Ability to crea	Ability to create and defend a scientific user study					
Contents	Students have	Students have a great degree of freedom to chose their own					
	topics within t	topics within the context of human aspects of security and					
	privacy.						
Prerequisites	Required:						
	Vorkenntnisse			_		_	
				_		. in BA-INF145	ó -
	Usable Securit	y and Pri	ivacy	gelehrt	werden.		
	Knowledge on	how to ru	un an	d evalu	ate user	studies are requ	ired .
	For example a	s it is tau	ıght ir	n BA-II	NF145 - U	Usable Security	and
	Privacy.						
Format	Teaching forms	at	Group	p size	h/week	Workload[h]	CP
rormat	Lab		8	3	4	60 T / 210 S	9
	T = face-to-fa	ce teachir	ng; S	= inde	pendent s	study	
Exam achievements	Oral presentat						ided)
Study achievements						(not gra	ided)
Forms of media							
Literature							

Module MA-INF 3320	Lab Securit	y in Dist	ributed	Systems	3			
Workload	Credit points	Duration	Freque	ency				
270 h	9 CP	1 semeste	er every	year				
Module	Prof. Dr. Mat	thew Smith						
coordinator								
Lecturer(s)	Prof. Dr. Mat	thew Smith						
Classification	Programme	Programme Mode Semester						
Classification	M. Sc. Compu	Optiona	al 2.					
Technical skills	The students	will carry o	it a pract	ical task	(project) in the			
	context of dist	ributed sec	urity, incl	ıding doc	umentation of t	he		
	implemented s	software/sys	tem.					
	Strong program	mming skill	s required	_				
Soft skills	Ability to pro				n decisions, to			
	prepare readable documentation of software; skills in							
				,	mall teams over	a		
	_		_		own results into			
	state-of-the-ar		-	J				
Contents	Security in dis			luding an	nongst others:			
	• Secure Mess	aging						
	App Security	y						
	• SSL/HTTPS	S						
	API Security	у						
	Machine Lea	arning for S	ecurity					
	• Passwords							
	• Intrusion De	etection Sys	tems					
	• Anomaly De							
	• Security Vis	ualisation						
Prerequisites	none							
Format	Teaching form	at G	oup size	h/week	Workload[h]	CP		
rormat	Lab		8	4	60 T / 210 S	9		
	T = face-to-fa	ce teaching	S = inde	pendent s	study			
Exam achievements	Oral presentat	ion, writter	report		(gra	ded)		
Study achievements					(not gra	ded)		
Forms of media								
Literature								

Module MA-INF 3321	Seminar Usable Security and Privacy							
Workload	Credit points	Duration	Ouration Frequency					
120 h	4 CP 1 semester every year							
Module	Prof. Dr. Matthew Smith							
coordinator								
Lecturer(s)	Prof. Dr. Mat	Prof. Dr. Matthew Smith						
Classification	Programme		Mode	Semest	ter			
Classification	M. Sc. Compu	ter Science	Optional	2.				
Technical skills	Ability to understand new research results presented in original							
	scientific paper	scientific papers.						
Soft skills	Ability to pres	ent and to c	ritically di	scuss the	se results in th	ne		
	framework of t	he correspon	nding area	•				
Contents	Current confer	ence and jou	rnal pape	rs				
Prerequisites	none							
Format	Teaching forma	at G	oup size	h/week	Workload[h]	CP		
rormat	Seminar		10	2	30 T / 90 S	4		
	T = face-to-face	ce teaching;	S = indep	endent st	udy			
Exam achievements	Oral presentat	ion, written	report		(gra	ded)		
Study achievements					(not gra	ded)		
Forms of media								
Literature								

Module MA-INF 3322	Applied Bir	nary Exp	loitation					
Workload	Credit points	Duration	Freque	ncv				
180 h	6 CP	1 semeste	_	-				
Module	Prof. Dr. Peter	Martini						
coordinator								
Lecturer(s)	Prof. Dr. Elma	r Padilla						
Classification	Programme		Mode	Semester				
Classification	M. Sc. Comput	er Science	Optional	2. or 3.				
Technical skills	Overflows, Form	Static and dynamic program analysis, Exploitation (Stack-based Buffer Overflows, Format String Exploits, Heap Exploitation, Use-After-Free Exploits) and Countermeasures (Stack Cookies, NX, ASLR, RELRO)						
Soft skills	Frustration tole trying to apply challenging prol	Frustration tolerance when working with binary representations and trying to apply taught techniques, focussed working on technically challenging problems, simultaneously applying knowledge from different areas of computer science						
Contents	Our computers run a lot of closed source binary programs meaning that the source code of those programs is not available. Naturally, those programs contain bugs, mistakes that the programmer made during the development. Those bugs could (under certain circumstances) be exploited by attackers and thus may lead to arbitrary code execution. In this lecture we aim to teach you how to find well known exploitable bugs and how to exploit them. After a brief recap of basic binary program analysis such as static and dynamic analysis, we will talk about vulnerability discovery in general, meaning that you will learn how to find exploitable bugs by yourself. Next we move on to basic stack-based buffer overflows and add mitigation techniques (stack cookies, NX, ASLR, RELRO,) as we progress and exploit them as well. After we finished the topic of stack-based buffer overflows we move on to more advanced topics such as heap exploitation, use-after-free exploits and others. The lecture ends with an introduction to fuzzing and an analysis of a sophisticated							
Prerequisites	real-world explo							
	none							
	Recommended	:						
	• Binary Analys 155)	sis skills (Le	cture: "Ap	plied Binary	y Analysis" BA-l	INF		
	Basic knowled	lge of the Li	nux operat:	ing system				
	• System Progra		ls in C (Lee	cture: "Syst	temnahe			
	Programmierun							
	• Basic Python							
	Teaching forms	at	Group size	h/week	Workload[h]	CP		
Format	Lecture			2	30 T / 45 S	2.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-face	e teaching: S	S = independent	dent study				
Exam achievements	Oral Examinati				(gra	ided)		
Study achievements	Successful exerc		ation		(not gra			
Forms of media		r r ar ozorpe			(220 810			
	The relevant lit	ono +	1	1 1 1				
Literature	i ne rejevani uu	eraliire wuu	ne annound	ed at the b	eginning of the			

Module	Lab Fuzzing	g Bootcan	np					
MA-INF 3323								
Workload	Credit points	Duration	Freque	ency				
270 h	9 CP	1 semeste	ter every year					
Module	Prof. Dr. Mat	thew Smith	·					
coordinator								
Lecturer(s)	Prof. Dr. Matthew Smith							
Classification	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	iter Science	Option	al 2. or	3.			
Technical skills	The students	The students will carry out a practical task (project) in the						
	context of fuzz	context of fuzz testing, including test and documentation of the						
	implemented software/system.							
Soft skills	Ability to prop	Ability to properly present and defend design decisions, to						
	prepare readal	ole documer	itation of	software;	skills in			
	constructively	collaboration	ng with of	thers in sr	nall teams over	a		
	longer period	of time; abil	ity to clas	ssify ones	own results into	o the		
	state-of-the-ar	t of the resp	o. area					
Contents								
Prerequisites	none							
Format	Teaching forms	at G	oup size	h/week	Workload[h]	CP		
Format	Lab		8	4	60 T / 210 S	9		
	T = face-to-fa	ce teaching:	S = inde	ependent s	study			
Exam achievements	Oral presentat	ion, written	report		(gra	ided)		
Study achievements					(not gra	ided)		
Forms of media								
Literature								

Module MA-INF 3324	Lab Design	of Usab	e Securi	ty Med	chanisms				
Workload	Credit points Duration Frequency								
270 h	9 CP 1 semester every year								
Module	Prof. Dr. Matthew Smith								
coordinator									
Lecturer(s)	Dr. Emmanue	l von Zezse	chwitz						
Classification	Programme Mode Semester								
Classification	M. Sc. Compu	iter Science	e Option	al 2. c	or 3.				
Technical skills	The students	will carry o	out a prac	tical task	(project) in the				
	context of usa	ble security	mechani	sms, incl	uding test and				
	documentation	documentation of the implemented software/system.							
Soft skills	Ability to prop	perly prese	nt and de	end desi	gn decisions, to				
	prepare readal	ble docume	entation of	softwar	e; skills in				
	constructively	collaborat	ing with c	thers in	small teams over	a			
	longer period	of time; ab	ility to cla	ssify one	es own results int	o the			
	state-of-the-ar	t of the res	sp. area						
Contents									
Prerequisites	none								
Format	Teaching forms	at C	roup size	h/weel	workload[h]	CP			
rormat	Lab		8	4	60 T / 210 S	9			
	T = face-to-fa	ce teaching	g; S = ind	ependent	study				
Exam achievements	Oral presentat	ion, writte	n report		(gra	aded)			
Study achievements		<u> </u>			(not gra	aded)			
Forms of media									
Literature									

4 Intelligent Systems

MA-INF 4111	L2E2	6 CP	Intelligent Learning and Analysis Systems: Machine Learning	99
MA-INF 4112	L2E2	6 CP	Intelligent Learning and Analysis Systems: Data Mining and	
			Knowledge Discovery	. 100
MA-INF 4113	L2E2	6 CP	Cognitive Robotics	. 101
MA-INF 4114	L2E2	6 CP	Robot Learning	102
MA-INF 4115	L3E1	6 CP	Introduction to Natural Language Processing	. 103
MA-INF 4116	Sem2	4 CP	AI Ethics Seminar	105
MA-INF 4201	L2E2	6 CP	Artificial Life	106
MA-INF 4203	L2E2	6 CP	Autonomous Mobile Systems	. 107
MA-INF 4204	L2E2	6 CP	Technical Neural Nets	. 108
MA-INF 4207	L2E2	6 CP	Dynamically Reconfigurable Systems	. 109
MA-INF 4208	Sem2	4 CP	Seminar Vision Systems	. 110
MA-INF 4209	Sem2	4 CP	Seminar Principles of Data Mining and Learning Algorithms	111
MA-INF 4210	Sem2	4 CP	Seminar Advanced Topics in Technical Informatics	112
MA-INF 4211	Sem2	4 CP	Seminar Cognitive Robotics	
MA-INF 4215	L2E2	6 CP	Humanoid Robotics	
MA-INF 4216	L2E2	6 CP	Data Mining and Machine Learning Methods in Bioinformatics	115
MA-INF 4217	Sem2	4 CP	Seminar Machine Learning Methods in the Life Sciences	. 116
MA-INF 4226	Lab4	9 CP	Lab Parallel Computing for Mobile Robotics	117
MA-INF 4228	L4E2	9 CP	Foundations of Data Science	118
MA-INF 4229	L4E2	9 CP	Pattern Recognition I	119
MA-INF 4230	L2E2	6 CP	Advanced Methods of Information Retrieval	. 120
MA-INF 4231	Sem2	4 CP	Seminar Advanced Topics in Information Retrieval	121
MA-INF 4232	Lab4	9 CP	Lab Information Retrieval in Practice	122
MA-INF 4302	L2E2	6 CP	Advanced Learning Systems	. 123
MA-INF 4303	L2E2	6 CP	Learning from Non-Standard Data	124
MA-INF 4304	Lab4	9 CP	Lab Cognitive Robotics	125
MA-INF 4306	Lab4	9 CP	Lab Development and Application of Data Mining and Learning	g
			Systems	
MA-INF 4307	Lab4	9 CP	Lab Field Programmable Gate Arrays	. 127
MA-INF 4308	Lab4	9 CP	Lab Vision Systems	128
MA-INF 4309	Lab4		Lab Sensor Data Interpretation	
MA-INF 4310	Lab4	9 CP	Lab Mobile Robots	. 130
MA-INF 4312	L2E2	6 CP	0	
MA-INF 4313	Sem2	4 CP	Seminar Semantic Data Web Technologies	. 132
MA-INF 4314	Lab4	9 CP	Lab Semantic Data Web Technologies	
MA-INF 4316	L2E2	6 CP	Graph Representation Learning	134
MA-INF 4318	Sem2	4 CP	Seminar Representation Learning for Big Data Analytics	135
MA-INF 4319	L4E2	9 CP	Game AI	. 136
MA-INF 4320	Lab4	9 CP	Lab Representation Learning on Graphs	. 137
MA-INF 4321	Sem2	4 CP	Seminar Learning from Time Series	138
MA-INF 4322	L4E2	9 CP	Lab Machine Learning on Encrypted Data	139
			Pattern Recognition II	
			Seminar Advanced Topics in Data Science	
MA-INF 4325	Lab4		Lab Data Science in Practice	
MA-INF 4326			Explainable AI and Applications	
MA-INF 4327			Lab Biomedical Data Science	
			Spatio-Temporal Data Analytics	
MA-INF 4329	Sem2	4 CP	Seminar Biological Intelligence	146

Module MA-INF 4111	Intelligent I Learning	Learning a	nd Anal	lysis Sys	stems: Mach	ine			
Workload	Credit points	Duration	Freque	ncy					
180 h	6 CP	1 semester	every y	ear					
Module	Prof. Dr. Stefan Wrobel								
coordinator									
Lecturer(s)	Prof. Dr. Stefan Wrobel								
Classification	Programme	S .							
Classification		M. Sc. Computer Science Optional 1. or 2.							
Technical skills		This module is one of two complementary modules in which							
	students gain an understanding of the most important								
	paradigms and		_	_	, ,	ey			
	are used in dat		,	-					
	behaviour (ma				=	-			
	in databases).								
	predictive learn teaches the ma	_	_	_					
	end of the mod		_			.e			
	appropriate me	,		-	_				
	learning applic			-	-				
	results, and wi				_	r			
	further develop				-				
	This module co	_		-	_				
	before or after	that modul	e.						
Soft skills	Communicativ	e skills (ora	and write	ten presen	ntation of solut	ions,			
	discussions in s	small teams	, self com	petences	(ability to acce	ept			
	and formulate								
Contents	Types of learns	_		*	-				
	non-parametric	-			•	ning			
	(e.g., decision								
	neighbourhood								
	approaches), retheory.	emiorcemen	learning,	evaruatio	on and learning	b			
Prerequisites	Required:								
Trerequisites	MA-INF 4102	- Intelligent	Learning	and Anal	vsis Systems h	as			
	not been passe	_	Learning	and man	lybib bybucinib n	as			
	Recommended:								
	Prior knowleds		ility theor	v linear s	algebra artifici	al			
	intelligence, in	_			· ,	.01			
	Teaching forma		roup size	h/week	Workload[h]	CP			
Format	Lecture		F	2	30 T / 45 S	2.5			
	Exercises			2	30 T / 75 S	3.5			
	T = face-to-face	ce teaching:	S = inder	ı nendent st	,	1			
Exam achievements	Written exam	oo waaming,	~ mac _l	ZIIGOIII BU		ded)			
Study achievements	Successful exer	rcise particir	ation		(not gra				
Forms of media	Lectures, exerc			es	(33 020	/			
	- Tom Mitchell				Hill, 1997				
Literature	- Ian Witten, I								
	2000	Live Frank,	→ ava willi	b, word	, and i sa continuous in the	,			

Module MA-INF 4112	Intelligent I Mining and				stems: Data			
Workload	Credit points	Duration	Freque					
180 h	6 CP	1 semester	every y	-				
Module		Prof. Dr. Stefan Wrobel						
coordinator								
Lecturer(s)	Prof. Dr. Wro	bel						
. ,	Programme		Mode	Semest	ter			
Classification	M. Sc. Compu	ter Science	Optional					
Technical skills	This module is				dules in which			
	students gain a		_	-				
	paradigms and	l methods of	intelligen	t learning	systems as th	ey		
	are used in dat	ta analysis aı	nd/or for	implemen	nting adaptive			
	behaviour (ma	chine learnin	g, data n	nining, kn	owledge discov	ery		
	in databases).	This module	concentr	ates on the	he core tasks o	f		
	pattern discove	·						
	algorithms for	,		-		the		
	module, studer		_	_				
	methods and s			-	•	,		
	applications ar				,	ıd		
	will know where to start whenever adaptation or further							
	development of algorithms and systems is necessary. This							
	module complements MA-INF 4111 and can be taken before or after that module.							
Soft skills	Communicativ		and writt	on progon	station of colut	iong		
Soft skills	discussions in	`		-				
	and formulate				•	շբւ		
Contents	Types of learn							
Comonis	descriptive dat			,		os.		
	clustering, pre-	_				,		
	warehouses, O				- \	xt,		
	multimedia da	/ -				,		
Prerequisites	Required:	,,						
	MA-INF 4102	- Intelligent	Learning	and Anal	ysis Systems h	as		
	not been passed.							
	Recommended	:						
	Prior knowledg	ge of probabi	lity theor	y, linear a	algebra, artifici	al		
	intelligence, in	formation sys	stems and	data bas	ses			
	Teaching forma	at Gr	oup size	h/week	Workload[h]	CP		
Format	Lecture			2	30 T / 45 S	2.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-face	ce teaching; S	S = indep	endent st	udy			
Exam achievements	Written exam	<u> </u>	<u></u>			ded)		
Study achievements	Successful exer	rcise participa	ation		(not gra			
Forms of media	Lectures, exerc	cises, softwar	e package	es				
	- Ian Witten, l	Eibe $\overline{\text{Frank, I}}$	Data Min	$\overline{\log, \mathrm{Morg}}$	an Kauffmann	,		
T:tonotune	2000							
Literature	- Jiawei Han, I	Micheline Ka	mber, Da	ta Mining	g: Concepts an	.d		
	Techniques, M			_	_			

Module MA-INF 4113	Cognitive F	Robotics						
	C	D4:	T					
Workload	Credit points 6 CP	Duration 1 gamagter	Freque	-				
180 h		1 semester	every y	ear				
Module	Prof. Dr. Sven Behnke							
coordinator	D C D C	D 1 1						
Lecturer(s)		Prof. Dr. Sven Behnke						
Classification	Programme Mode Semester							
	M. Sc. Compu		Optiona					
Technical skills					es of the intellig	gent		
	systems track.			_	-			
				o, .	perception, and	d		
	action-plannin	g in complex	environn	nents.				
	This module of	complements	MA-INF	4114 and	can be taken			
	before or after	that module	Э.					
Soft skills	Communicativ	ve skills (oral	and writt	en presen	tation of solut	ions,		
	discussions in	small teams	, self com	petences	(ability to acce	ept		
	and formulate	criticism, al	oility to ar	nalyze pro	blems)			
Contents	Probabilistic a	approaches to	state est	imation (Bayes Filters,			
	Kalman Filter, Particle Filter), motion models, sensor models,							
	self-localization, mapping with known poses, simultaneous							
	mapping and	localization (SLAM), i	terated cl				
	matching, pat	h planning, լ	place- and	person re	ecognition, obje	ect		
	recognition.							
Prerequisites	Required:							
	MA-INF 4101	- Theory of	Sensorimo	otor Syste	ms has not been	en		
	passed.							
	Teaching forms	at G	roup size	h/week	Workload[h]	CP		
Format	Lecture			2	30 T / 45 S	2.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-fa	ce teaching;	S = indep	endent st	udy			
Exam achievements	Written exam					ded)		
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)		
Forms of media								
	• S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics.							
	MIT Press, 20	005.						
T:4	• B. Siciliano,	O. Khatib (Eds.): Spi	ringer Hai	ndbook of			
Literature	Robotics, 2008		. –					
	• R. Szeliski:	Computer V	ision: Alg	orithms a	nd Application	ıs,		
	Springer 2010.							

Module	Robot Lear	ning							
MA-INF 4114	G 111	ъ.,							
Workload	Credit points	Duration	Freque	-					
180 h	6 CP 1 semester every year								
Module	Prof. Dr. Sven Behnke								
coordinator									
Lecturer(s)	Prof. Dr. Sven Behnke, Dr. Nils Goerke								
Classification	Programme	~ .	Mode	Semest					
	M. Sc. Compu		Optiona						
Technical skills		This lecture is one of two introductory lectures of the intelligent							
		systems track. Creating autonomous robots that can learn to							
					scinating challe				
		_		_	ingredients for				
	_		_		towards human				
	_	,			t learning, lear	rning			
	models for con	,			_				
	demonstration	demonstrations and imitation learning, and interactive learning.							
	This module c	This module complements MA-INF 4113 and can be taken							
	before or after	that module) .						
Soft skills	Communicativ	ve skills (oral	and writt	ten presen	ntation of solut	ions,			
		`		-	(ability to acce	,			
	and formulate	<i>'</i>		_	•	•			
Contents					esses, dynamic	;			
	programming,	Monte Carlo	methods	, tempora	al-difference				
					atic regulation	,			
	differential dy	namic progra	mming, p	artially o	bservable MDI	P_{S}			
	policy gradien								
	imitation learn	ning, learning	kinemat	ic models	, perceiving an	d			
	handling of ob	jects.							
Prerequisites	none								
	Teaching forms	at G	oup size	h/week	Workload[h]	CP			
Format	Lecture			2	30 T / 45 S	2.5			
	Exercises			2	30 T / 75 S	3.5			
	T = face-to-fa	ce teaching:	S — inder	ı Sendent st	,	ı			
Exam achievements	Written exam	ec cacining,	o — maer	Zendeni st		ded)			
Study achievements	Successful exe	rcise particin	ation		(not gra				
Forms of media	Duccessiui exe.	rence parmerp	G01011		(1100 gra	acaj			
TOTHIS OF HIEUIA	• R Sutton ar	nd A Barto:	Reinforce	ment Les	arning, MIT-Pr	.bee			
	1998.	.id A. Dario.	101111010			.coo,			
Literature	• O. Sigaud a	nd I Peters	Eds). Fr	om Moto	r Learning to				
	_		` ′		_				
	Interaction Learning in Robots. Springer, 2010.								

Introduction	to Natur	al Lang	uage Pr	rocessing		
		I _				
		every y	ear			
Prof. Dr. Lucie	e Flek					
	Flek					
_	er Science					
					ls fo	
building comput human languag emphasized, for covered applica Entity Recognit	tter software e. Contemporusing on mations vary intion, Argume	that und orary data achine lea a complex ent Minin	erstands a-driven a rning tecl ity, includes, or Em	and manipulat approaches are hniques. The ding for examp otion Analysis	es ble	
work on real-we offers you the can in-depth app	orld NLP ap hance to app plication usin	plication bly your n ng differen	projects. lewly acq nt framew	The final projuired skills tow works such as	ect	
Through lecture thorough introd linguistic basis advances in dee	es, exercises, luction to cu of computat ep learning a	and a fir atting-edg ional lang	nal projec ge researc guage me	t, you will gain h in NLP, from thods to recent	n th	
 Text representation (Words, sentences, paragraphs, documents), word embeddings, word2vec, BERT, word similarity Machine learning / deep learning algorithms for text classification, Transformers Basics of neural language modeling Basics of computational linguistics 						
stemming, lemmatization) - Syntactic analysis (part of speech tagging, chunking, and						
- Techniques for extracting meaning from text (semantic						
• NLP applications and projects (e.g., Sentiment Analysis, Named Entity Recognition, Question Answering, Summarization, Fake news detection, Plagiarism detection,						
• Basic program	nming know	ledge in F	-	_		
				1		
	t Gr	oup size			C]	
				,	3	
Exercises			1	15 T / 75 S	3	
T = face-to-fac	e teaching; S	S = indep	endent st	udy		
					ded	
	<u> </u>		/	,-		
• Lecture slides				(1100 810	acc	
Exercise slideNotebooks wi	S	ning	nnles			
	Credit points 6 CP Prof. Dr. Lucie Programme M. Sc. Comput This class provide building comput human language emphasized, for covered applicate Entity Recognity Group work du work on real-word offers you the can in-depth approvide an in-depth approvide an in-depth approvide and introcal inguistic basis advances in decourse provides An overview Text represent documents), word machine learn classification, To Basics of neuron Basics of neuron Basics of comparising temming, lemmon Comparising temming, lemmon Comparising temporary and the comparising temporary and the comparison of the	Credit points 6 CP 1 semester Prof. Dr. Lucie Flek Programme M. Sc. Computer Science This class provides a technic building computer software human language. Contempore emphasized, focusing on macovered applications vary in Entity Recognition, Argumed Group work during program work on real-world NLP appoffers you the chance to appan in-depth application usin PyTorch and spaCy and proffers you the chance to culinguistic basis of computate advances in deep learning a course provides: • An overview of NLP goals • Text representation (Word documents), word embeddin • Machine learning / deep leassification, Transformers • Basics of neural language • Basics of computational light of the stemming, lemmatization) - Syntactic analysis (part of parsing) - Techniques for extracting analysis), use of lexical resormanded in the stemming of the st	Credit points Duration 1 semester every years Prof. Dr. Lucie Flek Programme Mode M. Sc. Computer Science Optional This class provides a technical perspebuilding computer software that und human language. Contemporary data emphasized, focusing on machine lear covered applications vary in complex Entity Recognition, Argument Mining Group work during programming exework on real-world NLP application offers you the chance to apply your man in-depth application using differency Torch and spaCy and present it in Through lectures, exercises, and a first thorough introduction to cutting-edg linguistic basis of computational languadvances in deep learning and large course provides: • An overview of NLP goals, challenge to the course provides: • An overview of NLP goals, challenge to the course provides: • An overview of NLP goals, challenge to the course provides: • An overview of NLP goals, challenge to the course provides: • An overview of NLP goals, challenge to the course provides: • An overview of NLP goals, challenge to the course provides: • An overview of NLP goals, challenge to the course provides: • An overview of NLP goals, challenge to the course provides: • An overview of NLP goals, challenge to the course provides: • An overview of NLP goals, challenge to the course provides: • An overview of the goals, challenge to the course provides: • An overview of the goals, challenge to the course provides: • An overview of the goals, challenge to the course provides: • An overview of the goals, challenge to the course provides: • An overview of the goals, challenge to the course provides: • An overview of the goals, challenge to the course provides: • An overview of the goals, challenge to the course provides: • An overview of the goals, challenge to the course provides: • An overview of the goals, challenge to the course provides: • An overview of the goals to the goals	Credit points 6 CP	Prof. Dr. Lucie Flek Prof. Dr. Lucie Flek Programme M. Sc. Computer Science Mode Optional 1. or 2. This class provides a technical perspective on NLP? method building computer software that understands and manipulathuman language. Contemporary data-driven approaches are emphasized, focusing on machine learning techniques. The covered applications vary in complexity, including for exampentity Recognition, Argument Mining, or Emotion Analysis Group work during programming exercises will allow studen work on real-world NLP application projects. The final projoffers you the chance to apply your newly acquired skills towan in-depth application using different frameworks such as PyTorch and spaCy and present it in a poster session. Through lectures, exercises, and a final project, you will gain thorough introduction to cutting-edge research in NLP, fron linguistic basis of computational language methods to recent advances in deep learning and large language models. This course provides: • An overview of NLP goals, challenges, and applications • Text representation (Words, sentences, paragraphs, documents), word embeddings, word2vec, BERT, word simil • Machine learning / deep learning algorithms for text classification, Transformers • Basics of neural language modeling • Basics of computational linguistics - Transforming words to their base forms (tokenization, stemming, lemmatization) - Syntactic analysis (part of speech tagging, chunking, and parsing) - Techniques for extracting meaning from text (semantic analysis), use of lexical resources in NLP • NLP applications and projects (e.g., Sentiment Analysis, Named Entity Recognition, Question Answering, Summarization, Fake news detection, Plagiarism detection, Abusive language detection, Opinion mining) Recommended: • Basics of statistics recommended. • Basic programming knowledge in Python is of advantage. Teaching format Group size h/week Workload[h] Ecture Samper Samper Samper Samper Samper Samper Samper Samper Samper	

Module	AI Ethics S	eminar						
MA-INF 4116	G 111	D						
Workload	Credit points	Duration	_	iency				
120 h	4 CP Prof. Dr. Luci	1 semest	er every	year				
Module	Prof. Dr. Luci	е г ек						
coordinator	D. f D. I	: T71 - 1-						
Lecturer(s)		Prof. Dr. Lucie Flek						
Classification	Programme M. Sc. Compu	ton Caiona	Mode Option	$\begin{array}{c c} & \mathbf{Semes} \\ \text{nal} & 1. \text{ or } 2 \end{array}$				
Technical skills	-				e ethical dilem	mag		
Technical Skills					skills in assess			
		_		_	social impacts,	_		
					nd communicat			
	their reasoning	_	and soc.	ar issues, a		mg		
Soft skills	Students will l		the desi	on of ethica	l and socially			
Solv Sillis	responsible sys			_	·			
	multidisciplina			_				
	_				ll write a final	$_{ m term}$		
	essay on one o							
Contents	-			the ethica	l dilemmas			
	We study artificial intelligence and the ethical dilemmas associated with the research, design, deployment, and							
	interaction with AI systems.							
	Six broad modules structure the seminar:							
	 Foundations of AI and AI ethics Bias & fairness 							
	 Privacy & data privacy Social networks & civility of communication 							
	Social networks & civility of communication Politics & policy							
	• AI for "social good"							
	A typical lecture will consist of 2-3 student presentations that							
	focus on a research article and the broad context of its topic.							
	Following each presentation, we discuss the work with a focus on							
	assessing relevant ethical issues and potential approaches for							
	ethical design	and engine	ering.					
Prerequisites	Required:							
	No previous knowledge is required.							
	Recommended:							
	Previously attended classes in machine learning, robotics, data							
	mining, or related, can be useful for understanding the topics							
	but are not a			1 - ,	T			
Format	Teaching forms	at (Group siz	-	Workload[h]	CP		
	Seminar		10	2	30 T / 90 S	4		
	T = face-to-fa	ce teaching	S = inc	lependent st	tudy			
Exam achievements	Schriftliche Pr				(gra	ded		
Study achievements	Erfolgreiche Ü	bungsteiln	ahme		(not gra	ded		
Forms of media								
Literature								

Module	Artificial Li	fe							
MA-INF 4201			1						
Workload	Credit points	Duration	Freque	-					
180 h	6 CP	1 semester	every y	rear					
Module	Prof. Dr. Sven	n Behnke							
coordinator									
Lecturer(s)	Prof. Dr. Sven	n Behnke, Dr.							
Classification	Programme	~ .	Mode	Semest	ter				
	M. Sc. Compu		Optiona						
Technical skills	Detailed under	0		•	* *				
		principles of artificial life. Knowledge and understanding of the current state of research in the field of artificial life							
Soft skills	Capability to i	·							
	present and de								
	front of a grou	=	. Critica.	l discussion	on of the result	s of			
	the homework.				~				
Contents	Foundations of				· -				
	of Life"; mecha			-		s of			
	nonlinear dyna		,						
	evolutionary m	_							
	learning, artific		-	_					
	self-organising		_	-	, and swarm				
D 111	intelligence, pa	article swarm	optimiza	ttion.					
Prerequisites	none			1 / 1	*** 11 1511	GD			
.	Teaching forma	at Gro	oup size	h/week	Workload[h]	CP			
Format	Lecture			$\frac{2}{2}$	30 T / 45 S	2.5			
	Exercises			2	30 T / 75 S	3.5			
	T = face-to-face	ce teaching; S	S = indep	endent st					
Exam achievements	Written exam				(gra	ided)			
Study achievements	Successful exer				(not gra				
Forms of media	Pencil and pap	· –				ercise			
	group, implem		nall prog	rams, use	e of simple				
	simulation too								
	• Christoph A				*				
	Electronic Lib	=			_				
	• Eric Bonabeau, Marco Dorigo, Guy Theraulaz: Swarm								
	Intelligence: From Natural to Artificial Systems, Oxford								
Literature	University Pre	ss, Santa Fe I	Institute	Studies in	n the Science o	\mathbf{f}			
Liverandie	Complexity.								
	• Andrzej Osy		·	_	_				
	Multicriteria I				-				
	Soft Computin	ng, Physica-Ve	erlag, A	Springer-	Verlag Compar	ıy,			
	Soft Computing, Physica-Verlag, A Springer-Verlag Company, Heidelberg								

Module	Autonomous	Mobile	Systems			
MA-INF 4203						
Workload	•	Duration	Freque	ncy		
180 h	6 CP	1 semeste	every y	ear		
Module	Prof. Dr. Sven	Behnke				
coordinator						
Lecturer(s)	Dr. Dirk Schulz	z, Prof. Dr	Sven Bel	nke		
Classification	Programme		Mode	Semest	ter	
Classification	M. Sc. Comput		Optiona			
Technical skills	Profound know	_	_			$_{ m ture}$
	and function of	٠,			,	
	Knowledge of t	_				
	requirements for	_		-	_	fic
	applications an					
Soft skills	The students w	-				
	autonomous mo	-	-	_		-
	what part of th					
	of the art devel	_			_	and
	implement a so					
Contents	Requirements f					
	systems, e.g. fo	-	· ,		,	
	SLAM-methods		_	_		
	methods for act	_	_	arison of o	lifferent learnii	ıg
	paradigms for s	вресиис арр	lications.			
Prerequisites	Recommended:	_•				
	all of the follow	_	. ~ .	~		
	MA-INF 4101 -	- Theory of	Sensorim	otor Syste	ems	
	MA-INF 4113 -		Robotics			
	Teaching format	t G	roup size	h/week	Workload[h]	CP
Format	Lecture			2	30 T / 45 S	2.5
	Exercises			2	30 T / 75 S	3.5
	T = face-to-fac	e teaching;	S = indep	endent st	udy	
Exam achievements	Oral exam				(gra	ded)
Study achievements	Successful exerc	cise partici	oation		(not gra	ded)
Forms of media						
	• J. Buchli: Mo		_	_	,	by
	Advanced Robo	otic System	s and Pro	Literatur	Verlag	
Literature	• Sebastian Th		_	d, Dieter	Fox: Probabili	stic
Diterature	Robotics, MIT					
	• Howie Choset	t et al.: Pri	nciples of	Robot Mo	otion, MIT-Pre	ess,
	2005					

Module	Technical N	leural Net	5						
MA-INF 4204									
Workload	Credit points	Duration	Freque	-					
180 h	6 CP	1 semester	0 0	ear					
Module	Prof. Dr. Joac	chim K. Anla	uf						
coordinator									
Lecturer(s)		Prof. Dr. Joachim K. Anlauf, Dr. Nils Goerke							
Classification	Programme		Mode	Semest	ter				
	M. Sc. Compu		Optiona	I					
Technical skills		Detailed knowledge of the most important neural network							
		approaches and learning algorithms and its fields of application.							
			_		ural networks a				
		_			nilar to concep	ts of			
	brain function								
Soft skills					al paradigms f				
			•	0	ven task. They				
	_		_		ency and risk. '				
	_	-	-	nt a smal	l project with s	state			
	of the art neur								
Contents					nets, Hopfield r	iets,			
	self organizing	- (, .	_					
	learning vector	_							
					ning, Q-learning	g,			
	support vector		_	_					
		-			on approximati	,			
	-	-			speech process	ing,			
	action plannin			_					
	_				re and software	e:			
	tools, simulate	ors, analog a	nd digital	neural ha	rdware.				
Prerequisites	none			. , .					
.	Teaching forms	at G	oup size	h/week	Workload[h]	CP			
Format	Lecture			2	30 T / 45 S	2.5			
	Exercises			2	30 T / 75 S	3.5			
	T = face-to-fa	ce teaching;	S = indep	endent st					
Exam achievements	Written exam				(gra	ded)			
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)			
Forms of media									
	• Christopher	-							
			rsity Pres	s, ISBN-1	0: 0198538642	,			
Literature	ISBN-13: 978-								
					ttern Recogniti	ion,			
	Springer, ISBN-10: 1852334401, ISBN-13: 978-1852334406								

Module MA-INF 4207	Dynamically Reconfigurable Systems						
Workload	Credit points	Duration	Freque	ncv			
180 h	6 CP	1 semeste	_	t every 2	vears		
Module	Prof. Dr. Joachim K. Anlauf						
coordinator							
Lecturer(s)	Prof. Dr. Joac	chim K. An	lauf				
GI 10 II	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optiona	1 2.			
Technical skills	Knowledge of	Knowledge of the most important FPGA architectures, ability					
	to select appro	o select appropriate FPGAs for a given application, overview of					
	programming	programming tools					
Soft skills	Communicativ	Communicative skills (oral and written presentation of					
	solutions), soc	solutions), social skills (ability to solve problems in small teams,					
	discussions of	solution co	ncepts) self	competer	nces (ability to)	
	accept and for	mulate crit	icism, abili	ty to anal	lyze problems)		
Contents	Architecture o	f FPGAs,	Configurabl	e Logic B	Blocks, Wiring		
	/ *		· ·		tion Language	s,	
	Synthesis, Tec	00	1 1		oute, FPGA		
	Computing, Pa	artial Reco	nfigurabilit	y			
Prerequisites	none						
	Teaching forms	at (Group size	h/week	Workload[h]	CP	
Format	Lecture			2	30 T / 45 S	2.5	
	Exercises			2	30 T / 75 S	3.5	
	T = face-to-fa	ce teaching	S = indep	endent st	tudy		
Exam achievements	Oral exam				(gra	ded)	
Study achievements	Successful exe	rcise partic	pation		(not gra	ded)	
Forms of media							
Literature	Current resear	ch papers	and technic	al docum	entation		

Module	Seminar Vi	sion Syste	ms				
MA-INF 4208	G 114 1 4	D 41					
Workload	Credit points 4 CP	Duration 1 semester	Frequency				
120 h		CP 1 semester every semester of. Dr. Sven Behnke					
Module	Prof. Dr. Svei	і Беппке					
coordinator	Doof Do Care	Dobreleo De	of Dn Io	a alaissa IV	Aralouf		
Lecturer(s)		Prof. Dr. Sven Behnke, Prof. Dr. Joachim K. Anlauf, Dr. Nils Goerke					
Classification	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optional	2. or 3	3.		
Technical skills	• Knowledge i	n advanced t	opics in the	ne area o	f technical vision	on	
	systems, such	as image seg	mentation	, feature	extraction, and	d	
	object recogni	tion.					
	• Ability to ur			-			
				ent them	in a research t	alk	
		s well as in a seminar report.					
Soft skills	Self-competen	`	_		,		
	self-study), communication skills (preparation and clear didactic						
	_		,		sion, structured		
	writing of sem	inar report),	social ski	lls (abilit	y to formulate	and	
	accept criticisi						
Contents					l journals in th	e	
	field of vision	systems cove	ring funda	mental t	echniques and		
	applications.						
Prerequisites	Recommended						
	At least 1 of the	_					
	MA-INF 4111		Learning	and Ana	lysis Systems:		
	Machine Learn	ning					
	MA-INF 4204	- Technical	Neural Ne	ts			
Format	Teaching forms	at G	oup size	h/week	Workload[h]	CP	
rormat	Seminar		10	2	30 T / 90 S	4	
	T = face-to-fa			endent st			
Exam achievements	Oral presentat	ion, written	report		· -	ided)	
Study achievements					(not gra	ided)	
Forms of media	200	~					
	• R. Szeliski: Computer Vision: Algorithms and Applications,						
	Springer 2010.						
Literature	• C. M. Bishop: Pattern Recognition and Machine Learning,						
	Springer 2006.		~	,			
				uter Visi	ion: A Modern		
	Approach, Prentice Hall, 2003.						

Module MA-INF 4209	Seminar Principles of Data Mining and Learning Algorithms						
Workload	Credit points	Duration	Freque	ncv			
120 h	4 CP	1 semeste	_	-			
Module	Prof. Dr. Stef		or cvery y				
coordinator	1101. D1. 5001	aii wiosci					
Lecturer(s)	Prof. Dr. Stefan Wrobel						
	Programme	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optiona				
Technical skills	•		-		zed topics in th	ie	
	area of machin	-	0	•	*		
		competence to independently study scientific literature, present					
	_	t to others and discuss it with a knowledgeable scientific					
	auditorium. L	auditorium. Learn how to scientifically present prior work by					
	others, in writing and in presentations.						
Soft skills	Communicative skills (preparing and presenting talks, written						
	presentation o	f contents i	n a longer	document), self compete	nces	
	(time manager	ment with l	ong-rangin	g deadline	es, ability to ac	cept	
	and formulate	criticism, a	bility to an	nalyse, cre	eativity).		
Contents	Theoretical, st	atistical an	d algorithn	nical prin	ciples of data		
	mining and lea	arning algor	ithms. Sea	rch and c	ptimization		
	algorithms. Sp	pecialized le	arning algo	orithms fr	om the frontier	of	
	research. Fund	damental re	sults from	neighbou	ring areas.		
Prerequisites	Recommended						
	At least 1 of t	he following	: :				
	MA-INF 4111	- Intelliger	t Learning	and Ana	lysis Systems:		
	Machine Learn	ning					
	MA-INF 4112	– Intelliger	t Learning	and Ana	lysis Systems:		
	Data Mining a	and Knowle	dge Discov	ery			
Б	Teaching forms	at (Group size	h/week	Workload[h]	CP	
Format	Seminar		10	2	30 T / 90 S	4	
	T = face-to-fa	ce teaching	S = inder	endent st	udv		
Exam achievements	Oral presentat					ded)	
Study achievements	_	,			(not gra		
Forms of media	Scientific pape	ers and web	sites, intera	active pre			
	* *				ards the end of	f the	
Literature	previous seme						

Module MA-INF 4210	Seminar Ad	lvanced	Topi	ics in '	Technica	al Informati	cs
Workload	Credit points	Duration		Engguer	2011		
120 h	4 CP						
Module	4 CP 1 semester at least every 2 years Prof. Dr. Joachim K. Anlauf						
coordinator	1 101. D1. 30ac	1 101. D1. Joaciniii IX. Ainaui					
	Duef Du Jees	Prof. Dr. Joachim K. Anlauf					
Lecturer(s)		min K. A					
Classification	Programme	, a .		Mode	Semest		
	M. Sc. Compu			_		3.	
Technical skills	_	Current Topics in Technical Informatics					
Soft skills		Communicative skills (preparing and presenting talks, preparing					
	a structured written document), social skills (ability to accept						
	and formulate	criticism,	discu	ussions	of current	content) self	
	competences (time mana	agem	ent with	n long-ran	nging deadlines	3,
	understanding	of research	ch top	pics from	n original	literature)	
Contents	Current topics	s such as:	new a	architec	tures of c	omputers or	
	FPGAs (field	programm	able	gate ar	rays) or n	ew application	s of
	dynamically re	econfigura	ble sy	ystems	,		
Prerequisites	none			<u> </u>			
	Teaching form	at	Grou	ıp size	h/week	Workload[h]	CP
Format	Seminar		-	10	2	30 T / 90 S	4
	T = face-to-fa	ce teachin	g; S	= indep	endent st	udy	
Exam achievements	Oral presentat	ion, writte	en re	port		(gra	ded)
Study achievements						(not gra	ded)
Forms of media						-	
Literature	Current resear	ch papers					

Module	Seminar Co	gnitive Ro	botics					
MA-INF 4211								
Workload	Credit points	Duration	Frequency					
120 h	4 CP	1 semester	er every semester					
Module	Prof. Dr. Sver	ı Behnke						
coordinator								
Lecturer(s)	Prof. Dr. Sven Behnke, Dr. Nils Goerke							
Classification	Programme		\mathbf{Mode}	Semes	ter			
Classification	M. Sc. Compu	ter Science	Optional	2. or 3	3.			
Technical skills	Knowledge in	advanced to	pics in the	area of o	cognitive robot:	ics,		
	such as robot	perception, a	action plan	ning, and	d robot learnin	g.		
	Ability to und	erstand new	research i	esults pro	esented in origi	inal		
	scientific paper			_	_			
	in a seminar re	_						
Soft skills		Self-competences (time management, literature search,						
	_	self-study), communication skills (preparation and clear didactic						
	- / :	presentation of research talk, scientific discussion, structured						
	writing of sem		*		*			
	accept criticism							
Contents	Current resear	<u> </u>				e		
	field of cogniti				-			
	applications.		O .		•			
Prerequisites	Recommended	:						
	At least 1 of the	he following:						
	MA-INF 4113	 Cognitive 	Robotics					
	MA-INF 4114	Ü						
	Teaching forma		oup size	h/week	Workload[h]	CP		
Format	Seminar		10	2	30 T / 90 S	4		
	T = face-to-fa	ce teaching:	S = indep	endent st	,	ı		
Exam achievements	Oral presentat					ded)		
Study achievements	1	, , , , , , , , , , , , , , , , , , , ,	<u> </u>		(not gra			
Forms of media					· · ·			
	• S. Thrun, W	. Burgard a	nd D. Fox	Probabi	listic Robotics			
i e e e e e e e e e e e e e e e e e e e	MIT Press, 2005.							
	MIT Press, 20	U3.						
Literature	,		Eds.): Spr	inger Ha	ndbook of			
Literature	MIT Press, 20 • B. Siciliano, Robotics, 2008	O. Khatib (Eds.): Spr	inger Ha	ndbook of			

Module	Humanoid	Robotics						
MA-INF 4215								
Workload	Credit points	Duration	Frequer	су				
180 h	6 CP	1 semester	at least	every 2	years			
Module	Prof. Dr. Mar	en Bennewit	Z					
coordinator								
Lecturer(s)	Prof. Dr. Mar	Prof. Dr. Maren Bennewitz						
Classification	Programme		Mode	Semest	ter			
Classification	M. Sc. Compu		Optional					
Technical skills	This lecture co	This lecture covers techniques for humanoid robots such as						
	perception, na	perception, navigation, and motion planning.						
Soft skills	Communicativ	Communicative skills (oral and written presentation of solutions,						
	discussions in	discussions in small teams), ability to analyze problems.						
Contents		elf-calibration with least squares, 3D environment						
	representation	s, self-localiz	ation with	particle	filters, footste	р		
	planning, inve	rse kinemati	es, whole-b	oody mot	ion planning w	$_{ m vith}$		
	rapidly explor	ing random t	rees, stati	stical tes	ting.			
Prerequisites	Recommended							
	MA-INF 4113	- Cognitive	Robotics					
	Teaching forms	at G	oup size	h/week	Workload[h]	CP		
Format	Lecture			2	30 T / 45 S	2.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-fa	ce teaching;	S = indep	endent st	tudy			
Exam achievements	Oral exam				(gra	ded)		
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)		
Forms of media								
	• S. Thrun, W	. Burgard a	nd D. Fox:	Probabi	listic Robotics			
	MIT Press, 2005.							
Literature	• B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics							
ынеганиге	• K. Harada, I	E. Yoshida, I	K. Yokoi (Eds.), Mo	otion Planning	for		
	Humanoid Ro	bots, Springe	er					
	• Selected rese	earch papers.						

Module MA-INF 4216	Data Minin Bioinformat		chine Le	arning]	Methods in			
Workload	Credit points	Duration	Freque	ncy				
180 h	6 CP	1 semeste	er every y	rear				
Module	Dr. Holger Frö	öhlich						
coordinator								
Lecturer(s)		Dr. Holger Fröhlich						
Classification	Programme M. Sa. Compu	tor Sajonao	Mode	Semest	ter			
Technical skills	M. Sc. Compu - understandin		_		al data mining	and		
recimieat skins	machine learni	_	_	mamemo	n dava mining	ana		
	- understanding of their application in bioinformatics							
Soft skills	- communication					to		
Soft Skills	exercises	on. orar an	a willoudi p		on or solutions			
	- self-competer	nces: ability	, to analyz	e annlicat	ion problems a	nd		
				с аррпсас	ion problems a	iia		
	to formulate possible solutions - practical skills: ability to practically implement solutions							
	- social skills:	· ·	-	-				
Contents	This lecture gi							
Contents					- 0			
	statistical techniques as well as data mining and machine learning algorithms. The use of the respective methods to solve							
	problems in bioinformatics is explained. The goal is to							
	understand the	e explained	methods,	being able	e to apply then	n		
	correctly and p	-	_					
	following topic		ed in the co	ontext of	their application	on in		
	bioinformatics:	:						
	- Short introdu	action to B	oinformati	cs and Bi	omedicine			
	- Statistical Ba				•			
	inference, stati				models, logisti	ic		
	regression, Pri	ncipal Com	ponent An	alysis				
	- Clustering							
	- Hidden Mark	ov Models						
	- Principles of	Supervised	Machine I	Learning				
	- Elastic Net							
	- Basics of dee	n learning						
Prerequisites	none	<u> </u>						
	Teaching forma	at (Group size	h/week	Workload[h]	СР		
Format	Lecture		-	2	30 T / 45 S	2.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-face	ce teaching	S = indep	endent st	udy			
Exam achievements	Written exam				(gra	ded)		
Study achievements	Successful exer	rcise partic	pation		(not gra	$\overline{\mathrm{ded}}$		
Forms of media								
	T. Hastie, R. 7	,		n, The El	ements of			
	Statistical Learning, Springer, 2008							
Literature	S.Boslaugh, P. Watters, Statistics in a Nutshell, O'Reilly, 2008							
	N. Jones, P. Pevzner, An Introduction to Bioinformatics Algorithms, MIT Press, 2004							

26.1.1	C	1 T		.	. 41 1	41 T :C-		
Module MA-INF 4217	Seminar Ma Sciences	acnine L	ear	ning M	etnoas	in the Life		
		D 4:		Б				
Workload 120 h	Credit points 4 CP	Duration		Frequer	-			
	4 CP 1 semester every year Dr. Holger Fröhlich							
Module coordinator	Dr. noiger Fre	DI. Holger Hollinen						
	Dr. Holger Frö	ihliah						
Lecturer(s)	Programme	DIIIICII		Mode	Semest			
Classification	M. Sc. Compu	ıter Scienc		Optional		ter		
Technical skills	- understandin	g and kno	owle	dge of m	achine lea	arning methods e.g. biomedicine		
Soft skills		communication: oral scientific presentation of a defined topic						
	_	oility to reability to	ead,	understa	nd and a	literature for a nalyze scientific pic with other		
Contents	Machine learning techniques play a crucial role in modern life sciences, including biomedicine. The goal of this seminar is to discuss a variety of machine learning techniques in the context of their application to solve real-world problems in biomedicine. Topics will be selected from the following areas:							
	- Ensemble lea	rning						
	- Survival and	disease p	rogr	ession m	odels			
	- Bayesian Net	works						
	- Stochastic pr Mixture Mode		e.g. (Gaussian	Proceses	, Dirichlet Process		
	- MCMC meth	nods						
	- Deep learning Networks	g methods	s, e.	g. DNNs	, CNNs, I	Deep Belief		
	- feature select	ion and n	on-l	inear em	bedding 1	methods		
	- multi-modal	data fusic	on te	echniques	;			
	Attendees will a self-responsil		_	erform r	esearch a	bout their topic in		
Prerequisites	Recommended MA-INF 4216 Bioinformatics	– Data M	Iinin	g and M	achine Le	earning Methods in		
D .	Teaching forms	at	Gro	oup size	h/week	Workload[h] CP		
Format	Seminar			10	2	30 T / 90 S 4		
	T = face-to-face	ce teachin	ıg: S	= indep	endent st	udv		
Exam achievements	Oral presentat					(graded)		
Study achievements	F1 00 0110 00 0	, ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		- I		(not graded)		
Forms of media	powerpoint					(10 11 10		
Literature	selected journa	al and con	fere	nce pape	rs			
				Pape				

Module MA-INF 4226	Lab Paralle	l Computi	ng for I	Mobile 1	Robotics			
Workload	Credit points	Duration	Freque	ncy				
270 h	9 CP	1 semester	at leas	at least every 2 years				
Module	Prof. Dr. Mar	en Bennewit	Z					
coordinator								
Lecturer(s)	Prof. Dr. Mar	en Bennewit	Z					
Classification	Programme		Mode	Semes	ster			
Classification	M. Sc. Compu	iter Science	Optiona	d 2.				
Technical skills	Students will a	make practic	al experie	ence with	the design and			
	implementatio	n of paralleli	zed algor	ithms in	the context of			
	motion planni	ng and navig	ation.					
Soft skills	Ability to prop	perly present	and defe	nd design	n decisions, to			
	prepare readal	ole document	ation of	software;	skills in			
	constructively	constructively collaborating with others in small teams over a						
	longer period	longer period of time; ability to classify ones own results into the						
	state-of-the-ar	state-of-the-art of the resp. area						
Contents	Parallel progra	amming on t	ne GPU,	CUDA, s	shortest path			
	planning, colli	sion checking	, visibilit	y graph,	A* algorithm			
Prerequisites	Recommended	:						
	C++, Linux.							
	Since the exer	cises revolve	around p	ath plani	ning, one of tho	se		
	courses might	be helpful:						
	MA-INF 4203	: Autonomoi	s Mobile	Systems				
	MA-INF 4113:	: Cognitive I	Robotics					
	MA-INF 4310:	: Lab Mobile	Robots					
_	Teaching forms	at Gro	oup size	h/week	Workload[h]	CP		
Format	Lab		8	4	60 T / 210 S	9		
	T = face-to-fa	ce teaching;	S = inder	pendent s	study	•		
Exam achievements	Oral presentat					ded)		
Study achievements					(not gra	$\overline{\operatorname{ded}}$		
Forms of media					· -	· · ·		
Literature								

Module MA-INF 4228	Foundations	s of Data S	Science				
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semester	r every year				
Module	Dr. Michael N	lüsken	'				
coordinator							
Lecturer(s)	Dr. Michael Nüsken						
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Computer Science Optional 2. or 3.						
Technical skills	Knowledge: P	eculiarities o	f high dir	nensional	spaces in geom	etry	
	and probabilit	ies. Singular	vector d	ecomposi	tion. Basics in		
	machine learn	ing and clust	ering.				
	Skills: Unders	tanding of m	athemati	cal tools.			
Soft skills					oblems and abi	lity	
	_	to assess similar methods.					
Contents	Data science aims at making sense of big data. To that end,						
	various tools have to be understood for helping in analyzing the						
	arising structures.						
	Often data comes as a collection of vectors with a large number of components. To understand their common structure is the						
	_			_	a. The geometr	У	
	and the linear	_					
					ensional space to	urns	
	out to be often	_					
		_		_	ces when working	ng	
	with such data				·		
	singular vector	-		_			
	_	-			ng. If time perm	,	
	we also consider random graphs, which are the second most used model for real world phenomena.						
Prerequisites	none	world pheno	mena.				
1 1010quibites	Teaching forms	at Gro	oup size	h/week	Workload[h]	CF	
Format	Lecture			4	60 T / 105 S	5.5	
	Exercises			2	30 T / 75 S	3.5	
	T = face-to-face teaching; $S = \text{independent study}$						
Even achievements	Schriftliche Pr		5 — mae	репцепь 8	gra (gra	ded	
Exam achievements Study achievements	Erfolgreiche Ü	0	me		(not gra		
Forms of media	Priorgreione O	Dangsteiman	1116		(not gra	acu	
rorms or media	Avrim Blum	John Hongro	ft and D	avindran	Kannan (2018+	_)	
Literature	Foundations o			avmutall	raillall (2010†	٦).	
	Froundations 0	ı Data Sciene	J C.				

Module MA-INF 4229	Pattern Rec	cognition	I				
Workload	Credit points	Duration	Freque	ncv			
270 h	9 CP	1 semester	every ye	-			
Module	Prof. Dr. Christ	tian Bauckha					
coordinator							
Lecturer(s)	Prof. Dr. Christ	tian Bauckha	ge				
	Programme		Mode	Semester			
Classification	M. Sc. Compute	er Science	Optional	2.			
Technical skills	Upon completio	n, students s	hould be a	ble to			
	clustering, and o	se mathematical models for problems in data analysis, ing, and classification ement basic and advanced algorithms for model fitting and					
		sic and advar	iced aigori	unins for in	oder mung and		
	optimization • implement base classification						
G 6: 1.11	• implement bas					n	
Soft skills	Students will leafoundations of n					1	
	learn about basi		_		•		
	to implement th	to implement them on their own, and how to put them into practice.					
Contents	• fundamental c	concepts, prei	equisites,	and proced	ures in pattern		
	recognition						
	• basic and adva	_		_			
	• basic and adva				ry and statistics	3	
	• least squares t			ting			
	• maximum like		-				
	• maximum a-po						
	Bayesian infer			1.1	17C 1: :		
	• fundamental a	-	_	ry and the	VC dimension		
	• the curse of di			at anim m			
	methods and aGaussian mixt		r data cius	stering			
	• the method of		ultipliora e	and the KK	T conditions		
	• quadratic and				1 conditions		
	• algorithms for						
	• support vector		opumizau	1011			
	• the kernel tric						
	• neural network						
	• Hebbian learn						
Prerequisites	Recommended:						
Troroquisios	Students should		g knowled	lge in linear	algebra, probal	oility	
	theory, and stat						
	Teaching forma		roup size	h/week	Workload[h]	CP	
Format	Lecture		•	4	60 T / 105 S	5.5	
	Exercises			2	30 T / 75 S	3.5	
	T = face-to-face	teaching S	= indepen	dent study	,	1	
Exam achievements	Schriftliche Prüf		macpen	idoni biudy	(or:	aded)	
Study achievements	Erfolgreiche Üb	~	e		(not gra		
Forms of media	• lecture slides a			ne	(1100 816		
_ 511110 51 1110414	• lecture notes v				ade available or	ıline	
	Bishop, "Pattern						
Literature	Duda, Stork, Ha	_			S		
Diveracure					maina Almanith	a"	
	MacKay, "Inform	nation 1 neor	y, mereno	e, and Lea	ming Algorithm	.S	

Module	Advanced Methods	of Inform	ation R	etrieval		
MA-INF 4230						
Workload	Credit points Duration	_	-			
180 h	6 CP 1 semes	0 0	ear			
Module	Prof. Dr. Elena Demido	ova				
coordinator						
Lecturer(s)	Prof. Dr. Elena Demido					
Classification	Programme	Mode	Semest			
	M. Sc. Computer Science	_	I		,	
Technical skills	This module introduces data structures, and alg structured and semi-str knowledge graphs, relat	gorithms of in uctured data	nformation (includin	n retrieval for g, for example,		
	At the end of the modu choosing appropriate da	ata structures	and retri	ieval algorithm		
	specific applications and machine learning-based				and	
Soft skills	Communication skills: discussion of solutions.	oral and writ	ten preser	ntation and		
	Self-competences: ability to analyse and solve problems.					
Contents	The module topics include data structures, ranking methods, and efficient algorithms that enable end-users to effectively obtain the most relevant search results from structured, heterogeneous, and distributed data sources. Furthermore, we will study the corresponding evaluation techniques as well as novel applications.					
Prerequisites	none					
Trorequisites	Teaching format	Group size	h/week	Workload[h]	CP	
Format	Lecture	1	2	30 T / 45 S	2.5	
	Exercises		2	30 T / 75 S	3.5	
	T = face-to-face teachir	$\operatorname{ag} S = \operatorname{inder}$	endent st		ı	
Exam achievements	Schriftliche Prüfung	$\log_{10} D = \mathrm{Indep}$	CHacht St		ded)	
Study achievements	Erfolgreiche Übungsteil:	nahme		(not gra		
Forms of media	Errorgreiene Obungstein			(not gra	ucu)	
Torms or media	Selected chapters from:					
	 Christopher D. Manna Schütze, Introduction to University Press. 2008. Bhaskar Mitra and Na Neural Information Ret Information Retrieval: 	ing, Prabhak o Information ick Craswell crieval ", Four	Retrieva (2018), "A ndations a	l, Cambridge An Introduction and Trendső in		
Literature	- Ridho Reinanda, Edga "Knowledge Graphs: An Foundations and Trends 4, pp 289-444.	n Information	n Retrieva	l Perspective",		
	- Jeffrey Xu Yu, Lu Qir Databases. Synthesis Lo Claypool Publishers. 20	ectures on Da			ın &	
	Further references to rethe lecture.	levant materi	al will be	provided duri	ng	

Module MA-INF 4231	Seminar Ad	lvanced T	opics in l	Informa	tion Retriev	val		
Workload	Credit points	Duration	Frequer	ıcy				
120 h	4 CP	1 semeste	r every year					
Module coordinator	Prof. Dr. Eler	na Demidova	l					
Lecturer(s)	Prof. Dr. Elen	na Demidovs	<u> </u>					
Decturer(s)	Programme	la Demidova	Mode	Semest	tor			
Classification	M. Sc. Compu	Optional						
Technical skills	This module c		-			n .		
recimical skins	retrieval. The							
					-	-		
	study of state-			-	,			
	discussion with audience.	n their peer	s and prese	mation t	o the scientific			
C (4 1 11	Communication skills: oral and written presentation of scientific							
Soft skills		content. Self-competences: the ability to analyze problems, time						
	management,		, 1	1				
Contents	Statistical and		_					
	methods, inclu		-					
	process: data							
	ranking, and e		_	_				
	retrieval methor	ods for selec	ted data t	ypes and	applications in	1		
	specific domain	ns.						
Prerequisites	Recommended	:						
	MA-INF 4230	- Advanced	Methods of	of Informa	ation Retrieval	l		
D .	Teaching forms	at G	roup size	h/week	Workload[h]	CP		
Format	Seminar		10	2	30 T / 90 S	4		
	T = face-to-fa	ce teaching:	S = inden	endent st	udv	1		
Exam achievements	Oral presentat			CHACHO SC		ided)		
Study achievements	None	Jon, wilden	Teport		(not gra			
Forms of media	None				(Hot gra	idea)		
Forms of media	C-141 -14	C						
	Selected chapters from:							
	• Christopher D. Manning, Prabhakar Raghavan and Hinrich							
	• Christopher	D. Maiiiiii	5, 1 rabitate			/11		
	Schütze, Intro	•	• •	_		.11		
	-	duction to I	• •	_		.11		
Literature	Schütze, Întro	duction to I ess. 2008.	nformation	Retrieva	l, Cambridge			
Literature	Schütze, İntro University Pre	duction to I ess. 2008. era and Nick	nformation Craswell (Retrieva (2018), "A	l, Cambridge An Introduction	n to		
Literature	Schütze, Introd University Pre • Bhaskar Mit	duction to I ess. 2008. era and Nick ation Retrie	nformation Craswell (val ", Four	Retrieva (2018), "Adations a	d, Cambridge An Introduction and Trendső in	n to		
Literature	Schütze, Intro- University Pre • Bhaskar Mit Neural Inform	duction to I ess. 2008. era and Nick ation Retrie etrieval: Vo	nformation Craswell (val ", Four l. 13: No.	Retrieva (2018), "Adations a 1, pp 1-1:	d, Cambridge An Introduction and Trendső in 26.	n to		

Module	Lab Informa	ation Retri	eval in	Practio	ce		
MA-INF 4232	G 111	D					
Workload	Credit points	Duration	_	Frequency			
270 h	9 CP	1 semester	0 0				
Module	Prof. Dr. Elen	ia Demidova					
coordinator	D C D EI	D 11					
Lecturer(s)	Prof. Dr. Elen	na Demidova		T ~			
Classification	Programme		Mode Optional	$\begin{array}{c c} & \mathbf{Seme} \\ 1 & 2. \text{ or} \end{array}$			
	M. Sc. Compu						
Technical skills	retrieval. Part experience in o systems for sp	This module concentrates on practical experience in information retrieval. Participants acquire basic knowledge and practical experience in designing and implementing information retrieval systems for specific data types and applications.					
Soft skills	Communication	on skills: the a	ability to	work in	teams.		
	Self-competences: the ability to analyse problems and find practical solutions. Time management, creativity, presentation of results.						
Contents	Practical application of information retrieval methods to solve retrieval problems on real-world data and evaluate proposed solutions.						
Prerequisites	Recommended MA-INF 4230	-	Methods	of Inforn	nation Retrieva	1	
	MA-INF 4231 Retrieval	- Seminar Ac	lvanced T	Topics in	Information		
	Teaching forma	at Gro	up size	h/week	Workload[h]	CP	
Format	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching: S	S — inder	endent s	study	I	
Exam achievements	Oral presentat			, ciracire i	-	aded)	
Study achievements	None	MOII, WIIOCCII I	Срого		(not gra		
Forms of media	1.0110				(1100 810		
2 01 1110 01 1110010	Selected chapt	ers from:					
Selected chapters from: • Christopher D. Manning, Prabhakar Raghavan and Hi Schütze, Introduction to Information Retrieval, Cambrid University Press. 2008. • Bhaskar Mitra and Nick Craswell (2018), "An Introduction Retrieval Information Retrieval", Foundations and Trendson Information Retrieval: Vol. 13: No. 1, pp 1-126.					al, Cambridge An Introductio and Trendső in 126.	on to	
	the lab.	nces to releva	пі шатег	iai WIII D	e provided dur	шg	

Module	Advanced L	earning S	systems					
MA-INF 4302		J						
Workload	Credit points	Duration	Freque	ncy				
180 h	6 CP	1 semeste	r every 2	2 years				
Module	Prof. Dr. Stef	an Wrobel	1					
coordinator								
Lecturer(s)	Prof. Dr. Stef	an Wrobel						
Classification	Programme		Mode	Semes	ter			
Classification	M. Sc. Compu	iter Science	Optiona	1 2. or 3	3.			
Technical skills	Participants sp		•	•	O	ıe		
	particular clas			, .	-			
	necessary know	_	-	0 0		_		
	construct their		_	ı class, all	the way up to	the		
~	research fronti		_		. 1 1			
Soft skills	In group work	•	-					
	communication							
	- 0,	llanning, and learn how to present software projects to others. The module each time concentrates on one or more specific						
Contents			icentrates	on one or	more specific			
	algorithm classes, e.g.							
	• kernel machines							
	• neural networks							
	probabilistic and statistical learning approacheslogic-based learning approaches							
	_		roaches					
T	• reinforcemen							
Prerequisites	Recommended all of the follow							
	MA-INF 4111 Machine Learn	_	t Learning	and Ana	lysis Systems:			
	MA-INF 4112	0	t Learning	and Ana	lycic Systems			
	Data Mining a	_	_		iysis bystems.			
	Teaching forms		roup size	h/week	Workload[h]	СР		
Format	Lecture	10	Toup Size	· '	30 T / 45 S	2.5		
Torrido	Exercises			$\frac{2}{2}$	30 T / 75 S	3.5		
	T = face-to-fa	ao tonahina	S — indo	l oondont st	,			
Exam achievements	Written exam	ce teaching	5 – maer	Jendent st		ided)		
Study achievements	Successful exer	rcisa partici	nation		(not gra			
Forms of media	lectures, exerc				(Hot gra	ided)		
Torms or media				ng with K	ernels The M	ſТ		
	• B. Schoelkopf, A.J. Smola, Learning with Kernels, The MIT Press, 2002, Cambridge, MA							
	• John Shawe-Taylor, Nello Christianini, Kernel Methods for							
	Pattern Analysis, CUP, 2004							
	• Christopher Bishop, Pattern Recognition and Machine							
Literature	Learning, The			_				
		_			nce, and Learni	ing		
	Algorithms, 20			- /	•	_		
	• Richard Duc		art, David	Stork, Pa	ttern			
	Classification,		• ~					

Module MA-INF 4303	Learning fro	om Non-S	tandard	Data					
Workload	Credit points	Duration	Freque	ncy					
180 h	6 CP	1 semeste	r every y	vear					
Module	Prof. Dr. Stef	an Wrobel							
coordinator									
Lecturer(s)	Prof. Dr. Stefa	an Wrobel,	Dr. Tamas	s Horvath					
Classification	Programme		Mode	Semest	ter				
Classification	M. Sc. Compu		_						
Technical skills	Participants de	-	_		0 0	h			
	respect to one	-							
	non-tabular da	,		_		ant			
		n many applications. Each type of data not only requires							
		specialized algorithms but also knowledge of the surrounding							
		pre- and postprocessing operations which is acquired by the participants in the module. In group work, students acquire the necessary social and communication skills for effective team							
	work and project					ro.			
	projects to oth	_	, and lear	n now to	present sortwar	е			
Soft skills			l and writ:	ten presen	tation of solut	ions			
SOIT SKIIIS		Communicative skills (oral and written presentation of solutions, liscussions in teams), self-competences (ability to accept and							
	formulate criti	, ,	_	`					
	of an "open en			,					
Contents	The module w		verv vear,	concentra	ting on one				
	particular non-		,		_	t			
	Mining, Multin	media Mini	ig, Graph	Mining. I	Learning from				
	structured dat	a, Spatial I	ata Minin	g					
Prerequisites	Recommended								
	all of the follow	wing:							
	MA-INF 4111	- Intelligen	t Learning	and Ana	lysis Systems:				
	Machine Learr	ning							
	MA-INF 4112	- Intelligen	t Learning	and Ana	lysis Systems:				
	Data Mining a	and Knowle	lge Discov	ery					
	Teaching forms	at C	roup size	h/week	Workload[h]	CP			
Format	Lecture			2	30 T / 45 S	2.5			
	Exercises			2	30 T / 75 S	3.5			
	T = face-to-fa	ce teaching	S = indep	pendent st	udy				
Exam achievements	Written exam					ded)			
Study achievements	Successful exer				(not gra	ded)			
Forms of media	lectures, exerc								
	• Gennady Andrienko, Natalia Andrienko, Exploratory Analysis								
	of Spatial and Temporal Data, Springer, 2006								
	• Diane J. Cook, Lawrence B. Holder, Mining Graph Data,								
T.*/	Wiley & Sons, 2006 • Saso Dzeroski, Nada Lavrac, Relational Data Mining,								
Literature			vrac, Kela	попаг Dat	a wiming,				
	Springer, 2001 • Sholom M. V		Indurkhy	Tong 71	nang Frad I				
	Damerau, Tex		_	-					
	Unstructured 1	_			or rinary 2111g				
	Onsuluciared.	inioi maudil	, springer,	2004					

Module	Lab Cognit	ive Roboti	cs					
MA-INF 4304								
Workload	Credit points	Duration	Freque					
270 h	9 CP	1 semester	r every semester					
Module	Prof. Dr. Svei	n Behnke						
coordinator								
Lecturer(s)	Prof. Dr. Svei	n Behnke	Γ					
Classification	Programme		Mode	Seme				
	M. Sc. Compu		Optiona					
Technical skills	Participants a		_		_	-		
		_	-		of perception a	and		
	control algorit		_	-				
	group, they ar				e-of-the-art			
G 0: 1:11	solution, and				• 4 1 1 1	•1•4		
Soft skills	_	*	_	. –	iented work, ab	omty		
	to analyze problems and to find practical solutions),							
		communication skills (Work together in small teams, oral and						
	written presentation of solutions, critical examination of implementations)							
Contents	_	Robot middleware (ROS), simultaneous localization and						
Contents	mapping (SLA							
	,	,		_	on, person dete	ction		
		-		_	ning and contro			
	mobile manipi					,		
Prerequisites	Recommended	:						
	At least 1 of t	he following:						
	MA-INF 4113	- Cognitive	Robotics					
	MA-INF 4114	- Robot Lea	rning					
T	Teaching forms	at Gre	oup size	h/week	Workload[h]	CP		
Format	Lab		8	4	60 T / 210 S	9		
	T = face-to-fa	ce teaching;	S = indep	endent s	study			
Exam achievements	Oral presentat					aded)		
Study achievements					(not gra	aded)		
Forms of media								
	,	0	nd D. Fox	: Probab	oilistic Robotics	s		
	MIT Press, 2005.							
Literature	• B. Siciliano,	,	Eds.): Spi	ringer Ha	andbook of			
	Robotics, 2008							
	• Selected rese	earch papers.						

Module	1	_		cation o	f Data Mini	ng	
MA-INF 4306	and Learnin						
Workload	Credit points	Duration	Freque	-			
270 h	9 CP	1 semester	every	year			
Module	Prof. Dr. Stef	an Wrobel					
coordinator							
Lecturer(s)	Prof. Dr. Stef	an Wrobel					
Classification	Programme		Mode	Seme	ster		
	M. Sc. Computer Science Optional 3.						
Technical skills		•	•	0	the constructio		
	_		•		ms for machine		
	_	_			o work with exi	sting	
	state-of-the-ar	t systems ar	d apply t	hem to a	pplication		
		-	g them for	or the rec	quirements of the	ıeir	
	particular tasl	ζ.					
Soft skills	Communicativ	ve skills (app	ropriate o	oral prese	entation and wr	itten	
	documentation of project results), social skills (ability to work in teams), self-competences (time management, aiming at						
	long-range goa	als under lim	ited resso	ources, ab	ility to work u	nder	
	pressure, ability to accept/formulate ciriticsm)						
Contents	Data storage and process models of data analysis. Common						
	open source frameworks for the construction of data analysis						
	systems, specialized statistical packages. Pre-processing tools.						
	Mathematical	libraries for	numerica	l comput	ation. Search a	nd	
	optimization methods. User interfaces and visualization for						
	analysis system	ms. Data an	alysis algo	orithms for	or embedded ar	id	
	distributed sys	stems. Ubiqu	itous dis	covery sy	stems.		
Prerequisites	Recommended	l:					
	At least 1 of t	he following:					
	MA-INF 4111	– Intelligent	Learning	and Ana	alysis Systems:		
	Machine Learn	_		,			
	MA-INF 4112 – Intelligent Learning and Analysis Systems:						
	Data Mining a	0		•	arysis bystems.		
	Teaching form		oup size	h/week	Workload[h]	СР	
Format	Lab	at GI	8	4	60 T / 210 S	$\frac{GI}{9}$	
			ı	_		9	
	T = face-to-fa			pendent s			
Exam achievements	Oral presentat	tion, written	report		,-	aded)	
Study achievements					(not gra	aded)	
Forms of media	Computer Sof	· · · · · · · · · · · · · · · · · · ·		*			
Literature			l be anno	unced to	wards the end of	of the	
Literature	previous seme	ster.					

Module MA-INF 4307	Lab Field P	rogramm	able Ga	te Arra	ys	
Workload	Credit points	Duration	Freque	ancv		
270 h	9 CP	1 semeste	_	st every 2	vears	
Module	Prof. Dr. Joac		l l	<u> </u>	J COLIS	
coordinator	1101. 11. 0000	AIIIII 11. 21II	aar			
Lecturer(s)	Prof. Dr. Joac	him K. An	auf			
	Programme	Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Option	al 2. or	3.	
Technical skills	•		_		ts in VHDL and	<u>l</u>
	_		0		ets, knowledge	
	, .		•		ircuit implemen	
	in an FPGA (f				-	
Soft skills	Communicativ	e skills (or	l and wri	tten prese	entation of resul	lts),
	social skills (al	bility to co	perate in	small tea	ms, discussions	of
	solution conce	pts) self co	npetences	(ability t	o accept and	
	formulate criti	cism, abilit	y to analy	ze and fir	nd practical	
	solutions to pr	oblems)				
Contents	VHDL for Har	dware Des	ription, S	imulation	, and Synthesis	,
	SystemC for H	Iardware D	escription	, Simulati	on, and Synthes	sis,
	Synthesizable	Subsets, Te	st of Impl	ementation	ons on FPGA	
	Evaluation Bo	ards				
Prerequisites	Recommended	:				
	MA-INF 4207	- Dynamic	ally Recor	ıfigurable	Systems	
Format	Teaching forma	at G	oup size	h/week	Workload[h]	CP
Format	Lab		8	4	60 T / 210 S	9
	T = face-to-fa	ce teaching	S = inde	ependent s	study	
Exam achievements	Oral presentat	ion, writter	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
Literature	Technical docu	imentation				

Module MA-INF 4308	Lab Vision	Systems							
Workload	Credit points	Duration	Freque	ency					
270 h	9 CP	1 semester	every semester						
Module	Prof. Dr. Sver	n Behnke							
coordinator									
Lecturer(s)	Dr. Nils Goerl	ke							
Classification	Programme		Mode	Seme	ster				
Classification	M. Sc. Computer Science Optional 3.								
Technical skills	Students will a	acquire knov	ledge of	the design	n and				
	implementatio	n of parallel	algorithm	ns on GP	Us. They will a	pply			
	these techniqu	es to acceler	ate stand	lard mach	ine learning				
	algorithms for	data-intens	ve compu	iter visior	ı tasks.				
Soft skills	_	•	_	. –	iented work, ab	ility			
	to analyze pro		_		, ,				
		communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of							
	_								
	_	implementations)							
Contents		Basic matrix and vector computations with GPUs (CUDA).							
	Classification	,							
	support-vector			_	,				
	linear-discrimi		_		_				
	handling. Qua								
	algorithms for		n and ca	tegorizati	on.				
Prerequisites	Recommended	-							
	At least 1 of t								
		_	Learning	g and Ana	alysis Systems:				
	Machine Learn	ning							
	MA-INF 4204	- Technical	Neural N	lets					
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP			
Format	Lab		8	4	60 T / 210 S	9			
	T = face-to-fa	ce teaching;	S = inde	pendent s	study				
Exam achievements	Oral presentat	ion, written	report		(gra	ided)			
Study achievements					(not gra	ided)			
Forms of media					, 9				
	• R. Szeliski:	Computer V	ision: Alg	gorithms	and Application	ns,			
	Springer 2010.								
Literature	• C. M. Bisho	p: Pattern I	ecognitic	on and Ma	achine Learning	·,			
	Springer 2006.								
	• NVidia CUI	OA Program	ning Gui	de, Versic	on 4.0, 2011.				

Module	Lab Sensor Data Interpretation						
MA-INF 4309							
Workload	Credit points	Duration	Frequ	ency			
270 h	9 CP	1 semest	er at lea	st every 2	years		
Module	PD. Dr. Volke	r Steinhag	e				
coordinator							
Lecturer(s)	PD. Dr. Volke	PD. Dr. Volker Steinhage					
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	M. Sc. Computer Science Optional 2. or 3.					
Technical skills	Competence to	Competence to implement algorithms for sensor data					
	interpretation,	interpretation, efficient handling and testing, documentation.					
Soft skills	Efficient implementation of complex algorithms, abstract						
	thinking, docu	thinking, documentation of source code.					
Contents	Varying select	ed up-to-da	ate topics	on sensor	data interpreta	tion	
Prerequisites	Required:						
	All of the follo	owing:					
	MA-INF 2201	- Comput	er Vision				
	MA-INF 4206	- Selected	Topics in	Sensor Da	ata Interpretatio	on	
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
Format	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching	g; S = inde	ependent s	study		
Exam achievements	Oral presentat	ion, writte	n report		(gra	ded)	
Study achievements					(not gra	ded	
Forms of media							
Literature	Relevant litera	ture will b	e annound	ed at star	t of the lab.		

Module	Lab Mobile	Robots	<u> </u>						
MA-INF 4310	Lab Woone	100000	•						
Workload	Credit points	Duration	1	Freque	encv				
270 h	9 CP	1 semes		_	st every y	ear			
Module	Prof. Dr. Svei		,,,,,		, , , , , , , , , , , , , , , , , , ,				
coordinator	2101. 21. 2.01								
Lecturer(s)	Prof. Dr. Sver	n Behnke,	Dr.	Nils G	oerke				
	Programme	,		Mode	Seme	ster			
Classification	M. Sc. Compu	iter Scienc	ce (Option	al 2. or	3.			
Technical skills	Participants a	cquire bas	sic kr	owledg	ge and pra	actical experience	in		
	the design and	l impleme	ntati	on of c	ontrol alg	orithms for simple	.e		
	structured rob	otic syste	ms u	sing re	al mobile	robots.			
	Fundamental j	paradigms	s for	mobile	robots w	ill be identified an	nd		
	implemented i	n 2 persoi	n gro	ups.					
Soft skills	_	•		_	. –	iented work, abilit	ty		
	to analyze pro			_		, ,			
		,		_		l teams, oral and			
	written presen		solut	ions, cı	ritical exa	mination of			
~	_	mplementations) Robot middleware (e.g. ROS), robot simulation tools, basic							
Contents		, –		* *					
	capabilities for					,			
	architecture, n	_	_	_		M), visual based			
					- \	ivi), visuai based			
Prerequisites	Recommended	object detection, learning robot control.							
Trerequisites	At least 1 of t		ng:						
	BA-INF 132 –		_	er Rob	otik				
		•	_						
	BA-INF 131 -								
	MA-INF 1314				nnıng				
	MA-INF 2201	– Compu	iter V	ision					
	MA-INF 4113	- Cogniti	ive R	obotics	3				
	MA-INF 4114	- Robot I	Learı	ning					
	MA-INF 4203	- Autono	mous	s Mobi	le System	S			
	Teaching forms			p size	h/week		$\overline{\mathbf{CP}}$		
Format	Lab			3	4	60 T / 210 S	9		
	T = face-to-fa	ce teachin	ng: S	= inde	pendent s	study			
Exam achievements	Oral presentat				I	(grade	$\overline{\mathrm{ed}}$		
Study achievements	1	,		1		(not grade			
Forms of media	Robots simula	tion envir	onmo	ents, ro	bot contr	ol middleware,			
	computer vision	on librarie	s, pro	ogramr	ning, dem	onstration of robo	ot		
	capabilities (re	eal robotic	c syst	extra cents), extra cents	presentati	on and written			
	report of appr								
			$\frac{1}{2}$	D. For	x: Probab	oilistic Robotics.			
	MIT Press, 20				_				
						ence, Published by	V		
Literature	Advanced Rob					_			
	B. Siciliano,		b (Eo	is.): Sp	oringer Ha	andbook of			
	Robotics, 2008			1 1.					
	• Additional State-of-the-art publications.								

Module MA-INF 4312	Semantic D	Semantic Data Web Technologies					
Workload	Credit points	Duration	Freque	ncy			
180 h	6 CP	1 semeste	r every year				
Module coordinator	Prof. Dr. Jens	s Lehmann					
Lecturer(s)	Prof. Dr. Jens Dr. Maria Ma	,	Dr. Christ	oph Lang	çe,		
Classification	Programme M. Sc. Compu	iter Science	Mode Optiona	Semest	ter		
Technical skills	The goal of this lecture is to impart knowledge on the fundamentals, technologies and applications of the Semantic Web and information retrieval. As part of the lecture the basic concepts and standards for semantic technologies are explained.						
Soft skills							
Contents	technologies had of data, inform standards and applications are projects (e.g. applications surfreebase). The practically oried discussed with RDF syntax • RDF Schemate • ontologies in • RDF database	As part of the W3C Semantic Web initiative standards and technologies have been developed for machine-readable exchange of data, information and knowledge on the Web. These standards and technologies are increasingly being used in applications and have already led to a number of exciting projects (e.g. DBpedia, semantic wiki or commercial applications such as schema.org, OpenCalais, or Google's Freebase). The module provides a theoretically grounded and practically oriented introduction to this area. The topics discussed within the lecture include: • RDF syntax and data model • RDF Schema and formal semantics of RDF (S) • ontologies in OWL and formal semantics of OWL • RDF databases, triple and knowledge stores, query languages • Linked Data Web and Semantic Web applications					
Prerequisites	none				T		
Format	Teaching forms Lecture Exercises T = face-to-fa		roup size	h/week 2 2 2 pendent st	Workload[h] 30 T / 45 S 30 T / 75 S	2.5 3.5	
T	T = face-to-fa	ce teaching;	s = mdep	enaent st		1 1\	
Exam achievements	Written exam					$\frac{\operatorname{ded}}{\operatorname{ded}}$	
Study achievements	Successful exe	rcise partici	pation		(not gra	aea)	
Forms of media							
Literature							

Module	Seminar Semantic Data Web Technologies							
MA-INF 4313								
Workload	Credit points	Duration	ı	Frequer	\mathbf{cy}			
120 h	4 CP	1 semes	ter	r at least every year				
Module	Prof. Dr. Jens	s Lehmann	n					
coordinator								
Lecturer(s)	Dr. Christoph Lange, Dr. Maria Maleshkova							
Classification	Programme		N	Mode	Semest	ter		
Classification	M. Sc. Compu	M. Sc. Computer Science Optional 2.						
Technical skills	Through the s	Through the seminar, students will learn to work with tools and						
	technologies of	technologies of the Semantic Web as well as assess their						
	capabilities for given problems. They will gain the ability to							
	understand ne	understand new research results presented in original scientific						
	papers.	papers.						
Soft skills	Ability to pres	sent and to	o crit	ically d	iscuss tecl	hnologies and		
	research result	s in the fr	ramev	work of	Semantic	Web technolog	gies.	
Contents	• technologies	such as tr	riple	stores, 1	ink discov	very framework	ĸs,	
	NLP pipelines							
	• recent confer	rence and	jourr	nal pape	ers			
Prerequisites	none							
Format	Teaching forms	at	Grou	up size	h/week	Workload[h]	CP	
Format	Seminar			10	2	30 T / 90 S	4	
	T = face-to-fa	ce teachin	ıg; S	= indep	endent st	udy		
Exam achievements	Oral presentat	ion, writte	en re	port		(gra	ded)	
Study achievements						(not gra	ded)	
Forms of media								
Literature								

Module MA-INF 4314	Lab Semantic Data Web Technologies									
Workload	Credit points	Duration	Frequ	ency						
270 h	9 CP	9 CP 1 semester every year								
Module	Prof. Dr. Jens	Prof. Dr. Jens Lehmann								
coordinator										
Lecturer(s)	Prof. Dr. Jens	Lehmann,	Dr. Mari	a Malesch	nkova					
Classification	Programme		Mode	Seme	ester					
Classification	M. Sc. Compu	iter Science	Option	al 2.						
Technical skills	The students	The students will carry out a practical task (project) in the								
	context of Sen	context of Semantic Web technologies, including test and								
	documentation	n of the imp	lemented	software	/system.					
Soft skills	Ability to prop	perly preser	t and def	end design	n decisions, to					
	prepare readal	ole docume	ntation of	software;	skills in					
	constructively	collaborati	ng with o	thers in s	mall teams over	a				
	longer period	of time; abi	lity to cla	ssify own	results with reg	gard				
	to the state-of	the-art								
Contents										
Prerequisites	none									
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP				
rormat	Lab		8	4	60 T / 210 S	9				
	T = face-to-fa	ce teaching	S = inde	ependent :	study					
Exam achievements	Oral presentat	ion, writter	report		(gra	ided)				
Study achievements					(not gra	ided)				
Forms of media										
Literature										

Module MA-INF 4316	Graph Representat	tion Learn	ing					
Workload	Credit points Duration Frequency							
180 h	6 CP 1 semes	ter at least	every 2 year	ars				
Module	Dr. Pascal Welke							
coordinator								
Lecturer(s)	Dr. Pascal Welke							
Classification	Programme M. Sc. Computer Science	Mode Optional	Semester 1.					
Technical skills	• Deep understanding of representation and compo- runtime of algorithms in	 Deep understanding of the trade-off between expressiveness of graph representation and computational complexity, as well as practical runtime of algorithms in the context of machine learning applications. Ability to implement, practically apply, and theoretically analyze 						
Soft skills	 Social, methodological, communication, own deve formulations, algorithms, Learning to solve proje 	 Social, methodological, and analytical competences via communication, own development, and presentation of problem formulations, algorithms, and solutions. Learning to solve project tasks in a group. Learning to evaluate the trade-offs and limitations of existing 						
Contents	We will discuss general a graph structured data. In representation learning su	particular, c	omputation	al methods for g				
	kernels, as well as graph mining techniques will be discussed, analyzed, and applied. Regarding GNNs and graph kernels, we will discuss the expressive power and how these concepts are related, as well as several specific examples. In the area of graph mining, we will likely investigate fast (approximate) algorithms to count small patterns, such as triangles, or trees.							
	If time permits, we might venture into the realm of ranking on large-scale graphs, with applications such as recommender systems. The exercises will focus on practical implementations and the application of these methods to real world examples.							
Prerequisites	Recommended: Helpful: one or more of t MA-INF 4111 – Intellig Learning MA-INF 4112 – Intellig Mining and Knowledge D	ent Learning	v	•				
	• MA-INF 4212 – Data Science and Big Data							
	• MA-INF 1105 - Algorit							
	• MA-INF 1102 - Combin							
	Teaching format	Group size	h/week	Workload[h]	CP			
Format	Lecture		2	30 T / 45 S	2.5			
	Exercises		2	30 T / 75 S	3.5			
	T = face-to-face teaching	S = Independent	ident study					
Exam achievements	Oral exam or written exa		<u>J</u>	(gra	aded)			
Study achievements	Successful exercise partic			(not gra				
Forms of media	• Lecture slides	-		, 3	/			
	• Jupyter notebooks							
Literature	 William L. Hamilton: Graph Representation Learning, Synthesis Lectures on Artificial Intelligence and Machine Learning, Morgan and Claypool. Nils M. Kriege, Fredrik D. Johansson, Christopher Morris: A survey on 							
Differentife	graph kernels, Applied N	etwork Science	e 5(1):6.					
	• Karsten M. Borgwardt,		` /	al.: Graph Kern	els:			
				_				
	State-of-the-Art and Futu	_	s, roundatio	ons and trends	111			
	Machine Learning 13(5-6).							

Module MA-INF 4318	Seminar Representation Learning for Big Data Analytics						
Workload	Credit points Duration Frequency						
120 h	4 CP 1 semester every year						
Module	Prof. Dr. Emmanuel Müller						
coordinator							
Lecturer(s)	Prof. Dr. Emmanuel Müller						
CI :C ::	Programme Mode Semester						
Classification	M. Sc. Computer Science Optional 2. or 3.						
Technical skills	Ability to understand new research results presented in original scientific papers.						
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.						
Contents	Smart representations (such as embeddings, kernels, and dimensionality reduction methods) are useful models that allow the abstraction of data within a well-defined mathematical formalism. The representations we aim at are conceptual abstractions of real world phenomena (such as social interactions, chemical reactions and biological processes) into the world of statistics and discrete mathematics in such a way that the powerful tools developed in those areas are available for complex analyses in a simple and elegant manner. The focus will be the understanding and comparison of smart representations and their explicit/implicit data transformation models. We will study limitations and advantages of different techniques, and how the data representation changes the problem setup, reduces complexity, introduces robustness, or other valuable properties for big data analytics.						
Prerequisites	Recommended:						
Trerequisites	Open-minded for new problem settings, Programming in different languages (C++, Python, Java), Critical approach to existing solutions, Research curiosity						
Format	Seminar 10 2 30 T / 90 S 4						
	T = face-to-face teaching; S = independent study						
Exam achievements	Oral presentation, written report (graded)						
Study achievements	(not graded)						
Forms of media	 [1] Sergey Ivanov, Evgeny Burnaev. "Anonymous Walk Embeddings" ICML, 2018. [2] Tsitsulin, Anton, Davide Mottin, Panagiotis Karras, and Emmanuel Müller "VERSE: Versatile Graph Embeddings from Similarity Measures." WWW, 2018. 						
	[3] Yanardag, Pinar, and S. V. N. Vishwanathan. "Deep graph kernels." KDD, 2015.						
Literature	[4] Holger Dell, Martin Grohe, Gaurav Rattan "Lovász Meets Weisfeiler and Leman". ICALP, 2018						
	[5] Anton Tsitsulin, Davide Mottin, Panagiotis Karras, Alexander M. Bronstein, Emmanuel Müller "NetLSD: Hearing the Shape of a Graph". KDD, 2018						
	[6] Nino Shervashidze, Pascal Schweitzer, Erik Jan van Leeuwen, Kurt Mehlhorn, Karsten M. Borgwardt "Weisfeiler-Lehman Graph Kernels". JMLR, 2011						
	[7] Haochen Chen, Bryan Perozzi, Yifan Hu, Steven Skiena "HARP: Hierarchical Representation Learning for Networks". AAAI, 2018.						

Module	Game AI								
MA-INF 4319									
Workload	Credit points	Duration	Frequer	ıcy					
270 h	9 CP 1 semester every year								
Module	Prof. Dr. Chris	tian Bauckha	ge						
coordinator									
Lecturer(s)	Prof. Dr. Chris	tian Bauckha	ge						
` ,	Programme		Mode	Semester					
Classification	_	M. Sc. Computer Science Optional 2. or 3.							
Technical skills		Upon completion, students should be able to							
100mmodi simis	-	• know about fundamental concepts of artificial intelligence and how							
			-	artinciai in	telligence and n	.ow			
	they apply to co			1 6 1	. 11				
	• know about b			nods for pla	nning, problem				
	solving, and bel		_	. 1 . 6 . 1					
	• implement ba			thms for pla	anning, problem	L			
	solving, and bel		0						
	• implement nu								
Soft skills	Students will lea								
	artificial intellig								
	techniques for p			-					
	to implement th					ice			
	especially in the			mputer gan	ne agents.				
Contents	• historical over								
	• basic terms ar			-					
	• backward indi				_				
	• alpha-beta pr		restircted	searches, fe	atures, and				
	evaluation funct		_						
	• (traditional, u	,	ee search	algorithms					
	• Monte Carlo t				_				
	• algorithms for	-	_	-					
	• mathematical		computer a	algorithms i	for data clusteri	ng			
	• self organizing			/					
	• finite state ma								
	• fuzzy logic / f				g / programmıng	S			
	• probability th			vorks					
	Markov chains								
	• hidden Marko			_	*				
	Markov decisi								
	• the Bellman e			ent learning	r S				
	• temporal diffe	rence learning	5						
	• Q learning	, ,							
	• genetic algorit		etic progra	amming					
Prerequisites	Recommended			. 1.	1 1 1 1	•1• •			
	Students should					ollity			
	theory, and stat				ı	- CD			
.	Teaching forma	at G	roup size	 ' .	Workload[h]	CP			
Format	Lecture			4	60 T / 105 S	5.5			
	Exercises			2	30 T / 75 S	3.5			
	T = face-to-face	e teaching; S	= indepen	dent study					
Exam achievements	Oral exam				(gra	aded)			
Study achievements	Successful exerc	ise participat	ion		(not gra	aded)			
Forms of media	• lecture slides	are made avai	lable onlii	ne					
	• lecture notes	with program	ming exan	nples are m	ade available on	line			
	Russell and Nor	vig, "Artificia	l Intellige	nce: A Mod	lern Approach"				
Literature	Millington. "Art	ificial Intellig	ence For (Games"					
	Millington, "Artificial Intelligence For Games"								
2100140410	MacKay, "Inform	_			ming Algorithm	a"			

Module	Lab Representation Learning on Graphs								
MA-INF 4320									
Workload	Credit points	Duration	Duration Frequency						
270 h	9 CP 1 semester every year								
Module	Prof. Dr. Emmanuel Müller								
coordinator									
Lecturer(s)	Prof. Dr. Emi	manuel Mü	ller						
Classification	Programme		Mode	Seme	ester				
Classification	M. Sc. Compu	iter Science	Option	al 2. or	3.				
Technical skills	The students	The students will carry out a practical task (project) in the							
	context of repr	context of representation learning on graphs, including test and							
	documentation	documentation of the implemented software/system.							
Soft skills	Ability to prop	perly prese	nt and def	end desig	n decisions, to				
	prepare readal	ble docume	ntation of	software;	skills in				
	constructively	collaborat	ng with o	thers in s	mall teams over	a			
	longer period	of time; ab	lity to cla	ssify ones	own results into	o the			
	state-of-the-ar	t of the res	p. area						
Contents									
Prerequisites	none								
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP			
rormat	Lab		8	4	60 T / 210 S	9			
	T = face-to-fa	ce teaching	S = inde	ependent	study				
Exam achievements	Oral presentat	tion, writte	n report		(gra	ided)			
Study achievements					(not gra	$\overline{\operatorname{ded}}$			
Forms of media									
Literature									

Module MA-INF 4321	Seminar Learning from Time Series								
Workload	Credit points	Credit points Duration Frequency							
120 h	4 CP	1 semester	every ye	ear					
Module coordinator	Prof. Dr. Emi	nanuel Mülle	er						
Lecturer(s)	Prof. Dr. Emr	nanuel Mülle	er						
CI :C ::	Programme	Programme Mode Semester							
Classification	M. Sc. Compu	ter Science	Optional	2. or 3	3.				
Technical skills	Ability to und	erstand new	research r	esults pro	esented in origi	inal			
	scientific paper	rs.							
Soft skills	Ability to pres	sent and to c	ritically di	scuss the	ese results in th	ne			
	framework of	the correspon	nding area						
Contents	Current confer	ence and jou	rnal pape	rs					
Prerequisites	none								
Format	Teaching forms	at G	oup size	h/week	Workload[h]	CP			
Format	Seminar		10	2	30 T / 90 S	4			
	T = face-to-fa	ce teaching;	S = indep	endent st	udy				
Exam achievements	Oral presentat	ion, written	report		(gra	ded)			
Study achievements					(not gra	ded)			
Forms of media									
Literature									

Module	Lab Machin	ne Learning	g on Er	crypted	d Data				
MA-INF 4322		·		0 1					
Workload	Credit points	Duration	Freque	ency					
270 h	9 CP	1 semester	every	year					
Module	Dr. Michael N	lüsken	'						
coordinator									
Lecturer(s)	Dr. Michael N	lüsken							
Classification	Programme		Mode	Seme	ster				
Classification	M. Sc. Compu	iter Science	Option	al 2. or	3.				
Technical skills		=	_		(project) in the				
			_	test and	documentation of				
	the implement								
Soft skills	Ability to prop	perly present	and defe	end					
	design decision	ns, to prepare	e readabl	le docume	entation of software;				
	skills in constr	ructively coll:	aborating	with oth	ners in small teams				
		v	,						
			,		fy ones own results				
	into the state-				and installations of				
	understand ho data shows up from trustable insightful reseaseeming contraboth: protective extent and post (2019) for a real The target of encrypted data are chosing to solution for personal trustage.	data science methodology to automatically analyze large amounts of possibly privacy infringing data we have to carefully understand how to protect our data. Also more and more fake data shows up and we have to find ways to distinguish faked from trustable data. At the same time we want to allow insightful research and life-easing analyzes to be possible. This seeming contradiction has lead to various efforts for unifying both: protecting data and allowing analyzes, at least to some extent and possibly under some restrictions. See Munn et al. (2019) for a review on challenges and options. The target of the lab is to understand how computations on encrypted data may work in one particular application that we are chosing together. Ideally, we can come up with a novel							
	the tasks and an implementi evaluation,		_		protocol, prototype s, present an				
Prerequisites	none								
	Teaching forms	at Gro	oup size	h/week	Workload[h] CF				
Format	Lecture			4	60 T / 105 S 5.5				
	Exercises			2	30 T / 75 S 3.5				
	T = face-to-fa	ce teaching;	S = inde	pendent s	study				
Exam achievements	Schriftliche Pr				(graded)				
Study achievements	Erfolgreiche Ü		me		(not graded)				
Forms of media					/				
Literature									

Variable Credit points Duration Fequency 20 CP 1 semester vevry year	Module	Pattern Re	cognitio	n II							
Prof. Dr. Christian Bauckhage	MA-INF 4323	Consist	Dur-4!	. Th							
Module Prof. Dr. Christian Bauckhage Programme Mode Semester M. Sc. Computer Science Optional 2. or 3.		_	- 000								
Prof. Dr. Christian Bauckhage	* *										
Classification		Prof. Dr. Christian Baucknage									
Classification		D CD CI : 4	· D 11								
Classification	Lecturer(s)		ian Bauckn								
Upon completion, students should be able to • know about aspects of numerical computing and how these may affect practical implementations of machine learning / pattern recognition algorithms • know about iterative algorithms for machine learning / pattern recognition with large data sets • implement numerically robust algorithms for data dimensionality reduction • implement numerically robust data clustering and classification Students will learn about mathematical and algorithms for data analysis and pattern recognition. They will learn about iterative algorithms and dynamical systems approaches in this area, how to implement them on their own, and how to put them into practice. Contents • advanced concepts from linear algebra • QR-, spectral-, and singular value decompositions • iterative algorithms for least squares optimization • iterative algorithms for least squares optimization • iterative algorithms for principal component analysis • Hebbian learning and Oja's rule for principal compoentn analysis • associative memory networks • hopfield networks • Hopfield networks • Hopfield networks • Hopfield networks for pattern recognition • Hopfield networks for problem solving • energy minimization methods in machine learning and pattern recognition • latent factor models for data analysis • data matrix factorization techniques • multidimensional scaling • manifold learning • basic graph theory • graph cuts and graph clustering • graph diffusion processes • radial basis functions for classification • radial basis functions for c	Classification		g .								
know about aspects of numerical computing and how these may affect practical implementations of machine learning / pattern recognition algorithms know about iterative algorithms for machine learning / pattern recognition with large data sets implement numerically robust algorithms for data dimensionality reduction implement numerically robust algorithms for data dimensionality reduction implement numerically robust data clustering and classification Students will learn about mathematical and algorithmic foundations of robust implementations of machine learning algorithms for data analysis and pattern recognition. They will learn about iterative algorithms and dynamical systems approaches in this area, how to implement them on their own, and how to put them into practice. advanced concepts from linear algebra QR-, spectral-, and singular value decompositions iterative algorithms for least squares optimization iterative algorithms for least squares optimization iterative algorithms for length squares optimization iterative algorithms for principal component analysis Hebbian learning and Oja's rule for principal component analysis auto-encoder networks Hopfield networks Hopfield networks for pattern recognition Hopfield networks for pattern recognition Hopfield networks for problem solving energy minimization methods in machine learning and pattern recognition Hapfield networks for problem solving energy minimization methods in machine learning and pattern recognition latent factor models for data analysis data matrix factorization techniques manifold learning basic graph theory graph cuts and graph clustering graph diffusion processes radial basis functions for interpolation radial basis functions for for interpolation radial basis functions for for interpolation radial basis functions for density estimation Prerequisites Teaching format	TD 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1										
practical implementations of machine learning / pattern recognition algorithms • know about iterative algorithms for machine learning / pattern recognition with large data sets • implement numerically robust algorithms for data dimensionality reduction • implement numerically robust data clustering and classification Soft skills Students will learn about mathematical and algorithmic foundations of robust implementations of machine learning algorithms for data analysis and pattern recognition. They will learn about iterative algorithms and dynamical systems approaches in this area, how to implement them on their own, and how to put them into practice. Contents • advanced concepts from linear algebra • QR-, spectral-, and singular value decompositions • iterative algorithms for least squares optimization • iterative algorithms for principal component analysis • Hebbian learning and Oja's rule for principal compoentn analysis • Hebbian learning and Oja's rule for principal compoentn analysis • Hopfield networks for pattern recognition • Hopfield networks for problem solving • energy minimization methods in machine learning and pattern recognition • latent factor models for data analysis • data matrix factorization techniques • multidimensional scaling • manifold learning • basic graph theory • graph cuts and graph clustering • graph diffusion processes • radial basis functions for interpolation • radial basis functions for interpolation • radial basis functions for density estimation Prerequisites Prerequisites Prerequisites Prerequisites Recommende: Students should good working knowledge in linear algebra, probability theory, and statistics. Ideally, they will have attended the lecture Pattern Recognition (1). Teaching format Group size h/week Workloa(h) CP Exam achievements Format Lecture 4 60 T / 105 S 5.5 Exercises 2 30 T / 75 S 3.5 Exercises 2 30 T / 75 S 3.5 Exercises 2 30 T / 75 S 3.5 Exe	Technical skills										
• know about iterative algorithms for machine learning / pattern recognition with large data sets • implement numerically robust algorithms for data dimensionality reduction • implement numerically robust data clustering and classification Students will learn about mathematical and algorithmic foundations of robust implementations of machine learning algorithms for data analysis and pattern recognition. They will learn about iterative algorithms and dynamical systems approaches in this area, how to implement them on their own, and how to put them into practice. Contents • advanced concepts from linear algebra • QR-, spectral-, and singular value decompositions • iterative algorithms for least squares optimization • iterative algorithms for principal component analysis • Hebbian learning and Oja's rule for principal component analysis • Hebbian learning and Oja's rule for principal component analysis • auto-encoder networks • Hopfield networks • Hopfield networks for pattern recognition • Hopfield networks for pattern recognition • Hopfield networks for problem solving • energy minimization methods in machine learning and pattern recognition • latent factor models for data analysis • data matrix factorization techniques • multidimensional scaling • manifold learning • basic graph theory • graph cuts and graph clustering • graph diffusion processes • radial basis functions for interpolation • radial basis functions for interpolation • radial basis functions for density estimation Prerequisites Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics. Ideally, they will have attended the lecture Pattern Recognition (1). Format Format		practical implem	_		_	_	-	t			
with large data sets implement numerically robust algorithms for data dimensionality reduction implement numerically robust data clustering and classification Students will learn about mathematical and algorithmic foundations of robust implementations of machine learning algorithms for data analysis and pattern recognition. They will learn about iterative algorithms and dynamical systems approaches in this area, how to implement them on their own, and how to put them into practice. Contents • advanced concepts from linear algebra • QR-, spectral-, and singular value decompositions • iterative algorithms for least squares optimization • iterative algorithms for least squares optimization • iterative algorithms for principal component analysis • Hebbian learning and Oga's rule for principal component analysis • Hopfield networks • Hopfield networks • Hopfield networks • Hopfield networks for pattern recognition • Hopfield networks for pattern recognition • Hopfield networks for problem solving • energy minimization methods in machine learning and pattern recognition • latent factor models for data analysis • data matrix factorization techniques • multidimensional scaling • manifold learning • basic graph theory • graph cuts and graph clustering • graph diffusion processes • radial basis functions for interpolation • radial basis functions for classification • radial basis functions for density estimation Prerequisites Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics. Ideally, they will have attended the lecture Pattern Recognition (1). Tacking format Group size h/week Workload[h] CP Teaching		_		:41	1.	:	. / + +				
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implement numerically robust data clustering and classification		_		buat almani	+hma	for data di	manajanalitu nada	ation			
Soft skills Students will learn about mathematical and algorithmic foundations of robust implementations of machine learning algorithms for data analysis and pattern recognition. They will learn about iterative algorithms and dynamical systems approaches in this area, how to implement them on their own, and how to put them into practice. advanced concepts from linear algebra QRr., spectral-, and singular value decompositions iterative algorithms for least squares optimization iterative algorithms for principal component analysis Hebbian learning and Oja's rule for principal component analysis auto-encoder networks associative memory networks Hopfield networks Hopfield networks for pattern recognition Hopfield networks for problem solving energy minimization methods in machine learning and pattern recognition latent factor models for data analysis data matrix factorization techniques manifold learning basic graph theory egraph cuts and graph clustering graph diffusion processes radial basis functions for interpolation radial basis functions for classification radial basis functions for classification radial basis functions for density estimation								ICTIOII			
robust implementations of machine learning algorithms for data analysis and pattern recognition. They will learn about iterative algorithms and dynamical systems approaches in this area, how to implement them on their own, and how to put them into practice. Contents • advanced concepts from linear algebra • QR-, spectral-, and singular value decompositions • iterative algorithms for least squares optimization • iterative algorithms for principal component analysis • Hebbian learning and Oja's rule for principal component analysis • auto-encoder networks • associative memory networks • Hopfield networks • Hopfield networks for problem solving • energy minimization methods in machine learning and pattern recognition • Hothield networks for problem solving • energy minimization methods in machine learning and pattern recognition • latent factor models for data analysis • data matrix factorization techniques • multidimensional scaling • manifold learning • basic graph theory • graph cuts and graph clustering • graph diffusion processes • radial basis functions for interpolation • radial basis functions for interpolation • radial basis functions for density estimation Prerequisites Precommended: Students should good working knowledge in linear algebra, probability theory, and statistics. Ideally, they will have attended the lecture Pattern Recognition (1). Teaching format Group size h/week Workload[h] CP Lecture 4 60 T / 105 S 5.5 Exercises 2 30 T / 75 S 3.5 T = face-to-face teaching; S = independent study Exam achievements Schriftliche Prüfung (graded) Forms of media electure slides are made available online • lecture slides are made available online • lecture notes with programming examples are made available online • MacKay, "Information Theory, Inference, and Learning Algorithms" • Haykin, "Neural Networks for Pattern Recognition" • Elden, "Matrix Methods in Data Mining and Pattern Recognition" • Skillicorn, "Understanding Complex Datasets"	C - & -1-:11-										
pattern recognition. They will learn about iterative algorithms and dynamical systems approaches in this area, how to implement them on their own, and how to put them into practice. Contents • advanced concepts from linear algebra • QR-, spectral-, and singular value decompositions • iterative algorithms for principal component analysis • Hebbian learning and Oja's rule for principal component analysis • Hebbian learning and Oja's rule for principal component analysis • associative memory networks • Hopfield networks • Hopfield networks for pattern recognition • Hopfield networks for problem solving • energy minimization methods in machine learning and pattern recognition • latent factor models for data analysis • data matrix factorization techniques • multidimensional scaling • manifold learning • basic graph theory • graph cuts and graph clustering • graph diffusion processes • radial basis functions for interpolation • radial basis functions for density estimation Prerequisites Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics. Ideally, they will have attended the lecture Pattern Recognition (1). Format Group size h/week Workload[h] CP	Soft skills										
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Ontents • advanced concepts from linear algebra • QR-, spectral-, and singular value decompositions • iterative algorithms for least squares optimization • iterative algorithms for principal component analysis • Hebbian learning and Oja's rule for principal compoentn analysis • Hebbian learning and Oja's rule for principal compoentn analysis • auto-encoder networks • associative memory networks • Hopfield networks • Hopfield networks for pattern recognition • Hopfield networks for problem solving • energy minimization methods in machine learning and pattern recognition • latent factor models for data analysis • data matrix factorization techniques • multidimensional scaling • manifold learning • basic graph theory • graph cuts and graph clustering • graph diffusion processes • radial basis functions for interpolation • radial basis functions for classification • radial basis functions for density estimation Prerequisites Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics. Ideally, they will have attended the lecture Pattern Recognition (1). Teaching format Group size h/week Workload[h] CP Lecture Recognition (1). Teaching format Group size h/week Workload[h] CP Lecture Schriftliche Prüfung (graded) Exam achievements Schriftliche Prüfung (graded) Forms of media • lecture slides are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are								4 la ain			
• advanced concepts from linear algebra • QR-, spectral-, and singular value decompositions • iterative algorithms for least squares optimization • Hebbian learning and Oja's rule for principal compoentn analysis • auto-encoder networks • associative memory networks • Hopfield networks for pattern recognition • Hopfield networks for problem solving • energy minimization methods in machine learning and pattern recognition • latent factor models for data analysis • data matrix factorization techniques • multidimensional scaling • manifold learning • basic graph theory • graph cuts and graph clustering • graph diffusion processes • radial basis functions for interpolation • radial basis functions for classification • radial basis functions for density estimation Prerequisites Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics. Ideally, they will have attended the lecture Pattern Recognition (1). Teaching format Group size h/week Workload[h] CP Lecture 4 60 T / 105 S 5.5 Exercises 2 30 T / 75 S 3.5 T = face-to-face teaching; S = independent study Exercises 2 30 T / 75 S 3.5 T = face-to-face teaching; S = independent study Exercises C 2 30 T / 75 S 3.5 T = face-to-face teaching; S = independent study Exercises C 2 30 T / 75 S 3.5 T = face-to-face teaching; S = independent study Exercises C 2 30 T / 75 S 3.5 T = face-to-face teaching; S = independent study Exercises C 30 T / 75 S 3.5 T = face-to-face teaching; S = independent study Exercises C 30 T / 75 S 3.5 T = face-to-face teaching; S = independent study Exercises C 30 T / 75 S 3.5 T = face-to-face teaching; S = independent study Exercises C 30 T / 75 S 3.5 T = face-to-face teaching; S = independent study Exercises C 30 T / 75 S 3.5 T =					,	now to im	piement them on	tneir			
• QR-, spectral-, and singular value decompositions • iterative algorithms for least squares optimization • iterative algorithms for principal component analysis • Hebbian learning and Oja's rule for principal component analysis • auto-encoder networks • associative memory networks • Hopfield networks for pattern recognition • Hopfield networks for pattern recognition • Hopfield networks for problem solving • energy minimization methods in machine learning and pattern recognition • latent factor models for data analysis • data matrix factorization techniques • multidimensional scaling • manifold learning • basic graph theory • graph cuts and graph clustering • graph diffusion processes • radial basis functions for interpolation • radial basis functions for density estimation Prerequisites Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics. Ideally, they will have attended the lecture Pattern Recognition (1). Reaching format Group size h/week Workload[h] CP Lecture 4 60 T / 105 S 5.5 Teaching format Group size h/week Workload[h] CP Lecture 4 60 T / 105 S 5.5 Teaching format Group size h/week Workload[h] CP Exercises 2 30 T / 75 S 3.5 T = face-to-face teaching; S = independent study Exercises (graded) Study achievements Study achievements Forms of media • lecture slides are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online • leden, 'Marrix Methods in Data Mining and Pattern Recognition' • Eidlen, 'Marrix Method	Cantonta										
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• Skillicorn, "Understanding Complex Datasets"		• Haykin, "Neura	al Networks	s and Lear	ning	Machines"	0 0				
	Literature	• Haykin, "Neura • Bishop, "Neura	al Networks al Networks	s and Lear for Patter	ning l rn Re	Machines" cognition"					
	Literature	Haykin, "NeuraBishop, "NeuraElden, "Matrix	al Networks al Networks : Methods i	s and Lear for Patter n Data Mi	ning l rn Re ining	Machines" cognition" and Pattern					

Module	Seminar Ad	lvanced T	opics in I	Data Sc	ience			
MA-INF 4324								
Workload	Credit points	Duration	Frequen	Frequency				
120 h	4 CP	1 semeste	0 0	every year				
Module	Prof. Dr. Elena Demidova							
coordinator								
Lecturer(s)	Prof. Dr. Eler	na Demidov	a					
Classification	Programme M. Sc. Compu	iter Science	Mode Optional	Semest 2. or 3				
Technical skills	This module of The students of state-of-the-ar	This module concentrates on specialized topics in data science. The students obtain skills in the independent, in-depth study of state-of-the-art scientific literature on specific topics, discussion with their peers and presentation to the scientific audience.						
Soft skills	scientific conte	 Communication skills: oral and written presentation of scientific content. Self-competences: the ability to analyze problems, time management, creativity. 						
Contents	data generation	uding typica on, integrati n. Specialize	al steps of ton, cleaning data repr	he data s g, explora resentatio	science process: ation, modelling on and analytic	g		
Prerequisites	Recommended BA-INF 150 -		in die Dat	a Science)			
	Teaching forms		roup size	h/week	Workload[h]	СР		
Format	Seminar		10	2	30 T / 90 S	4		
	T = face-to-face teaching; S = independent study							
Exam achievements	Oral presentat	tion, writter	report		(gra	ded)		
Study achievements	None				(not gra	$\overline{\mathrm{ded}}$		
Forms of media								
Literature	Relevant litera seminar	ature will be	e announced	l at the b	peginning of th	е		

Module	Lab Data Science in Practice								
MA-INF 4325									
Workload	Credit points	Duration	Freq	Frequency					
270 h	9 CP	1 semest	er every	year					
Module	Prof. Dr. Elena Demidova								
coordinator									
Lecturer(s)	Prof. Dr. Eler	na Demido	va						
Classification	Programme		Mode	Sem	ester				
Classification	M. Sc. Compu	iter Scienc	e Optio	nal $\mid 2$. o	r 3.				
Technical skills	This module c	oncentrate	s on prac	tical expe	erience in data				
	analytics. Par	ticipants a	cquire ba	sic knowle	edge and practica	al			
	experience in	the design	and imple	ementatio	on of data science)			
	workflows for	workflows for specific data types and applications.							
Soft skills	Communicate	tion skills:	the abilit	y to work	in teams.				
	Self-compete	ences: the	ability to	analyse p	problems and find	l			
	practical solut	ions. Time	managei	nent, crea	ativity, presentat	ion			
	of results.								
Contents	Practical apple	ication of s	statistical	and mac	hine learning-bas	ed			
	methods to so	lve data ar	nalytics p	oblems o	n real-world data	asets			
	and evaluate p	proposed so	olutions.						
Prerequisites	Recommended	:							
	BA-INF 150 -	Einführun	g in die I	Oata Scien	nce				
	MA-INF 4230	- Advance	d Method	s of Infor	rmation Retrieva	l			
Format	Teaching forms	at C	Froup size	h/weel	Workload[h]	CP			
rormat	Lab		8	4	60 T / 210 S	9			
	T = face-to-fa	ce teaching	g; S = inc	lependent	study				
Exam achievements	Oral presentat	ion, writte	n report		(gra	aded)			
Study achievements	None				(not gra	aded)			
Forms of media									
Literature									

Module MA-INF 4326	Explainable	AI an	d App	licati	ions				
Workload	Credit points	Duratio	n Fre	quen	ey .				
180 h	6 CP 1 semester every year								
Module	Dr. Tiansi Dong								
coordinator	D D								
Lecturer(s)	Dr. Tiansi Dong		N	- C					
Classification	Programme M. Sc. Computer	r Science	Mode Options		emester				
Technical skills	• Know the dual-		_		human min	d. and two main	AI		
	paradigms • Develop white- • Understand the systems, and Kno Deep-Learning sy	box neura e problems ow the sta	l AI systes and lim	ems itation:	s of Blackbo	ox Deep-Learning			
Soft skills	 connectionist AI Develop neural symbolic AI and Know the limit self-driving. Kno Deep-Learning sy 	 Know System 1 and 2 of the mind, prons and cons of symbolic AI and connectionist AI Develop neural-geometric systems that have both good features of symbolic AI and connectionist AI Know the limitation of famous Deep-Learning systems, such as GPT3, self-driving. Know standard methods to explore the explainability of 							
Contents	1. Introduction: self-driving cars								
	2. Dual-system theories (System 1 and 2), nine laws of cognition, criteria of semantic models								
	3. The target and		e-of-art n	ethods	s of XAI				
	4. Neural-symbolic AI								
	5. Cognitive map	os, Collage	s, Menta	Spati	al Represen	tation, Events			
	6. Qualitative Spatial Representation and Reasoning								
	7. Rotating Sphere Embedding: A New Wheel for Neural-Symbolic Unification								
	8. Neural Syllogi	stic Reaso	ning						
	9. Recognizing V	ariable Er	vironme	nts					
	10. Humor Unde	rstanding							
	11. Rotating Sph Vision, and Action	eres as bu	ıilding-bl	ock sen	nantic comp	ponents for Lang	uage,		
Prerequisites	none								
	Teaching forms	at	Group	size	h/week	Workload[h]	CP		
Format	Lecture				2	30 T / 45 S	2.5		
	Exercises				2	30 T / 75 S	3.5		
T 1.	T = face-to-face	teaching;	S = inde	oenden	t study		1 1		
Exam achievements	Written exam	a mantiain	ation				raded)		
Study achievements Forms of media	Successiui exercis	se particip	ation			(not g	raded)		
Literature	 Successful exercise participation (not grade) Kahneman, D. (2011). Thinking fast and slow. Farrar, Straus and Girdenest Gaedenfors, P. (2017). The Geometry of Meaning. MIT Press. Attardo, Hempelmann, Maio (2003). Script Oppositions and Logical Mechanisms: Modeling Incongruities and their Resolutions, HUMOR 15(1)3-46 Tversky, B. (2019). Mind in Motion. Basic Books, New York. Dong, et al. (2020). Learning Syllogism with Euler Neural-Networks. arXiv:2007.07320 Dong, T. (2021). A Geometric Approach to the Unification of Symbolic Structure and Neural Networks. Springer. Knauff and Spohn (2021). Handbook of Rationality. MIT Press, Cambridge, MA, USA. Samek et.al. (2019), Explainable AI: Interpreting, Explaining and Visualizing Deep Learning. Springer. Greg Dean (2019). Step by Step to Stand-Up Comedy (Revised Edition ISBN: 978-0-9897351-7-9 								

Module MA-INF 4327	Lab Biomedical Data Science								
Workload	Credit points	Duration	Freque	encv					
270 h	9 CP	1 semeste	_	-					
Module	Prof. Dr. Holg	Prof. Dr. Holger Fröhlich							
coordinator									
Lecturer(s)	Prof. Dr. Holg	ger Fröhlich							
CI 'C '	Programme		Mode	Seme	ster				
Classification	M. Sc. Compu	iter Science	Options	al 3.					
Technical skills	The students	will carry or	it a pract	ical task ((project) in the				
	context of bion	context of biomedical data science, including test and							
	documentation	documentation of the implemented software/system.							
Soft skills	Ability to prop	perly presen	t and defe	end design	n decisions, to				
	prepare readal	ble documer	ntation of	software;	skills in				
	constructively	collaboration	ng with ot	hers in sr	nall teams over a	a			
	longer period	of time; abil	ity to clas	ssify ones	own results into	the			
	state-of-the-ar	t of the resp	o. area						
Contents	Varying select	ed topics cle	ose to cur	rent resea	rch in the area of	of			
	biomedical dat	ta science.							
Prerequisites	none								
Format	Teaching forms	at G	oup size	h/week	Workload[h]	\mathbf{CP}			
roimat	Lab		8	4	60 T / 210 S	9			
	T = face-to-fa	ce teaching:	S = inde	pendent s	study				
Exam achievements	Oral presentat	tion, writter	report		(grad	ded)			
Study achievements					(not grad	$\overline{\text{ded}}$			
Forms of media									
Literature									

Module MA-INF 4328	Spatio-Temporal Data Analytics						
Workload	Credit points	Duration	Frequency				
180 h	6 CP	1 semeste					
Module	Prof. Dr. Elena Demidova						
coordinator							
Lecturer(s)	Prof. Dr. Elena Demidova						
	Programme Mode Seme			Semes	ter		
Classification	M. Sc. Computer Science		Optional	2. or 3	2. or 3.		
Technical skills	This module is	ntroduces th	e students	to the ac	dvanced metho	ds,	
	data structures, and data analytics algorithms for spatio-temporal data. At the end of the module, the students						
	will be capable of choosing appropriate data representations,						
	data structures and algorithms for specific applications and correctly applying relevant statistical and machine learning-based data analytics procedures.						
Soft skills	Communication	on skills: ora	and write	ten presei	ntation and		
	discussion of solutions. Self-competences: the ability to analyze and solve problems.						
Contents	and analysis methods, and algorithms that enable analyz						
	spatio-temporal data and building predictive models effective						
	and effectively. Furthermore, we will study the corresponding						
	evaluation techniques and novel applications.						
Prerequisites	none				1	I	
	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
Format	Lecture			2	30 T / 45 S	2.5	
	Exercises			2	30 T / 75 S	3.5	
	T = face-to-face teaching; $S = independent study$						
Exam achievements	Schriftliche Prüfung (graded)						
Study achievements	Erfolgreiche Übungsteilnahme (not graded)				$\overline{\operatorname{ded}}$		
Forms of media							
Literature							

Module MA-INF 4329	Seminar Biological Intelligence						
Workload	Credit points Duration Frequency						
120 h	4 CP 1 semester every year						
Module	Prof. Dr. Dr. Dominik Bach						
coordinator							
Lecturer(s)	Prof. Dr. Dr. Dominik Bach						
Classification	Programme		Mode	Semest	Semester		
Classification	M. Sc. Computer Science Optional 2. or 3.		3.				
Technical skills	Ability to understand new research results presented in original						
	scientific papers.						
Soft skills	Ability to present and to critically discuss these results in the						
	framework of the corresponding area.						
Contents	Current conference and journal papers.						
Prerequisites	none						
Format	Teaching forma	t Gı	oup size	h/week	Workload[h]	CP	
Format	Seminar		10	2	30 T / 90 S	4	
	T = face-to-face teaching; $S = independent study$						
Exam achievements	Oral presentation, written report (graded)						
Study achievements	(not graded)						
Forms of media							
Literature							

5 Master Thesis

MA-INF 0401	30 CP	Master Thesis	148
MA-INF 0402	2 CP	Master Seminar	149

Module MA-INF 0401	Master Thesis							
Workload	Credit points	Duration	Freque	ncy				
900 h	30 CP	1 semeste	semester every semester					
Module	'							
coordinator								
Lecturer(s)	All lecturers of computer science							
Classification	Programme		Mode	Se	Semester			
Classification	M. Sc. Compu			·				
Technical skills	Ability to solve a well-defined, significant research problem under supervision, but in principle independently							
Soft skills	Ability to write a scientific documentation of considerable length according to established scientific principles of form and style, in particular reflecting solid knowledge about the state-of-the-art in the field							
Contents	Topics of the thesis may be chosen from any of the areas of							
	computer science represented in the curriculum							
Prerequisites	none	none						
	Teaching format		Froup size	h/week		CP		
Format	Independent preparation of scientific thesis individual coad	s with		0	900 S	30		
	T = face-to-face teaching; S = independent study							
Exam achievements	Master Thesis (graded)							
Study achievements	(not graded)							
Forms of media								
Literature	Individual bibliographic research required for identifying relevant literature (depending on the topic of the thesis)							

Module MA-INF 0402	Master Seminar						
Workload	Credit points Duration Frequency						
60 h	2 CP	1 semester					
Module	2 CT T Schicover Croff Schicover						
coordinator							
Lecturer(s)	All lecturers of computer science						
CI :C .:	Programme		Mode Semester		mester		
Classification	M. Sc. Compu	iter Science	Compuls	sory 4.	4.		
Technical skills	Ability to document and defend the results of the thesis work in						
	a scientifically appropriate style, taking into consideration the						
	state-of-the-art in research in the resp. area						
Soft skills							
Contents	Topic, scientific context, and results of the master thesis						
Prerequisites	none						
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
	Seminar			2	30 T / 30 S	2	
	T = face-to-face teaching; $S = $ independent study						
Exam achievements	Oral presentation of final results (graded)						
Study achievements	(not graded)						
Forms of media							
T:4	Individual bibliographic research required for identifying						
Literature	relevant literature (depending on the topic of the thesis)						