# 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:

- $\mathbf{A}$  = number of the area of competence
- $\mathbf{S} = \text{semester}$  within the master curriculum
- $\mathbf{XY}$  = 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	40
3	Information and Communication Management	71
4	Intelligent Systems	98
5	Master Thesis	147

## 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 1107	L2E2	6 CP	Foundations of Quantum Computing	. 6
MA-INF 1108	L2E2	6 CP	Introduction to High Performance Computing: Architect	ure
			Features and Practical Parallel Programming	. 8
MA-INF 1201	L4E2	9 CP	Approximation Algorithms	. 9
MA-INF 1202	L4E2	9 CP	Chip Design	10
MA-INF 1203	L4E2	9 CP	Discrete and Computational Geometry	11
MA-INF 1205		6 CP	Graduate Seminar Discrete Optimization	12
MA-INF 1206	Sem2	4  CP	Seminar Randomized and Approximation Algorithms	13
MA-INF 1207	Lab4	9 CP	Lab Combinatorial Algorithms	14
MA-INF 1209	Sem2	4  CP	Seminar Advanced Topics in Cryptography	15
MA-INF 1213	L4E2	9 CP	Randomized Algorithms and Probabilistic Analysis	16
MA-INF 1217	Sem2	4  CP	Seminar Theoretical Foundations of Data Science	17
MA-INF 1218	L4E2	9 CP	Algorithms and Uncertainty	18
MA-INF 1219	Sem2	4  CP	Seminar Algorithmic Game Theory	19
MA-INF 1220	Sem2	4  CP	Seminar Algorithms for Computational Analytics	20
MA-INF 1221	Lab4	9 CP	Lab Computational Analytics	21
MA-INF 1222	Lab4	9 CP	Lab High Performance Optimization	22
MA-INF 1223	L4E2	9 CP	Privacy Enhancing Technologies	23
MA-INF 1224	L2E2	5  CP	Quantum Computing Algorithms	24
MA-INF 1225	Lab4	9 CP	Lab Exploring HPC technologies	25
MA-INF 1301	L4E2	9 CP	Algorithmic Game Theory	27
MA-INF 1304	Sem2	4 CP	Seminar Computational Geometry	28
MA-INF 1305		6 CP	Graduate Seminar on Applied Combinatorial	
			Optimization	29
MA-INF 1307	Sem2	4 CP	Seminar Advanced Algorithms	30
MA-INF 1308	Lab4	9 CP	Lab Algorithms for Chip Design	
MA-INF 1309	Lab4	9 CP	Lab Efficient Algorithms: Design, Analysis and	
			Implementation	32
MA-INF 1314	L4E2	9 CP	Online Motion Planning	33
MA-INF 1315	Lab4	9 CP	Lab Computational Geometry	34
MA-INF 1316	Lab4	9 CP	Lab Cryptography	
MA-INF 1320	Lab4	9 CP	Lab Advanced Algorithms	
MA-INF 1321	L2E2	6 CP	Binary Linear and Quadratic Optimization	
MA-INF 1322	Sem2	4 CP	Seminar Focus Topics in High Performance Computing .	
MA-INF 1323	L4E2	9 CP	Computational Topology	

Module	Combinator	Combinatorial Optimization						
MA-INF 1102								
Workload	Credit points	Duration	Frequ	ency				
270 h	9 CP	1 semest	er at least every year					
Module	Prof. Dr. Jens	Prof. Dr. Jens Vygen						
coordinator								
Lecturer(s)	All lecturers o	All lecturers of Discrete Mathematics						
Classification	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	iter Science	Option	al   1. or	2.			
Technical skills	Advanced know	Advanced knowledge of combinatorial optimization. Modelling						
	and development of solution strategies for combinatorial							
	optimization p	optimization problems						
Soft skills	Mathematical	Mathematical modelling of practical problems, abstract						
	thinking, prese	thinking, presentation of solutions to exercises						
Contents	Matchings, b-1	Matchings, b-matchings and T-joins, optimization over						
	matroids, subr	nodular fu	action min	nimization	, travelling			
	salesman prob	lem, polyh	edral comb	oinatorics,	NP-hard probl	lems		
Prerequisites	none							
	Teaching forma	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	ided)		
Study achievements	Successful exer	rcise partic	pation		(not gra	ided)		
Forms of media								
	• B. Korte, J.	Vygen: Co	mbinatori	al Optimi	zation: Theory	and		
	Algorithms. S	pringer, 6tl	edition,	2018				
	• A. Schrijver:	Combinat	orial Opti	mization:	Polyhedra and			
Literature	Efficiency. Spr	inger, 2003						
Literature	• W. Cook, W	. Cunningl	iam, W. F	ulleyblan	k, A. Schrijver:			
	Combinatorial	Optimizat	ion. Wiley	y, 1997				
	• A. Frank: Co	onnections	in Combin	natorial O	ptimization. Or	xford		
	University Pre	ess, 2011						

Module	Cryptograp	$\mathbf{h}\mathbf{y}$								
MA-INF 1103										
Workload	Credit points	- Y								
270 h	9 CP 1 semester   every year									
Module	Dr. Michael Nüsken									
coordinator										
Lecturer(s)	Dr. Michael Nüsken									
Classification	Programme		Mode	Seme	ster					
Classification	M. Sc. Compu	iter Science	Option	al   1. or	2.					
Technical skills	Understanding	Understanding of security concerns and measures, and of the								
	interplay betw	een computi	ng power	and secu	rity requiremen	ıts.				
	Mastery of the	e basic techn	iques for	cryptosys	stems and					
	cryptanalysis									
Soft skills	Oral presentat	ion (in tuto	rial group	s), writte	n presentation	(of				
	exercise solution	ons), team c	ollaborat	ion in solv	ving homework	`				
	problems, criti	ical assessme	ent							
Contents	Basic private-l	key and pub	ic-key cr	yptosyste	ms: AES, RSA,	,				
					nge, cryptograp					
					toring integers a					
	discrete logari	, ,		,	0 0					
Prerequisites	none	,								
<del>-</del>	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	Written exam				(gra	ded)				
Study achievements	Successful exe	rcise particip	ation		(not gra	$\overline{\operatorname{ded}}$				
Forms of media					, 3					
	• Jonathan Ka	atz & Yehud	a Lindell	(2015/20	08). Introduction	on to				
Literature	Modern Crypt			` '	,					
	• Course notes									

Module	Algorithms	Algorithms for Data Analysis							
MA-INF 1105									
Workload	Credit points	Duration	Freque	ncy					
180 h	6 CP	1 semester	at least	every 2	years				
Module	Prof. Dr. Petr	Prof. Dr. Petra Mutzel							
coordinator									
Lecturer(s)	Prof. Dr. Petr	Prof. Dr. Petra Mutzel							
Classification	Programme		Mode	Semes	ter				
Classification	M. Sc. Compu	iter Science	Optional	l   1. or 2	2.				
Technical skills	Deeper insight	s into selecte	ed method	ls and tec	hniques of mod	dern			
	algorithmics w	algorithmics with respect to big data and/or analytics tasks							
Soft skills	Presentation o	Presentation of solutions and methods, critical discussion of							
	applied metho	applied methods and techniques.							
Contents	Advanced algo	rithmic tech	niques and	d data str	ructures relevai	nt to			
	analytic tasks	for big data	i.e., algor	rithms for	graph similar	ity,			
	parallel algorit	hms, I/O-da	ta structu	ires, and	streaming				
	algorithms.								
Prerequisites	Required:								
	none								
	Recommended	:							
	Introductory k	nowledge of	foundatio	ns of algo	orithms and da	ta			
	structures is es	_		Ü					
	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	Foundations	s of Quant	um Con	nputing					
MA-INF 1107									
Workload	Credit points	Duration	Freque	ncy					
180 h	6 CP	1 semester	every 2	years					
Module	Prof. DrIng.	Christian B	auckhage						
coordinator									
Lecturer(s)	Prof. DrIng.	Prof. DrIng. Christian Bauckhage							
Classification	Programme Mode Semester								
	M. Sc. Compu		Optiona						
Technical skills	able to describ quantum regis quantum comp quantum comp knowledge and	Upon successful completion of this module, students should be able to describe fundamental concepts and techniques (qubits, quantum registers, quantum gates, quantum circuits) in quantum computing. Students will be equipped with specific, quantum computing related programming know-how; based on knowledge and skills acquired, students should be able to  • devise quantum computing algorithms for basic computational							
	tasks	1	0 0		1				
	• run these alg	gorithms on	(simulated	d) quantu	m computers				
Soft skills	In the exercises, students will have the opportunity to put their knowledge into practice, since they will realize small projects on computing with quantum gates and their solutions using quantum inspired methods or genuine quantum methods. This requires teamwork; upon successful completion of the module, students should be able to								
	• draft and im	plement bas	ic quantui	m comput	ing algorithms	3			
	• apply quantualgorithms	_	_	_					
	$\bullet$ prepare and	_	sentation	s about th	neir work in fro	$\operatorname{ont}$			
	of an audience								
Contents	Boolean algebra classical digita mathematical vector spaces, operators, qub computing; qu	d computing foundations tensor productions, superposits,	classical of quantu acts, unita sition, ent	reversible m compu ry operat	e computing; ting (complex cors, Hermitian				
Prerequisites	Recommended								
-	Good working		f theory a	and practi	ce of linear alg	ebra			
	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	sudy				
Exam achievements	Schriftliche Pr	üfung			(gra	ded)			
Study achievements	Erfolgreiche Ü	bungsteilnal	me		(not gra	ded)			
Forms of media	<ul><li>lecture slides</li><li>notebooks w</li><li>online</li></ul>	,				;			
Literature	Theoretical M  • M.A. Nielser Quantum Info Anniversary ec  • P. Wittek, " 2016  • M. Schuld, F Computers", S	<ul> <li>L. Susskind, A. Friedman, "Quantum Mechanics: The Theoretical Minimum", Penguin, 2015</li> <li>M.A. Nielsen, I.L Chuang, "Quantum Computation and Quantum Information", Cambridge University Press, 10th Anniversary edition, 2010</li> <li>P. Wittek, "Quantum Machine Learning", Academic Press,</li> </ul>							

Module MA-INF 1108	Introduction to High Performance Computing: Architecture Features and Practical Parallel Programming								
Workload	Credit points	Duration	1	Freque	ncv				
180 h	6 CP	1 semes		every y	-				
Module	Prof. Dr. Estela Suarez								
coordinator									
Lecturer(s)	Prof. Dr. Estela Suarez								
	Programme								
Classification	M. Sc. Compu	ter Sciene		Optional					
Technical skills	_	Understanding principles of computer architecture of modern							
	level (system a their implicati program paral multi-node fea Understanding	HPC systems at component (processor, accelerators) and system level (system architecture, network, memory hierarchy) and their implication for application programming. Ability to program parallel computers, employing multi-core and multi-node features. Programming CPU and GPUs. Understanding the quality of performance and scaling behaviour, and applying the measures needed to improve them.							
Soft skills	,					sent it in a clea			
	and comprehe	_		_	_				
Contents	Computer archaetwork) and				ponents (	CPU, memory	·,		
	Software envir	onment							
	Access to HPC Centre	C compute	e reso	ources at	the Jülic	ch Supercompu	iting		
	Practical use of OpenMP, CUI	-	prog	grammin	g paradig	gms (MPI,			
	Performance o and strategies				ling behav	vior, understan	ding		
	Current challe	nges in H	PC						
Prerequisites	Required: Knowledge of and Python).	a modern	prog	grammin	g languag	ge (ideally C/C	C++		
	Interest in Hig	h Perforn	nance	e Compi	iting				
	Cannot be tak			_	_	06			
			omp	ieung m	.A-1111 11	.00.			
	Recommended			m anabit	- ot				
	Bachelor lectu Teaching forms					Workload[h]	CP		
Format	Lecture	20	Gro	up size	h/week	30 T / 45 S	2.5		
romat	Exercises				$\frac{2}{2}$	30 T / 45 S	$\begin{vmatrix} 2.5 \\ 3.5 \end{vmatrix}$		
		1 .	C	. 1			5.5		
T	T = face-to-fa	ce teachir	ng; S	= indep	endent st		1 - 1\		
Exam achievements	Written exam	, .	• 41		•	,-	ded)		
Study achievements	Successful part		ın tl	ne exerci	ises	(not gra	uea)		
Forms of media	Laptop and pr		wid A	Pattor	ron: Com	nuter Architec	rturo		
Literature	<ul> <li>John L. Hennessy, David A. Patterson: Computer Archite</li> <li>A Quantitative Approach. Morgan Kaufmann Publishers.</li> <li>David A. Patterson, John L. Hennessy: Computer</li> <li>Organization and Design - The Hardware / Software Interf</li> <li>Morgan Kaufmann Publishers, 2013</li> <li>Message Passing Interface Forum: MPI: A Message-Passi</li> </ul>					nn Publishers, nputer oftware Interfa	2012 ce.		
	<ul> <li>Message Fassing Interface Forum: MF1: A Message-Fassing Interface Standard, Version 3.1</li> <li>OpenMP Application Programming Interface, Version 4.5, November 2015</li> </ul>								

24 1 1	Approximat	ion Algori	thma						
Module MA-INF 1201	Approximat	Jon Algori	umns						
Workload	Credit points	Duration	Freque	encv					
270 h	9 CP	1 semester	_	st every y	ear				
Module		Prof. Dr. Jens Vygen							
coordinator	Tion Dr. bens vygen								
Lecturer(s)	All lecturers of	All lecturers of Discrete Mathematics,							
	Senior Prof. D			,					
CI 10 11	Programme		Mode	Seme	ster				
Classification	M. Sc. Compu	ter Science	Option	al   2. or	3.				
Technical skills	Introduction to	o design and	analysis	of most i	important				
	approximation	algorithms	for NP-h	ard comb	inatorial				
	optimization p	oroblems, and	l various	technique	es for proving lo	ower			
	and upper bou	ınds, probabi	listic me	thods and	d applications				
Soft skills				ods, critic	al discussion of				
	applied metho		_						
Contents		_	_	-	on Schemes. De	_			
	_		_		or selected NP-l	nard			
	problems, like			-	,				
	MAXSAT, TS			٠,	9 ,				
	Facility Locati			-	-				
	techniques (lik								
	Search, randor		_						
	MCMC-Metho	* *			nalysis of				
<b>D</b>	approximation		a PCP-s	systems.					
Prerequisites	Recommended		foundati	ong of ala	conithma and				
	Introductory k complexity the	_		ons or arg	gorunnis and				
	Teaching forma		up size	h/week	Workload[h]	СР			
Format	Lecture	at Gre	oup size	4	60 T / 105 S	5.5			
Tormat	Exercises			2	30 T / 75 S	3.5			
		ao too ahina	C — inda	_	,	0.0			
Exam achievements	T = face-to-fa Oral exam	ce teaching;	s = mae	pendent s		ded)			
Study achievements	Successful exer	rcise narticin	ation		(not gra				
Forms of media	Successial exe	reise particip	<u> </u>		(1100 810	acaj			
Torms or media	• S. Arora, C.	Lund: Hard	ness of A	pproxima	ations In				
	· · · · · · · · · · · · · · · · · · ·								
	Approximation Algorithms for NP-Hard Problems (D. S. Hochbaum, ed.), PWS, 1996								
		, ,		l approxir	native Algorith	men			
					es (5th edition)				
Literature	Universität Bo		,		,	,			
		*	binatoria	al Optimi	zation: Theory	and			
	Algorithms (6t			_	Č				
	• V. V. Vazira	ni: Approxir	nation A	lgorithms	s, Springer, 2001	1			
	• D. P. Willian	mson, D. B.	Shmoys:	The Desi	gn of				
	Approximation Algorithms, Cambridge University Press, 2011								

Module MA-INF 1202	Chip Design	1							
Workload	Credit points	Duration	Freque	nev					
270 h	9 CP	1 semester	_	-					
Module	Prof. Dr. Jens		CVCIJ	Jear					
coordinator	1101. 21. 0011.	, ,,8011							
Lecturer(s)	All lecturers o	All lecturers of Discrete Mathematics							
Eccturer (b)	Programme	1 21801000 111	Mode	Seme	ster				
Classification	M. Sc. Compu	ter Science	Option	1					
Technical skills	Knowledge of design. Comporteal-world protection Techniques to	Knowledge of the central problems and algorithms in chip design. Competence to develop and apply algorithms for solving real-world problems, also with respect to technical constraints.  Techniques to develop and implement efficient algorithms for							
Soft skills	very large instances.  Mathematical modelling of problems occurring in chip design, development of efficient algorithms, abstract thinking, presentation of solutions to exercises								
Contents		Problem formulation and design flow for chip design, logic							
			_	-	s and optimizat	ion			
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	<u> </u>				aded)			
Study achievements	Successful exer	rcise particip	ation		(not gra	aded)			
Forms of media					·				
Literature	<ul> <li>C.J. Alpert, D.P. Mehta, S.S. Sapatnekar: The Handbook of Algorithms for VLSI Physical Design Automation. CRC Press, New York, 2008.</li> <li>S. Held, B. Korte, D. Rautenbach, J. Vygen: Combinatorial optimization in VLSI design. In: "Combinatorial Optimization: Methods and Applications" (V. Chvátal, ed.), IOS Press, Amsterdam 2011, pp. 33-96</li> <li>S. Held, J. Vygen: Chip Design. Lecture Notes (distributed during the course)</li> <li>L. Lavagno, I.L. Markov, G. Martin, and L.K. Scheffer, eds.: Electronic Design Automation for IC Implementation, Circuit Design, and Process Technology. CRC Press, 2nd edition, 2016</li> </ul>								

Module	Discrete and Computational Geometry								
MA-INF 1203									
Workload	Credit points	Duration	Frequer	ncy					
270 h	9 CP	1 semester	r every year						
Module	Prof. Dr. Anne Driemel								
coordinator									
Lecturer(s)		Prof. Dr. Anne Driemel, PD Dr. Elmar Langetepe,							
	Dr. Herman H	Iaverkort							
Classification	Programme		Mode	Seme	ster				
Classification	M. Sc. Compu		Optional						
Technical skills	Knowledge of fundamental theorems and concepts in the area								
	discrete and co	omputational	geometry	y; design	and analysis of	f			
	geometric algo	orithms; comb	oinatorial	analysis	of the complex	ity			
	of geometric c	onfigurations	; to apply	this know	owledge				
	autonomously	in solving ne	ew probler	ns.					
Soft skills	Social compet	ence (commu	nication,	presenti	ng one's own				
	solutions, goal	-oriented disc	cussions in	n teams)	, methodical				
	competence (analysis, abstraction, proofs), individual								
	competence (commitment and willingness to learn, creativity,								
	endurance).								
Contents	Fundamentals	of convex ser	ts, Vorono	oi diagra	ms, hyperplane				
	arrangements, well-separated pair decomposition, spanners,								
	metric space embedding, dimension reduction, VC-dimension,								
	epsilon-nets, visibility, point location, range searching,								
	randomized incremental construction, geometric distance								
	problems in di			. –					
Prerequisites	Recommended								
-	BA-INF 114 –	Grundlagen	der algori	ithmisch	en Geometrie				
	Teaching form			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 = independent study								
Exam achievements	Oral exam	ce teaching, i	<u> — шаер</u>	endent a		ded)			
Study achievements	Successful exe	rcise narticin	ation		(not gra				
Forms of media	Duccessiai exe	reise particip	a01011		(Hot gra	iaca			
Torms or media	▲ Jiri Matouse	k Lectures	n Discret	e Coom	etry Springer				
	• Jiri Matousek. Lectures on Discrete Geometry. Springer								
	Graduate Texts in Mathematics. ISBN 0-387-95374-4.  • Mark de Berg, Otfried Cheong, Marc van Kreveld, and Mark								
		0,	0,		,	aik			
Literature	Overmars. Co	_	_	_					
	Applications (		u). Spring	ger. 15B1	.N				
	978-3-540-779			ът .	1				
	• Narasimhan		_						
	• Klein, Conci	rete and Abst	tract Vorc	noı Diag	grams				

Module	Graduate S	eminar Di	screte C	Optimiz	ation		
MA-INF 1205							
Workload	Credit points	Duration	Freque	ncy			
180 h	6 CP	6 CP   1 semester   every year					
Module	Prof. Dr. Jens	Prof. Dr. Jens Vygen					
coordinator							
Lecturer(s)	All lecturers o	All lecturers of Discrete Mathematics					
Classification	Programme		Mode	Seme	Semester		
Classification	M. Sc. Compu	iter Science	Optiona	d 2.			
Technical skills	Competence to	Competence to understand new research results based on					
	original literat	original literature, to put such results in a broader context and					
	present such results and relations.						
Soft skills	Ability to read	d and unders	tand rese	arch pape	ers, abstract		
	thinking, prese	entation of m	athemati	ical result	ts in a talk		
Contents	A current rese	arch topic in	discrete	optimiza	tion will be cho	sen	
	each semester	and discusse	d based o	on origina	al literature.		
Prerequisites	Recommended	:					
	MA-INF 1102	- Combinat	orial Opti	imization			
Format	Teaching forms	at Gre	oup size	h/week	Workload[h]	CP	
rormat	Seminar		10	4	60 T / 120 S	6	
	T = face-to-fa	ce teaching;	S = indep	pendent s	study		
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
T *4	The topics and the relevant literature will be announced towards						
Literature	the end of the previous semester.						

Module MA-INF 1206	Seminar Randomized and Approximation Algorithms						
Workload	Credit points Duration Frequency						
120 h	4 CP	1 semes	ster	every y	•		
Module	Prof. Dr. Heik	ko Röglin					
coordinator							
Lecturer(s)	Prof. Dr. Ann	e Drieme	l, Pr	of. Dr. 7	Γhomas K	Tesselheim,	
	Prof. Dr. Heik	ko Röglin,	, PD	Dr. Elm	nar Lange	tepe,	
	Dr. Herman H	laverkort,	Sen	ior Prof.	Dr. Mar	ek Karpinski	
Classification	Programme			Mode	Semest	ter	
Classification	M. Sc. Computer Science   Optional   2.						
Technical skills	Ability to perform individual literature search, critical reading,						
	understanding	understanding, and clear presentation.					
Soft skills	Presentation o	f solution	s an	d metho	ds, critica	l discussion of	
	applied metho	ds and te	chni	ques			
Contents	Current topics	in design	n and	d analysi	s of rando	mized and	
	approximation	algorithr	ms b	ased on l	lastest res	earch literatur	e
Prerequisites	none						
Format	Teaching forms	at	$\operatorname{Grc}$	oup size	h/week	Workload[h]	CP
Format	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	The relevant li	iterature	will	be annou	inced in t	ime.	

Module	Lab Combin	natorial A	gorithn	ns		
MA-INF 1207						
Workload	Credit points	Duration	Freque	-		
270 h	9 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	Semes	ster	
Classification	M. Sc. Computer Science		Optiona	$1 \mid 2$ .	2.	
Technical skills	Competence to	o implement	advanced	combina	torial algorithn	ns,
	handling nonti	rivial data st	ructures,	testing, o	documentation.	
	Advanced soft	ware techniq	ues.			
Soft skills	Efficient imple	ementation of	complex	algorith	ms, abstract	
	thinking, docu	mentation o	source c	ode		
Contents	Certain combi	natorial algo	rithms w	ill be cho	sen each semest	er.
	The precise ta	sk will be ex	plained in	a meeti	ng in the previo	ous
	semester.					
Prerequisites	Recommended	:				
	MA-INF 1102	- Combinate	orial Opti	imization		
Format	Teaching forms	at Gro	oup size	h/week	Workload[h]	CP
rormat	Lab		8	4	60 T / 210 S	9
	T = face-to-fa	ce teaching;	S = indep	pendent s	study	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
T*4	The topics and	d the relevan	t literatu	re will be	announced tow	vards
Literature	the end of the	previous ser	nester			

Module	Seminar Ad	lvanced 7	Topics in	Cryptog	graphy	
MA-INF 1209						
Workload	Credit points	Duration	Freque	ncy		
120 h	4 CP	1 semest	er   every s	emester		
Module	Dr. Michael N	lüsken				
coordinator						
Lecturer(s)	Dr. Michael N	füsken				
Classification	Programme		Mode	Semes	ter	
Classification	M. Sc. Compu	iter Science	e Optiona	$1 \mid 2$ . or $3$	3.	
Technical skills	Understanding	Understanding research publications, often written tersely.				
	Distilling this	Distilling this into a presentation. Determination of relevant				
	irrelevant mat	erial. Deve	loping a pr	esentation	that fascinate	es
	fellow students					
Soft skills	_		0		orally and in v	isual
	media. Motiva	_		participa	ite. Critical	
	assessment of					
Contents					g from year to	year,
	is studied in d	epth, based	d on curren	t research	literature	
Prerequisites	Required:					
	MA-INF 1103	- Cryptog	raphy			
	and one further course in cryptography like The Art of					
	Cryptography	or eSecuri	ty.			
Format	Teaching form	at	Group size	h/week	Workload[h]	CP
rormat	Seminar		10	2	30 T / 90 S	4
	T = face-to-fa	ce teaching	g; S = indep	endent st	tudy	
Exam achievements	Oral presentat	ion, writte	n report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						·
Literature	Current crypto	ographic lit	terature.			

270 h  Module coordinator  Lecturer(s)  Classification  Technical skills	analysis of algorandomized alg	ter Science of models a	Mode Optiona	year Semental 2. or iques for	4.		
270 h  Module coordinator  Lecturer(s)  Classification  Technical skills	9 CP Prof. Dr. Heik Prof. Dr. Heik Programme M. Sc. Comput Understanding analysis of algorandomized algoral and written	1 semester to Röglin to Röglin ter Science g of models a orithms as w	Mode Optionand techn	year Semental 2. or iques for	4.		
Module coordinator  Lecturer(s)  Classification  Technical skills	Prof. Dr. Heik Prof. Dr. Heik Programme M. Sc. Compu Understanding analysis of algorandomized algoral and written	to Röglin  ter Science of models a	Mode Optiona	Semental 2. or iques for	4.		
coordinator  Lecturer(s)  Classification  Technical skills	Prof. Dr. Heik Programme M. Sc. Compu Understanding analysis of algorandomized algoral and written	ter Science of models a	Options nd techn	al 2. or iques for	4.		
Lecturer(s)  Classification  Technical skills	Programme M. Sc. Comput Understanding analysis of algorandomized algoral and writt	nter Science g of models a orithms as w	Options nd techn	al 2. or iques for	4.		
Classification Technical skills	Programme M. Sc. Comput Understanding analysis of algorandomized algoral and writt	nter Science g of models a orithms as w	Options nd techn	al 2. or iques for	4.		
Technical skills	M. Sc. Compute Understanding analysis of algrandomized algorized and write	g of models a orithms as w	nd techn	iques for			
Technical skills	Understanding analysis of alg- randomized alg- Oral and writt	g of models a orithms as w	nd techn	iques for	the probabilistic		
Soft skills		Understanding of models and techniques for the probabilistic analysis of algorithms as well as for the design and analysis of randomized algorithms					
		Oral and written presentation of solutions and methods,					
		resign and analysis of randomized algorithms					
	• complexity classes						
	• Markov chains and random walks						
	• tail inequalities						
•	• probabilistic method						
S	smoothed and average-case analysis						
	<ul><li>simplex algo</li><li>local search</li><li>clustering algo</li><li>combinatoria</li><li>multi-objection</li></ul>	algorithms gorithms al optimization	-	ems			
Prerequisites	none						
	Teaching forma	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-face teaching; $S = $ independent study						
Exam achievements	Oral exam				(gra	ded)	
Study achievements S	Successful exer	rcise particip	ation		(not gra	$\overline{\text{ded}}$	
Forms of media							
	<ul><li>lecture notes</li><li>research arti</li><li>Motwoni Re</li></ul>	cles	ndomize d	Algorith	ma Cambridas		
Literature			ıdomized	Aigorith	ms, Cambridge		
	University Pre	,	_1_1_1.	1 C		.1	
1	• Mitzenmach University Pre			and Con	puting, Cambri	ıage	

Module MA-INF 1217	Seminar Th	eoretical l	Foundati	ons of l	Data Science	е
Workload	Credit points	Duration	Frequen	ıcv		
120 h	4 CP	1 semester	_	•		
Module	Prof. Dr. Heil	ko Röglin				
coordinator		S				
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				
C1 10 11	Programme		Mode	Semester		
Classification	M. Sc. Compu	iter Science	Optional	2. or 3	3.	
Technical skills	Ability to und	erstand new	research r	esults pro	esented in original	inal
	scientific pape	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	ırnal pape	rs		
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 = indep	endent st	udy	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
Literature						

Module	Algorithms	and Unce	rtainty			
MA-INF 1218						
Workload	Credit points	Duration	Freque	ency		
270 h	9 CP	1 semeste	r at leas	st every 2	years	
Module	Prof. Dr. Tho	mas Kessell	eim			
coordinator						
Lecturer(s)	Prof. Dr. Tho	mas Kessell	neim			
Classification	Programme		Mode	Seme	ster	
Classification	M. Sc. Computer Science   O		Option	al   2. or	2. or 3.	
Technical skills	Understanding			_	•	
		· U	0	• 0	algorithms with	1
		erformance guarantees in the context of uncertainty.				
Soft skills	Oral and writt			lutions ar	nd methods	
Contents	• Advanced O					
	Markov Dec.					
	• Stochastic a		_			
	Online Learn	ning Algorit	hms and	Online Co	onvex Optimizat	tion
Prerequisites	Recommended					
		_	,	,	d probability the	
	_		ut certai	n algorith	ms is not necess	sary.
	Teaching forms	at G1	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	Oral exam				(gra	ded)
Study achievements	Successful exe	rcise partici	pation		(not gra	ded)
Forms of media						
Literature	lecture notes,	research art	icles			

Module	Seminar Al	$\overline{\text{gorithmic}}$	Game T	heory		
MA-INF 1219						
Workload	Credit points	Duration	Frequen	ıcy		
120 h	4 CP	1 semeste	r   every y	ear		
Module	Prof. Dr. Tho	mas Kessell	neim			
coordinator						
Lecturer(s)	Prof. Dr. Tho	Prof. Dr. Thomas Kesselheim				
Classification	Programme		Mode	Semes	ter	
Classification	M. Sc. Computer Science   Optional   2. or 3.		3.			
Technical skills	Ability to und	erstand nev	research r	esults pro	esented in origi	inal
	scientific pape	rs.				
Soft skills	Ability to perf	form individ	ual literatu	ıre search	ı, critical readii	ng,
	and clear dida	ctic present	ation			
Contents	Advanced topi	ics in Algori	thmic Gan	ne Theory	and Algorithr	nic
	Mechanism De	esign based	on current	conference	ce and journal	
	papers					
Prerequisites	none					
Format	Teaching form	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	tudy	
Exam achievements	Oral presentat	ion, writter	report		(gra	ded)
Study achievements					(not gra	$\overline{ded}$
Forms of media						
Literature						

Module	Seminar Al	gorithms	or Comp	outation	nal Analytic	s
MA-INF 1220						
Workload	Credit points	Duration	Frequen	ıcy		
120 h	4 CP	1 semester	at least	every ye	ar	
Module	Prof. Dr. Peti	a Mutzel				
coordinator						
Lecturer(s)	Prof. Dr. Peti	Prof. Dr. Petra Mutzel				
Classification	Programme	ogramme Mode Semester				
Classification	M. Sc. Computer Science   Optional   2. or 3.		3.			
Technical skills	Ability to perf	form individ	ual literatu	ire search	, critical readi	ng,
	understanding	, and clear of	lidactic pre	esentation	ı.	
Soft skills	Ability to pres	sent and to o	ritically di	scuss the	ese results in th	ne
	framework of	the correspo	nding area	•		
Contents	Current topics	in algorithi	ns for com	putationa	al analytics bas	sed
	on recent research	arch literatu	re.			
Prerequisites	Recommended	:				
	Interest in Alg	$ m_{corithms}$				
Format	Teaching form	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 = indep	endent st	udy	
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	nced in t	ime.	

Module	Lab Compu	tational A	nalytic	$\mathbf{s}$		
MA-INF 1221						
Workload	Credit points	Duration	Freque	ency		
270 h	9 CP	1 semeste	every	year		
Module	Prof. Dr. Petr	a Mutzel				
coordinator						
Lecturer(s)	Prof. Dr. Petr	a Mutzel				
Classification	Programme		Mode	Seme	ster	
Classification	M. Sc. Computer Science		Option	al   2. or	3.	
Technical skills	Ability to desi	Ability to design, analyze and implement efficient algorithms for				
	computational	analytics p	roblems.	The LAB	also includes	
	_	evaluation a	nd docum	entation	of the implement	nted
	software.	software.				
Soft skills	Ability to prop			_		
	prepare readal			,		
			0		mall teams over	
				ssify ones	own results into	the the
	state-of-the-ar					
Contents				_	gorithms and da	ta
	structures for		al analyt	ics proble	ems.	
Prerequisites	Recommended	-				
	Interests in alg	,			1	
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP
Tormat	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	Lab High P	erformanc	e Optin	nization	l	
MA-INF 1222						
Workload	Credit points	Duration	Freque	ency		
270 h	9 CP	1 semester	every	year		
Module	Prof. Dr. Petr	a Mutzel				
coordinator						
Lecturer(s)	Prof. Dr. Petr	a Mutzel, Di	. Sven N	Iallach		
Classification	Programme		Mode	Semes	ster	
Classification	M. Sc. Compu	ter Science	Optiona	al 2. or	2. or 3.	
Technical skills	Ability to desi	gn, analyze a	nd imple	ement alg	orithms for	
	computational	analytics an	d optimi	zation pro	oblems. The lab	)
	also includes e	xperimental	evaluatio	n and do	cumentation of	the
	implemented s	oftware.				
Soft skills	Ability to prop	perly present	and defe	end design	decisions, to	
	prepare readal	ole document	ation of	software;	skills in	
					nall teams over	a
	longer period	of time; abilit	y to clas	sify ones	own results into	the the
	state-of-the-ar	t of the resp.	area	Ü		
Contents						
Prerequisites	none					
TD	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 = inde	pendent s	study	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media					-	
	The relevant li					

Module MA-INF 1223	Privacy Enl	hancing Te	chnolo	gies			
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	Knowledge: C	ryptographic	schemes	s for enha	ncing privacy,		
	underlying security notions, applications and restrictions.						
	Skills: Secure	application o	f sophist	icated cry	yptographic		
	schemes. Eval	uation of the	ir correc	tness, effic	ciency and secu	rity	
	in an applicati	ion setting.					
Soft skills	Competences:	Ability to as	sess sche	emes and	their use in		
	applications. (	Critical assess	sment of	applicati	ons.		
Contents	With more and	d more data	available	e a clear s	eparation of		
	sensitive data is necessary and needs to be protected. Some of						
	that data must stay within strict environments, for examples						
	hospitals must store certain highly sensitive medical information						
	about patients but they are not allowed to store it outside its						
	own facilities. Some of that data is stored or collected in a cloud						
	environment in encrypted form, say data from a medical device						
	or a smart home. But it shall still be possible to derive						
	important conclusions from it, for example to send immediate						
	help to a patient suffering a heart attack.						
	Innovative solutions are needed in this area of tension. The						
	research in cryptography provides some highly sophisticated						
	tools for solving the like problems.						
	• Fully homomorphic encryption (FHE).						
	• Zero-Knowledge techniques, in particular: Non-interactive						
	zero-knowledge proof (NIZKs).						
	• Secure multi-party computations (MPC).						
	Anonymisati	ion, TOR. Ps	eudonyn	nization.	Blinding.		
	• Weaker priva	acy notions, l	ike diffe	rential pr	ivacy.		
Prerequisites	Recommended	:					
	Basic knowled	ge in cryptog	raphy is	highly re	ecommended.		
	A profound mathematical background does help. In particular,						
	precise mathematical formulation and reasoning are important,						
	but also topics	s like element	ary num	ber theor	y and discrete		
	mathematics,	especially lat	tices, are	e interesti	ng.		
	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	Schriftliche Pr					ided)	
Study achievements	Erfolgreiche Ü	bungsteilnah	me		(not gra	$\overline{\operatorname{ded}}$	
Forms of media	_				. 3		
	-						

Module	Quantum C	omputin	g Algorit	hms				
MA-INF 1224								
Workload	Credit points	Duration	Freque	-				
150 h	5 CP	1 semest		years				
Module	Prof. Dr. Chr.	istian Bauc	eknage					
coordinator	Dood Do Chai	:_4: D	1-1					
Lecturer(s)	Prof. Dr. Chr.	istian Bauc						
Classification	Programme M. Sc. Compu	iter Science	Mode Optiona	Semest				
Technical skills	Upon successf	ul completi	on of this r	nodule, st	udents should	be		
	able to describ	e fundame	ntal concep	ts behind	working quan	$\operatorname{tum}$		
	algorithms.							
	Students acqui	ire quantui	n computin	g progran	nming know-ho	ow;		
	based on know	_	_		_			
	to	Ü	•	,				
	• run quantum	n algorithm	s on (simul	ated) qua	ntum computi	nσ		
	platforms		(5111141	arca) qua		0		
	• devise their	own algorit	hms for op	timizatior	n or classificati	on		
	problems that	_						
Soft skills	In the exercise	s, students	can put th	eir quant	um computing			
	knowledge into	practice a	and realize s	small proj	ects involving	the		
	implementatio	knowledge into practice and realize small projects involving the implementation of quantum algorithm. This requires teamwork;						
	upon successful completion of the module, students should be							
	able to							
	• draft and implement basic quantum computing algorithms							
	• apply quantum computing (simulations) to test these							
	algorithms							
	• prepare and give oral presentations about their work in front							
	of an audience							
Contents	quantum gate							
	Bernstein-Vazi							
	amplitude amp	,	- '			,		
	Trotterization.	, variationa	l quantum	computin	g for optimizat	tion		
Prerequisites	Required:	//D 1	C O					
	MA-INF 1107			1				
T	Teaching forms	at (	Group 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		S = indep	endent st		1 1		
Exam achievements	Schriftliche Pr		1		· -	$\frac{\mathrm{ded}}{\mathrm{ded}}$		
Study achievements	Erfolgreiche Ü			_ 1_ '1	(not gra	aea)		
Forms of media	• lecture slides							
	• notebooks w online	un prograi	nınıng exai	npies are	made avanable	•		
	M.A. Nielsen,	II Chuan	r "Ouentu	m Compu	tation and			
	Quantum Info							
	Anniversary ed		_	Omversity	y 1 1055, 10th			
		,		· '' A	1 · D	0016		
Literature	P. Wittek, "Q							
	M. Schuld, F.			-	g with Quantu	m		
	Computers", S	Springer, 21	nd edition,	2021				
	S. Ganguly, "Quantum Machine Learning: An Applied							
	Approach", Apress, 2021							

Module	Lab Explori	ing HPC to	echnolog	gies		
MA-INF 1225						
Workload	Credit points	Duration	Frequen			
270 h	9 CP	1 semester	every ye	ear		
Module	Prof. Dr. Este	ela Suarez				
coordinator						
Lecturer(s)	Prof. Dr. Este	ela Suarez				
Classification	Programme	~ .	Mode	Seme		
	M. Sc. Compu		Optional			
Technical skills	Understanding a use case from complex code developed.  Adapting and running applications to different kinds of					
		· –		_	ecific architecture	
			_		s. Understanding	
	and using para		- ·	_	_	
	programming I				_	
	understanding				analysis tools,	
	improve them.	-				
Soft skills	-				on developers, tools	
Soft Skills					olution oriented	
	/	·			work language" and	
		_				
	expertise. Presenting performed work and results obtained and					
	classifying own results into the state-of-the-art. Preparing software documentation.					
Contents	The students carry out a practical task (project) in High					
Contents				(2 0	, .	
	Performance Computing (HPC), including test of different hardware architectures and software tools, documentation of the					
	implemented software/system. Contents: HPC systems:					
	access/use of compute resources at Jülich Supercomputing					
	Centre; Use of different processor architectures; Software					
	environment, performance analysis tools; Parallel programming;					
	Benchmarking tools/procedures; Performance of applications					
	and scaling be					
Prerequisites	Required:	,				
-	-Passed the exam of MA-INF 1106 or MA-INF 1108.					
	-Knowledge modern programming languages (C/C++, Python).					
	-Willing to stay for at least 2 days per week during 4 weeks at the Jülich Supercomputing Centre, dates to be discussed.					
	_	-			_	
Romanks	the Jülich Sup	ercomputing	Centre, d	ates to	be discussed.	
Remarks	the Jülich Sup Registration fi	ercomputing rst via direct	Centre, d	ates to municat	be discussed.	
Remarks	the Jülich Sup Registration fi lecturer, in ord	ercomputing rst via direct der to identif	Centre, d mail com y suitable	ates to municat	be discussed. ion with the or the stay at JSC.	
Remarks Format	the Jülich Sup Registration fi lecturer, in ord Teaching forms	ercomputing rst via direct der to identif	Centre, domail comy suitable pup size	ates to municat dates for h/week	be discussed.  ion with the or the stay at JSC.  Workload[h] CP	
	the Jülich Sup Registration fi lecturer, in ord Teaching forms Lab	rst via direct der to identif at Gro	Centre, domail com y suitable oup size	ates to municate dates for h/week	be discussed.  ion with the or the stay at JSC.  Workload[h] CP  60 T / 210 S 9	
Format	the Jülich Sup Registration fi lecturer, in ord Teaching forma Lab T = face-to-fa	rst via direct der to identif at Groce teaching;	Centre, domination of mail compy suitable pup size 2  S = indep	ates to municate dates for h/week	be discussed.  ion with the or the stay at JSC.  Workload[h] CF 60 T / 210 S 9 study	
Format  Exam achievements	the Jülich Sup Registration fi lecturer, in ord Teaching forms Lab	rst via direct der to identif at Groce teaching;	Centre, domination of mail compy suitable pup size 2  S = indep	ates to municate dates for h/week	be discussed.  cion with the or the stay at JSC.  Workload[h] CF 60 T / 210 S 9 study  (graded)	
Format  Exam achievements Study achievements	the Jülich Sup Registration fi lecturer, in ord Teaching forms Lab T = face-to-fa Oral presentat	rst via direct der to identifiet Greek Gre	Centre, domail com y suitable pup size 2 S = indep	municated dates for h/week  4 endent s	be discussed.  ion with the or the stay at JSC.  Workload[h] CP 60 T / 210 S 9 study  (graded) (not graded)	
Format  Exam achievements	the Jülich Sup Registration fi lecturer, in ord Teaching forma Lab T = face-to-fa Oral presentat Own laptop to	percomputing rst via direct der to identife at Groot G	Centre, do mail com y suitable pup size 2 S = indepreport	ates to municate dates for h/week  4 endent s	be discussed.  cion with the or the stay at JSC.  Workload[h] CF 60 T / 210 S 9 etudy  (graded) (not graded) supercomputers.	
Format  Exam achievements Study achievements	the Jülich Sup Registration fi lecturer, in ord Teaching forms Lab T = face-to-fa Oral presentat  Own laptop to John L. Hen	percomputing rst via direct der to identife der der der der der der der der der de	Centre, do mail com y suitable pup size 2 S = indep report I program A. Patters	ates to municat dates for h/week  4 endent s on the secon: Con	be discussed.  Join with the stay at JSC.  Workload[h] CP  60 T / 210 S 9  Study (graded)  (not graded)  Supercomputers.  Imputer Architecture	
Format  Exam achievements Study achievements	the Jülich Sup Registration fi lecturer, in ord Teaching forma Lab T = face-to-fa Oral presentat  Own laptop to  John L. Hen - A Quantitati	rst via direct der to identified Groot Gro	Centre, domail composite pup size 2 S = indepreport I program A. Patters	ates to municate dates for h/week  4 endent s on the s son: Con Kaufma	be discussed.  Fion with the or the stay at JSC.  Workload[h] CP  60 T / 210 S 9  study  (graded)  (not graded)  supercomputers.  mputer Architecture  ann Publishers, 2012	
Format  Exam achievements Study achievements	the Jülich Sup Registration fi lecturer, in ord Teaching forma Lab T = face-to-fa Oral presentat  Own laptop to  John L. Hen - A Quantitati  David A. Pa	ret via direct der to identif at Groce teaching; ion, written connect and nessy, David ive Approach tterson, John	Centre, do mail com y suitable pup size 2  S = indepreport  I program A. Patters A. Morgan a L. Henno	ates to municate dates for h/week  4 endent s on the seson: Con Kaufman essy: Con the sesy: Con the	be discussed.  From with the stay at JSC.  Workload[h] CF 60 T / 210 S 9 9 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
Format  Exam achievements  Study achievements  Forms of media	the Jülich Sup Registration fi lecturer, in ord Lab T = face-to-fa Oral presentat  Own laptop to  John L. Hen - A Quantitati  David A. Pa Organization a	ret via direct der to identife der to identife der der der der der der der der der de	Centre, do mail com y suitable pup size 2  S = indep report  I program A. Patters. Morgan a L. Henne The Hard	ates to municate dates for h/week  4 endent s on the seson: Con Kaufman essy: Con the sesy: Con the	be discussed.  Fion with the or the stay at JSC.  Workload[h] CP  60 T / 210 S 9  study  (graded)  (not graded)  supercomputers.  mputer Architecture  ann Publishers, 2012	
Format  Exam achievements  Study achievements	the Jülich Sup Registration fi lecturer, in ord Teaching forms Lab T = face-to-fa Oral presentat  Own laptop to John L. Hen - A Quantitati David A. Pa Organization a Morgan Kaufn	ret via direct ler to identif at Gro  ce teaching; cion, written  connect and nessy, David ive Approach tterson, John and Design - nann Publish	Centre, do mail com y suitable oup size 2  S = indep report  I program A. Patters. Morgan a L. Henne The Hard ers, 2013	ates to municate dates for h/week  4 endent s on the seson: Con Kaufman essy: Con ware / S	be discussed.  ion with the br the stay at JSC.  Workload[h] CP 60 T / 210 S 9 study  (graded) (not graded) (not graded) (supercomputers. mputer Architecture ann Publishers, 2012 mputer Software Interface.	
Format  Exam achievements  Study achievements  Forms of media	the Jülich Sup Registration fi lecturer, in ord Teaching forma Lab T = face-to-fa Oral presentat  Own laptop to  John L. Hen - A Quantitati  David A. Pa Organization a Morgan Kaufn  Message Pas	ret via direct der to identife der teaching; dien, written der teaching der der teaching der der teaching der der teaching der teachin	Centre, do mail com y suitable pup size 2  S = indepreport  I program A. Patters A. Morgan a L. Henne The Hard ers, 2013 e Forum:	ates to municate dates for h/week  4 endent s on the seson: Con Kaufman essy: Con ware / S	be discussed.  From with the stay at JSC.  Workload[h] CF 60 T / 210 S 9 9 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
Format  Exam achievements  Study achievements  Forms of media	the Jülich Sup Registration fi lecturer, in ord Teaching forma Lab T = face-to-fa Oral presentat  Own laptop to  John L. Hen - A Quantitati  David A. Pa Organization a Morgan Kaufn  Message Pas Interface Stand	ret via direct der to identified Green Gre	Centre, do mail com y suitable pup size 2  S = indepreport  I program A. Patters A. Morgan a L. Henne pure Henne pure Henne pure Henne pure hers, 2013 be Forum:	ates to municate dates for h/week  4 endent s on the s son: Con Kaufma essy: Co ware / S MPI: A	be discussed.  ion with the br the stay at JSC.  Workload[h] CP 60 T / 210 S 9 study  (graded) (not graded) (not graded) (supercomputers. mputer Architecture ann Publishers, 2012 mputer Software Interface.	

Module	Algorithmic	Game Th	eory								
MA-INF 1301											
Workload	Credit points	Duration	Freque	ency							
270 h	9 CP	1 semester	every :	2 years							
Module	Prof. Dr. Tho	Prof. Dr. Thomas Kesselheim									
coordinator											
Lecturer(s)	Prof. Dr. Tho	Prof. Dr. Thomas Kesselheim,									
,	Senior Prof. D	r. Marek Ka	rpinski								
	Programme		Mode	Seme	ster						
Classification	M. Sc. Compu	iter Science	Optiona	al 2. or	3.						
Technical skills			-		hmic) game the	eory					
	_			, –	ques and metho	-					
	, –	,	_		c agents. Analy						
	and designing		_	_		O					
	computational	·	_								
Soft skills					al discussion of						
	applied metho			,							
Contents	• basic game t	heory									
	• computabilit	y and hardne	ess of equ	ıilibria							
	• convergence		_								
	• (bounds on	the) loss of pe	erforman	ce due to	selfish behavio	or					
	• designing inc	, –									
	• maximizing										
	• designing me	echanisms for	stable a	nd fair a	llocations withou	out					
	money										
Prerequisites	Recommended	:									
	Introductory k	nowledge of	foundati	ons of alg	gorithms and						
	complexity the	eory is essenti	al.								
	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-face teaching; $S = $ independent study										
Exam achievements	Written exam		·	•		ided)					
Study achievements	Successful exer	rcise participa	ation		(not gra						
Forms of media		1 1			( 0						
	• N. Nisan, T.	Roughgarde	n, E. Tai	rdos, V.V	. Vazirani (ed.)	:					
	• N. Nisan, T. Roughgarden, E. Tardos, V.V. Vazirani (ed.): Algorithmic Game Theory, Cambridge Univ. Press, 2007										
	• T. Roughgarden, Twenty Lectures on Algorithmic Game										
	Theory, Cambridge Univ. Press, 2016										
	• A. Karlin, Y. Peres, Game Theory, Alive, AMS, 2017										
	• Y. Shoham, K. Leyton-Brown, Multiagent Systems,										
Literature	• Y. Shoham,	K. Levton-Bi	own, Mi	• Y. Shoham, K. Leyton-Brown, Multiagent Systems, Cambridge Univ. Press, 2009							
Literature	1	· ·		uitiagent	systems,						
Literature	Cambridge Un	niv. Press, 200	09	J	,	on					
Literature	Cambridge Un  D. M. Kreps	niv. Press, 200 :: A Course in	09	J	Theory, Princet	on					
Literature	Cambridge Un  D. M. Kreps Univ. Press, 1	niv. Press, 200 a: A Course in 1990	09 n Microe	conomic	,						

Module	Seminar Computational Geometry						
MA-INF 1304							
Workload	Credit points   Duration   Frequency						
120 h	4 CP	1 semest	er	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	[averkort					
Classification	Programme			Mode	Semest	ter	
Classification	M. Sc. Compu	iter Scienc	e	Optional	2-4.		
Technical skills	To independent	tly study	pro	blems at	research	level, based on	1
	research public	cations, to	pre	epare a c	oncise sur	nmary, to pres	ent
	the summary i	in a scienti	ific '	talk, to l	ead a crit	ical discussion	
	with other sen	ninar parti	cipa	ants.			
Soft skills							
Contents	Current topics	in compu	tati	onal geo	metry.		
Prerequisites	Recommended	:					
	BA-INF 114 –	Grundlag	en o	der algor	ithmische	n Geometrie	
	MA-INF 1203	– Discrete	an	d Compu	itational	Geometry	
Format	Teaching forms	at	Gro	up size	h/week	Workload[h]	CP
rormat	Seminar			10	2	30 T / 90 S	4
	T = face-to-fa	ce teaching	g; S	= indep	endent st	udy	
Exam achievements	Oral presentat	ion, writte	en r	eport		(gra	ded)
Study achievements						(not gra	ded
Forms of media	Multimedia pr	ojector, bl	ack	board.			
Literature	The relevant li	iterature w	vill 1	be annou	inced.		

Module	Graduate Seminar on Applied Combinatorial						
MA-INF 1305	Optimization	Optimization					
Workload	Credit points	Duration	Freque	ency			
180 h	6 CP	1 semester	every y	year			
Module	Prof. Dr. Jens	Prof. Dr. Jens 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	_				esults and pract		
				applicat	tions, as well as		
G & 1.11	presentation o			1	1 , ,		
Soft skills	Ability to reac				,		
<b>Q</b>	O/ 1	thinking, presentation of mathematical results in a talk Current topics in chip design and related applications					
Contents	•	•	gn and re	erated app	Diffications		
Prerequisites	Recommended	-					
	At least 1 of t	_					
	MA-INF 1102	- Combinate	orial Opti	imization			
	MA-INF 1202	- Chip Desi	gn				
Format	Teaching forms	at Gro	oup size	h/week	Workload[h]	CP	
Format	Seminar		10	4	60 T / 120 S	6	
	T = face-to-fa	ce teaching;	$S = inde_{I}$	pendent s	study		
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature	The topics and the end of the			re will be	announced tow	ards	

Module	Seminar Advanced Algorithms						
MA-INF 1307							
Workload	Credit points	Credit points Duration Frequency					
120 h	4 CP	1 semester	r   every y	ear			
Module	Prof. Dr. Tho	mas Kessell	eim				
coordinator							
Lecturer(s)	Prof. Dr. Ann	e Driemel, I	Prof. Dr.	Chomas Κ	Kesselheim,		
	Prof. Dr. Heil	ko Röglin, P	D Dr. Elm	ar Lange	tepe,		
	Dr. Herman H	Iaverkort					
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	iter Science	Optiona	1 3.	3.		
Technical skills	Presentation of	of selected ac	dvanced to	pics in alg	gorithm design	and	
	various applica	ations					
Soft skills	Ability to perf	orm individ	ual literati	ıre search	, critical readi	ng,	
	understanding	, and clear of	didactic pr	esentation	n		
Contents	Advanced topi	cs in algorit	hm design	based on	newest research	ch	
	literature						
Prerequisites	none						
Format	Teaching form	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 = 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	Lab Algorithms for Chip Design						
MA-INF 1308							
Workload	Credit points	Duration	Frequency				
270 h	9 CP	1 semester	every y	year			
Module	Prof. Dr. Jens	Vygen					
${f coordinator}$							
Lecturer(s)	All lecturers o	f Discrete M	athematic	cs			
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu		Optiona		3.		
Technical skills	_		0		SI design, efficient	$_{ m ent}$	
	handling of ve		,	ting, doc	umentation.		
	Advanced soft						
Soft skills	Efficient imple		•	0	,		
	_ ·			problem	in VLSI design,	,	
	documentation						
Contents		0 0 1			en each semeste		
	_	sk will be ex	plained ir	n a meeti	ng in the previo	ous	
	semester.						
Prerequisites	Recommended						
	At least 3 of the						
	MA-INF 1102	- Combinate	orial Opti	imization			
	MA-INF 1202	- Chip Desig	gn				
	MA-INF 1205	- Graduate	Seminar 1	Discrete	Optimization		
T .	Teaching forms	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 = inder	pendent s	study	•	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra	$\overline{\text{ded}}$	
Forms of media							
Literature	The topics and	the relevant	literatur	re will be	announced tow	ards	
Literature	the end of the previous semester						

Module	Lab Efficient Algorithms: Design, Analysis and						
MA-INF 1309	Implementa	Implementation					
Workload	Credit points	Credit points   Duration   Frequency					
270 h	9 CP	1 semester	at leas	t every y	ear		
Module	Prof. Dr. Heil	ko Röglin	'				
coordinator							
Lecturer(s)	Prof. Dr. Ann	e Driemel, F	rof. Dr.	Thomas 1	Kesselheim,		
	Prof. Dr. Heil	ko Röglin, Pl	Dr. Eln	nar Lang	etepe,		
	Dr. Herman H	Iaverkort					
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Optiona	ıl 3.			
Technical skills	Ability to desi	gn, analyze a	and imple	ement effi	cient algorithm	s for	
	selected comp	utational pro	blems.				
Soft skills	ability to work	on advance	d algorith	mic imp	ementation		
	projects, to we	ork in small	eams, cle	ear didact	tic presentation	and	
	critical discuss	sion of result	3				
Contents	Design of effic	ient exact an	d approx	imate alg	orithms and da	ta	
	structures for	selected com	putationa	al probler	ns.		
Prerequisites	none						
Format	Teaching forms	at Gro	oup size	h/week	Workload[h]	CP	
rormat	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching;	S = indep	pendent s	study		
Exam achievements	Oral presentat	tion, written	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature	The relevant l	iterature will	be anno	unced in	time.		

Module	Online Mot	ion Planni	ng				
MA-INF 1314		Г					
Workload	Credit points	Duration					
270 h	9 CP	1 semester	every	year			
Module	PD Dr. Elmar	Langetepe					
coordinator							
Lecturer(s)	Prof. Dr. Rolf	Klein, PD I	Or. Elma	r Langete	epe		
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Option	al 1-4.			
Technical skills	To acquire fun	damental kn	owledge	on topics	and methods in	1	
	online motion	planning					
Soft skills							
Contents	Search and ex	ploration in	ınknown	environn	nents (e.g., grap	hs,	
	cellular enviro	nmwents, po	lygons, s	trets), on	line algorithms,		
	competitive ar	nalysis, comp	etitive c	omplexity	functional,		
	optimization,	shortest water	hman re	oute, tethe	ered robots, mar	rker	
	algorithms, sp	iral search, a	pproxim	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 = inde	pendent s	study		
Exam achievements	Oral exam				(gra	ded)	
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)	
Forms of media	Java applets o	f geometry la	ab				
Literature	GC	1 4.1	•11 1		led in the lectur		

Module	Lab Compu	tational C	eometr	y		
MA-INF 1315						
Workload	Credit points Duration Frequency					
270 h	9 CP	1 semester	every y	vear		
Module	Prof. Dr. Ann	e Driemel	'			
coordinator						
Lecturer(s)	Prof. Dr. Ann	e Driemel, F	D Dr. El	mar Lang	getepe,	
	Dr. Herman H	Iaverkort				
Classification	Programme		Mode	Seme	ster	
Classification	M. Sc. Compu	iter Science	Optiona	1 2.		
Technical skills	Ability to desi	gn, analyze,	implemer	nt and do	cument efficien	t
	algorithms for	selected pro	blems in	computat	tional geometry	
Soft skills	Ability to prop	perly present	, defend a	and discu	ss design and	
	implementatio	n decisions,	to docum	ent softw	are according to	0
	given rules and	d to collabor	ate with	other stu	dents in small	
	groups.					
Contents	Various proble	ems in comp	itational	geometry	•	
Prerequisites	none					
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 = indep	pendent s	study	
Exam achievements	Oral presentat	tion, written	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
Literature	The relevant l	iterature wil	be anno	unced in	time.	

Module	Lab Crypto	graphy					
MA-INF 1316							
Workload	Credit points	Duration	tion Frequency				
270 h		9 CP   1 semester   every year					
Module	Dr. Michael N	Dr. Michael Nüsken					
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	The students	will carry o	ut a pract	ical task (	(project) in the		
	context of Cry	ptography,	including	test and	documentation of	f	
	the implement	ed software	/system.				
Soft skills	Ability to prop	perly prese	t and def	end			
	design decision	ns, to prepa	re readab	le docume	entation of softwar	re;	
	skills in constr	ructively co	laborating	g with oth	ners in small team	ıs	
	over a longer p	period of ti	ne; ability	to classif	fy ones own result	$\operatorname{ts}$	
	into the state-	of-the-art of	f the resp	. area			
Contents							
Prerequisites	none						
Format	Teaching forms	at G	roup size	h/week	Workload[h]	$\mathbf{CP}$	
Format	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching	$S = \operatorname{ind} \epsilon$	ependent s	study		
Exam achievements	Oral presentat	ion, writte	report		(grade	ed)	
Study achievements					(not grade	$\overline{\mathrm{ed}}$	
Forms of media							
Literature							

Module	Lab Advanc	ced Algo	rithms			
MA-INF 1320						
Workload	Credit points	Duration	Frequ	ency		
270 h	9 CP	1 semest	ter at lea	st every	2 years	
Module	Prof. Dr. Tho	mas Kesse	lheim			
coordinator						
Lecturer(s)	Prof. Dr. Tho	mas Kesse	lheim, Pro	of. Dr. H	eiko Röglin	
Classification	Programme		Mode	Sem	ester	
Classification	M. Sc. Compu	iter Scienc	e Option	$al \mid 2. o$	r 3.	
Technical skills	Implementation	on of algori	ithms from	advance	d algorithmic th	eory,
	evaluating the	se algorith	m on suita	ably chose	en instances, and	l
	discussing how	theoretic	al results t	ransfer to	o practice.	
Soft skills	Ability to prop	perly prese	ent, defend	and disc	uss design and	
	implementatio	n decision	s and obse	rved cond	clusions, and to	
	collaborate wi	th other st	udents in	small gro	oups.	
Contents	Various proble	ems from c	urrent rese	earch and	courses on	
	algorithmic th	eory.				
Prerequisites	none					
Format	Teaching forms	at (	Group size	h/week	Workload[h]	CP
Format	Lab		8	4	60 T / 210 S	9
	T = face-to-fa	ce teachin	g; S = ind	ependent	study	
Exam achievements	Oral presentat	ion, writte	en report		(gra	ded)
Study achievements					(not gra	ided)
Forms of media						
Literature	The relevant l	iterature v	vill be ann	ounced ir	time.	

Module MA-INF 1321	Binary Line	ear and Qu	ıadratic	Optimi	zation			
Workload	Credit points	Duration	Fraguer	2017				
180 h	6 CP	1 semester	Frequency at least every 2 years					
	Dr. Sven Mallach							
Module	Di. Sven Manach							
coordinator								
Lecturer(s)	Dr. Sven Mallach							
Classification	Programme		Mode	Semest				
	M. Sc. Compu		Optional					
Technical skills	Deeper unders	_	-					
	potentially lar	_	_		-			
	Application-sp		_					
	combinatorial	-	-	,	g quadratic			
	objective func	tions, algorit	hm design	١.				
Soft skills	Social, method	dological, an	d analytica	al compet	ences via			
	communication, own development, presentation, and critical							
	assessment of problem formulations, algorithms, and solutions							
	covered in the course or the excercises. Learning to abstract, but							
	also learning the limitations of abstraction.							
Contents	Computational methods in (mixed-)integer programming such as							
	cutting plane separation and branch-and-bound along with a							
	short and acce	essible introd	luction int	o their th	eoretical basis.			
	Study of pract	ically releva	nt binary	linear and	d binary quadra	atic		
		=	_		inear Ordering			
		-			em, along with	-		
			_	_				
	particular separation problems arising there. If there is time, linearizations of quadratic objective functions and more							
	sophisticated formulations of binary quadratic problems are							
	discussed.							
Prerequisites	none							
	Teaching forms	at G	roup size	h/week	Workload[h]	CI		
Format	Lecture			2	30 T / 45 S	2.		
- 01 IIIMU	Exercises			$\frac{2}{2}$	30 T / 75 S	1		
		. 1.	a		'	J 5.6		
	T = face-to-fa	ce teaching;	S = indep	endent st		, ,		
Exam achievements	Oral exam				(gra			
Study achievements	Successful exe	rcise particij	oation		(not gra	ded		
Forms of media								
Literature								

Module	Seminar Focus Topics in High Performance						
MA-INF 1322	Computing						
Workload	Credit points	Duration	Frequer	ıcy			
120 h	4 CP 1 semester   every year						
Module	Prof. Dr. Estela Suarez						
coordinator							
Lecturer(s)	Prof. Dr. Estela Suarez						
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	iter Science	Optional	2. or 3	3.		
Technical skills	Ability to perf	Ability to perform individual literature search, critical reading,					
	understanding, prepare a concise summary, and clear didactic						
	presentation						
Soft skills	Ability to present and critically discuss these results in the						
	framework of the corresponding area						
Contents	_				e computing, b	ased	
	on recent review	ew and resear	ch literat	ure			
Prerequisites	Recommended	•					
	Interest in Hig	gh Performan	ce Compu	iting			
Format	Teaching forms	at G1	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	tion, written	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature	Literature and further information about this seminar will be						
Diterature	announced in	time in the v	rebsite of	lecturer.			

Module	Computational Topology									
MA-INF 1323	•	•	ο <i>ι</i>							
Workload	Credit points	Duration	Freque	ency						
270 h	9 CP	1 semester		years						
Module	Prof. Dr. Ann	e Driemel								
coordinator										
Lecturer(s)	Prof. Dr. Anne Driemel, Dr. Benedikt Kolbe									
	Programme Mod			Seme	Semester					
Classification	M. Sc. Compu	iter Science	Optiona	al 2. or	3.					
Technical skills	Knowledge of	fundamental	theorem	s and cor	cepts in the are	ea of				
	computational	computational topology in particular, persistent homology and								
	topological da	topological data analysis; design and analysis of combinatorial								
	algorithms in	topological c	ontexts;	analysis c	of the complexit	y; to				
	apply this kno	wledge auto	nomously	to solvin	g new problems	s and				
	analysing new	analysing new data sets.								
Soft skills	Social compete	ence (commi	inication	presenti	ng one's own					
	solutions, goal	solutions, goal-oriented discussions in teams), methodical								
	competence (analysis, abstraction, proofs), individual									
	competence (c	competence (commitment and willingness to learn, creativity,								
	perseverance).									
Contents		-			and cohomology	7				
	theory and per		· ·	-	<u> </u>					
		-			or the computat					
	\ /	,		, –	nce modules an					
	_			-	theorems, quive	r				
	_	• ,			diagrams and					
	barcodes, alge			_		_				
	_	_		_	sistence, topolo	gical				
	data analysis,		_	_	= .					
	machine learni	ing, identific	ation of g	geometric	objects.					
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		S = inde	pendent s						
Exam achievements	Schriftliche Pr				(gra	aded)				
Study achievements	Erfolgreiche Ü	bungsteilnal	ime		(not gra	aded)				
Forms of media										
		,		` /	Computational					
					ematical Society	y.				
	• Steve Oudot (2015). Persistence Theory: From Quiver									
	Representations to Data Analysis (Vol. 209). American									
Literature	Mathematical	=								
	• Magnus Bak			,	022). An					
	Introduction t	-			<b>/</b>					
	• Allen Hatche	` ′	_	Topology	(Vol. 44).					
	Cambridge University Press.									

## 2 Graphics, Vision, Audio

MA-INF :	2113	L2E2	6 CP	Foundations of Audio Signal Processing	41
MA-INF	2201	L4E2	9 CP	Computer Vision	42
MA-INF	2203	L4E2	9 CP	Selected Topics in Signal Processing	43
MA-INF	2206	Sem2	4  CP	Seminar Vision	44
MA-INF	2207	Sem2	4  CP	Seminar Graphics	45
MA-INF	2208	Sem2	4  CP	Seminar Audio	46
MA-INF	2209	L4E2	9 CP	Advanced Topics in Computer Graphics I	47
MA-INF :	2212	L2E2	6 CP	Pattern Matching and Machine Learning for Audio Signa	.l
				Processing	
MA-INF	2213	L3E1	6  CP	Advanced Computer Vision	49
MA-INF :	2214	L2E2	6 CP	Computational Photography	50
MA-INF :	2215	Sem2	$4~\mathrm{CP}$	Seminar Digital Material Appearance	51
MA-INF :	2216	Lab4	9 CP	Lab Visual Computing	52
MA-INF :	2217	L2E2	6 CP	Advanced Deep Learning for Graphics	53
MA-INF	2218	L2E2	6 CP	Video Analytics	54
MA-INF	2219	Sem2	4 CP	Seminar Visualization and Medical Image Analysis	55
MA-INF	2220	Lab4	9 CP	Lab Visualization and Medical Image Analysis	56
MA-INF	2221	Sem2	4 CP	Seminar Visual Computing	57
MA-INF	2222	L4E2	9 CP	Visual Data Analysis	
MA-INF	2223	Sem2	4 CP	Seminar Advances in Multimodal Learning	59
MA-INF	2224	Lab4	9 CP	Lab Challenges in Computer Vision	60
MA-INF	2307	Lab4	9 CP	Lab Vision	61
MA-INF	2308	Lab4	9 CP	Lab Graphics	62
MA-INF	2309	Lab4	9 CP	Lab Audio	63
MA-INF	2310	L4E2	9 CP	Advanced Topics in Computer Graphics II	64
MA-INF	2312	L3E1	6 CP	Image Acquisition and Analysis in Neuroscience	65
MA-INF	2313	L2E2	6 CP	Deep Learning for Visual Recognition	
MA-INF	2314	L4E2	9 CP	Image Processing, Search and Analysis I	67
MA-INF	2315	L4E2	9 CP	Seminar Computational Photography	
MA-INF	2316	L4E2	9 CP	Lab Digital Material Appearance	
MA-INF	2317	L2E2	6 CP	Numerical Algorithms for Visual Computing and Machine	e
				Learning	70

Module	Foundations	Foundations of Audio Signal Processing						
MA-INF 2113								
Workload	Credit points	Duration	Freque	ency				
180 h	6 CP	1 semest	er every	year				
Module	apl. Prof. Dr.	Frank Ku	rth					
coordinator								
Lecturer(s)	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen							
Classification	Programme		Mode	Semes	ter			
Classification	M. Sc. Compu	iter Scienc	e Option	al   1.				
Technical skills	• Introduction	• Introduction to basic concepts of analog and digital signal						
	processing;	1 0/						
	Applications	• Applications in the field of Audio Signal Processing;						
	• Signal Proce	• Signal Processing Algorithms;						
	• Implementin	• Implementing basic Signal Processing Algorithms						
Soft skills	Solving basic S	Solving basic Signal Processing Problems; Implementing Signal						
	Processing Alg	gorithms u	sing state-o	of-the-art s	software			
	frameworks; C	apability t	to analyze;	Time man	agement;			
	Presentation s	kills; Discu	ussing own	solutions a	and solutions o	f		
	others, and wo	orking in g	roups.					
Contents			_	_	l Signal Proces	sing;		
	Fourier Transf	,	0		, 0			
	Filters; Audio	_		-	·			
	Windowed For	ırier Trans	sform; 2D-S	Signal Proc	cessing			
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	g; S = inde	pendent st	tudy			
Exam achievements	Written exam				(gra	ded)		
Study achievements	Successful exer				(not gra	ded)		
Forms of media	Slides, Blackbo	Slides, Blackboard, Whiteboard						
Literature								

Module MA-INF 2201	Computer	Vision							
Workload	Credit points	Duration	Freque	ency					
270 h	9 CP	1 semester							
Module	Prof. Dr. Jürg	gen Gall							
coordinator									
Lecturer(s)	Prof. Dr. Jürgen Gall								
Cl:64:	Programme		Mode	Seme	ster				
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	Productive work in small teams, development and realization of							
	individual app	individual approaches and solutions, critical reflection of							
	competing me	thods, discus	sion in g	roups.					
Contents	The class will	The class will cover a number of mathematical methods and							
		_			ample, linear fil				
	_ ,	, .		, –	tation, graph cu	ıts,			
	mean shift, ac				=				
	,	_		, _	oral filtering, a				
		, -	_	,	tracking, camera	· ·			
	,			,	pose estimation				
			, deform	able mest	nes, RGBD visio	on.			
Prerequisites	Recommended		, ,	1 .	1 1 111 1				
			lgebra, a	nalysis, p	probability theorem	ry,			
	C++ program		. 1		l				
_	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					
Exam achievements	Written exam				(gra	ded)			
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)			
Forms of media									
	• R. Hartley, A		: Multip	le View G	eometry in				
Literature	Computer Vis			_					
2100140410		-		-	and Application				
	• S. Prince: C	omputer Visi	on: Mod	lels, Leari	ning, and Infere	nce			

Module	Selected To	pics in Sign	nal Pro	ocessing				
MA-INF 2203								
Workload	Credit points	Duration	Freque	-				
270 h	9 CP	1 semester	every	year				
Module	apl. Prof. Dr.	Frank Kurth						
coordinator								
Lecturer(s)	apl. Prof. Dr.	Frank Kurth	, Prof. 1	Dr. Micha	nel Clausen			
Classification	Programme		Mode	Semes	ster			
Classification	M. Sc. Compu	iter Science	Option	al 2.				
Technical skills	Learning adva				-			
	techniques in	digital signal	processi	ng. Study	examples from	the		
	field of digital	audio signal	processi	ng with a	focus on music			
	audio. Develo	p skills for an	alysing	audio sign	als and designi	ng		
	audio features	for selected a	pplicati	on scenar	ios. Mathemati	cal		
	modelling of signal processing problems in practical applications.							
	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.							
Contents	Advanced techniques for filter design, design and extraction of							
	features describing multimedia signals, efficient DSP algorithms,							
	general concepts for content-based analysis of multimedia							
	signals. Selected signal processing applications, for example							
	content-based music analysis, signal compression, denoising,							
	source separation.							
Prerequisites	none							
	Teaching forms	at Gro	up size	h/week	Workload[h]	Cl		
Format	Lecture			4	60 T / 105 S	5.		
	Exercises			2	30  T / 75  S	3.		
	T = face-to-face teaching;  S = independent study							
Exam achievements	Written exam		- 11140	Politicality	(gra	ded		
Study achievements	Successful exe	rcise participa	tion		(not gra			
Forms of media		1 1			( 0			
	• Lecture script and selected research publications							
	• Hayes: Statistical Digital Signal Processing and Modelling,							
	John Wiley, 1996							
Literature			al Signa	l Processi	ing. Prentice Ha	all		
2110141410	• Proakis, Manolakis: Digital Signal Processing, Prentice Hall, 1996							
	• Klapuri, Davy: Signal Processing, Methods for Music Transcription, Springer, 2006							

Module MA-INF 2206	Seminar Vision							
Workload	Credit points	Duration	Frequen	ıcv				
120 h	4 CP	1 semester	1 1 1 1 1					
Module								
	Prof. Dr. Jürgen Gall							
coordinator	D ( D 1"	G 11						
Lecturer(s)	Prof. Dr. Jürg	Prof. Dr. Jürgen Gall						
Classification	Programme		$\mathbf{Mode}$	Semest	ter			
Classification	M. Sc. Compu	iter Science	Optional	2. or 3.				
Technical skills	Ability to und	Ability to understand new research results presented in original						
	scientific pape	scientific papers.						
Soft skills	Ability to pres	sent and to c	ritically di	scuss the	se results in th	ne		
	framework of		•					
Contents	Current confer							
Prerequisites	Required:	<del></del>						
•	MA-INF 2201	- Computer	Vision					
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	tion, written	report		(gra	ded)		
Study achievements					(not gra	ded)		
Forms of media								
Literature								

Module MA-INF 2207	Seminar Graphics						
Workload	Credit points	Duration		Frequen	ıcv		
120 h	4 CP	-     - · · ·					
Module	Prof. Dr. Reinhard Klein						
coordinator							
Lecturer(s)	Prof. Dr. Reir	nhard Kleir	ı				
Classification	Programme		$\mathbf{N}$	Aode	Semest	ter	
Classification	M. Sc. Compu	iter Science	e C	)ptional	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 t	the corresp	ondi	ing area			
Contents	Current confer	ence and j	ourn	al pape	rs.		
Prerequisites	Recommended	:					
	Mathematical	backgroun	d (m	$\operatorname{nultidim}$	ensional a	analysis and lin	near
	algebra, basic	numerical	metl	hods)			
	Basic knowled	ge in Com	outei	r Graph	ics		
<b>-</b>	Teaching forms	at	Grou	ıp size	h/week	Workload[h]	CP
Format	Seminar		1	10	2	30 T / 90 S	4
	T = face-to-fa	ce teaching	;; S =	= indep	endent st	udy	
Exam achievements	Oral presentat	ion, writte	n rep	port		(gra	ded)
Study achievements						(not gra	ded)
Forms of media							
Literature							

Module MA-INF 2208	Seminar Audio						
Workload	Credit points	Credit points   Duration   Frequency					
120 h	4 CP						
Module	apl. Prof. Dr.	apl. Prof. Dr. Frank Kurth					
coordinator							
Lecturer(s)	apl. Prof. Dr. Frank Kurth, Dr. Michael Clausen						
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	iter Science	Optional	2.	2.		
Technical skills	Ability to understand new research results presented in original						
	scientific paper	scientific papers.					
Soft skills	Ability to pres	sent and to c	ritically dis	scuss the	se results in th	ne	
	framework of t	the correspon	nding area.				
Contents	Current confer	rence and jou	ırnal paper	s.			
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 = indepe	endent st	udy		
Exam achievements	Oral presentat	tion, written	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature							

Module	Advanced T	onics in	Comp	utor Gran	hics I			
MA-INF 2209	Advanced	opics ii	Comp	uter Grap	ilics i			
Workload	Credit points	Duration	n Frequ	iency				
270 h	9 CP	1 semest	_	=				
Module	Prof. Dr. Reinha		or cvery	<i>y</i> 001				
coordinator	1 Tol. Dr. Itelinia	ra mom						
Lecturer(s)	Prof. Dr. Reinha	rd Klein						
, ,	Programme	1110111	Mode	Semester				
Classification	M. Sc. Computer Science   Optional   2. or 3.							
Technical skills	_				ng. Knowledge of			
	principles, techni				0			
		_	_		light transport			
	_	<ul> <li>recognize and understand the physical quantities of light transport</li> <li>explain a range of surface and volumetric material models</li> </ul>						
	• explain the ren							
	_	_		_	ions, especially Monte			
	Carlo methods	icinciii inc	inous to so	ive these equat	ions, especially wonte			
	• Assess / Evalua	ate the per	formance a	nd conceptual	limits of the			
	implemented sim			na conceptadi				
Soft skills				uired students	should be able to			
Soft Skills		_	_					
		<ul> <li>read and judge current scientific literature in the area of rendering</li> <li>identify the major literature concerning a given problem in rendering and</li> </ul>						
	_	-			blem in rendering and			
	gain an overview				hana frans different			
	application fields	is concerni	ng rendern	ig with research	hers from different			
	1 1 1	o and com	municata d	ifferent colution	as and work in a toam			
		• present, propose and communicate different solutions and work in a team to solve a rendering problem						
Contents	This course intro			cal quantities a	s well as the			
Contents				_				
	mathematical and algorithmic tools required to understand and simulate the 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 in							
		_	_	_	Markov Chain Monte			
	Carlo Methods.		_					
	• rendering and n	_	_					
	_		_		adiosity, Monte Carlo,			
	photon mapping	.801101111115 0	o borve the	se equations, re	acrosity, monte carro,			
	• analytical and	data driver	surface ar	nd subsurface n	naterial models.			
	especially BRDF			ra babbarraco n	indication into doils,			
	• differentiable re							
	In addition, resul	_	to of the n	rt rosoorah will	he presented			
Prerequisites	Recommended		ite-oi-tile-a	it research will	be presented.			
Trerequisites			rcod: basic	knowledge in	computer graphics,			
	(numerical) analy			_	computer grapmes,			
	Teaching forma		Group s	·	Workload[h]   CP			
Format	Lecture			4	60 T / 105 S 5.5			
=======	Exercises			2	30 T / 75 S 3.5			
		l Localina C	in don on	ı	00 1 / 10 2   0.0			
T	T = face-to-face			ident study	( 1- 1)			
Exam achievements Study achievements	Oral presentation		_		(graded)			
•	Successful exercis	se participa	1011		(not graded)			
Forms of media	M Dham W	lalrah 1	C II	morra Dharaina 11	r Dogod Dandarin			
	From Theory to 1				y Based Rendering:			
					Illumination Institute			
	_				Illumination, Institute			
Literature					ogy, Vienna, 1999 URL:			
	https://cg.iit.bme				umination, 2nd ed.,			
	B&T, 2006	ла, г. рек	aeri. Auva	ncea Giobai III	ummation, zhu eu.,			
		Δ Hitabb	ikor'e Cuid	e to Multiple S	Scattering 2016			
	• D'Eon, Eugene. A Hitchhiker's Guide to Multiple Scattering, 2016							

Module	Pattern Matching and Machine Learning for Audio							
MA-INF 2212	Signal Processing							
Workload	Credit points Dura	tion	Freque	ncy				
180 h	6 CP 1 se	mester	ester every year					
Module	apl. Prof. Dr. Frank Kurth							
${f coordinator}$								
Lecturer(s)	apl. Prof. Dr. Frank	Kurth	, Prof. D	r. Michae	el Clausen			
Classification	Programme		Mode	Semest	ter			
Classification	M. Sc. Computer Sc	eience	Optiona	l   2.	2.			
Technical skills	• Introduction into selected topics of digital signal processing;							
	• 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;			*	_	ions		
	and solutions of others, and working in groups.							
Contents	The lecture is presen			,				
	motivated from the			-	•	re:		
	Windowed Fourier t		,		,			
	Matching; Signal Cl		ion; Hide	den Mark	ov Models;			
	Support Vector Mac	hines						
Prerequisites	none				T			
	Teaching format	Gro	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 tea	ching; S	S = indep	endent st	tudy			
Exam achievements	Written exam				(gra	ded		
Study achievements	Successful exercise p				(not gra	$\overline{\mathrm{ded}}$		
Forms of media	Slides, Blackboard, Whiteboard							
Literature								

Module	Advanced C	Computer	Vision				
MA-INF 2213							
Workload	Credit points	Duration	Freque	Frequency			
180 h	6 CP	1 semest	er every	year			
Module	Prof. Dr. Jürg	gen Gall					
coordinator							
Lecturer(s)	Prof. Dr. Jürg	gen Gall					
Classification	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optiona	$1 \mid 2$ . or $3$	3.		
Technical skills		Students will learn about various learning methods and their applications to computer vision problems.					
Soft skills	Productive wo	Productive work in small teams, development and realization of					
	individual app	individual approaches and solutions, critical reflection of					
	competing methods, discussion in groups.						
Contents	The class will cover a number of learning methods and their applications in computer vision. For example, linear methods for classification and regression, boosting, random forests, neural networks, SVMs, prototype methods, nearest neighbors, Gaussian processes, metric learning, structured learning, image classification, object detection, action recognition, pose estimation, face analysis, tracking.						
Prerequisites	Required:						
	MA-INF 2201	- Comput	er Vision				
	Teaching forms	at	Group 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 = inde	pendent st	tudy		
Exam achievements	Oral exam				(gra	ded)	
Study achievements	Successful exe	rcise partic	ipation		(not gra	ded	
Forms of media							
Literature		<u> </u>					

Module MA-INF 2214	Computation	nal Phot	ography					
Workload	Credit points	Duration	Freque	ncy				
180 h	6 CP	1 semeste	er every year					
Module	Prof. Dr. Mat	thias Hullin	1					
coordinator								
Lecturer(s)	Prof. Dr. Mat	Prof. Dr. Matthias Hullin						
Classification	Programme		Mode	Semest	ter			
Classification	M. Sc. Compu	iter Science	Optiona	2. or 3	3.			
Technical skills	Foundations in	optics and	image sen	sors. Sign	nal processing a	and		
	inverse proble	ms in imagi	ng. Color s	paces and	d perception.			
	Image alignme	ent and bler	ding. High	-dimensio	onal			
	representation	s of light tr	ansport (lig	ght fields,	reflectance fiel	lds,		
	reflectance dis	tributions).	Computat	ional illui	mination.			
Soft skills	• to read and	understand	current lit	erature in	the field			
			•		ography technic	ques		
	• to propose and implement solutions to a given problem							
	• to follow goo	od scientific	practice by	y planning	g, documenting	g		
	and communic	eating their	work					
Contents	• Image sensor	rs						
	• Optics							
	• Panoramas							
	• Light fields							
	• Signal proce			lems				
	• Color, perce	_						
	• Reflectance	fields and li	ght transpo	ort matric	ees			
Prerequisites	Required:							
	Basic knowled	_						
		_		_	numerical anal	lysis		
	and numerical							
	Teaching forms	at C	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				(gra	ded)		
Study achievements	Successful exe	rcise partici	pation		(not gra	ded)		
Forms of media						*		
Literature								

Module MA-INF 2215	Seminar Di	gital Mate	rial App	earance	9		
Workload	Credit points	Duration	Frequen	cy			
120 h	4 CP	4 CP   1 semester   every year					
Module	Prof. Dr. Mat	Prof. Dr. Matthias Hullin					
coordinator							
Lecturer(s)	Prof. Dr. Matthias Hullin						
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	iter Science	Optional	2.	2.		
Technical skills	Ability to und	Ability to understand new research results presented in original					
	scientific paper	scientific papers.					
Soft skills	Ability to pres	sent and to c	ritically di	scuss the	ese results in th	ıe	
	framework of t	the correspon	nding area.				
Contents	Current confer	ence and jou	ırnal papeı	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 = independent	endent st	udy		
Exam achievements	Oral presentat	ion, written	report		(gra	ded	
Study achievements		(not graded)					
Forms of media							
Literature							

Module	Lab Visual	Computin	$\mathbf{g}$				
MA-INF 2216							
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semeste	every	year			
Module	JunProf. Dr. Florian Bernard						
coordinator							
Lecturer(s)	JunProf. Dr.	Florian Be	rnard				
Classification	Programme		Mode	Semes	ster		
Classification	M. Sc. Compu	iter Science	Option	al   1-3.			
Technical skills	Students will of	Students will carry out a practical task (project) in the context					
	of visual comp	of visual computing, including test and documentation of the					
	implemented s	implemented software/system.					
Soft skills	Ability to prop	Ability to properly present and defend design decisions, to					
	prepare readal	ole documen	tation of	software;	skills in		
	constructively	collaboratin	g with ot	thers in sr	nall teams over	a	
	longer period	of time; abil	ty to clas	ssify ones	own results inte	o the	
	state-of-the-ar						
Contents			-	0	ds and applicati	ions.	
	You will get a						
			_	_	s. At the end of	the	
	semester, you	will present	the meth	od, give a	a short		
			a repor	t describii	ng the method	and	
	experimental of	outcomes.					
Prerequisites	none						
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP	
Tormat	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	$\operatorname{ided})$	
Forms of media							
Literature							

Module	Advanced I	Deep Lea	rning fo	r Graphi	cs		
MA-INF 2217		•	J	•			
Workload	Credit points	Duration	Freq	uency			
180 h	6 CP	1 semest	er ever	r every year			
Module	Prof. Dr. Rein	hard Klei	1				
coordinator							
Lecturer(s)	Dr. Michael V	Dr. Michael Weinmann					
CI 'C '	Programme		Mode	Semes	ster		
Classification	M. Sc. Compu	ıter Scienc	Optio	nal   1-4.			
Technical skills	Students will l	be introdu	ed to ad	apt and app	oly deep learnin	ıg	
	techniques to	techniques to various applications in computer graphics.					
Soft skills	Productive wo	Productive work in small teams, development and realization of					
	individual app	ndividual approaches and solutions, critical reflection of					
	competing me	competing methods, discussion in groups.					
Contents	This course fo	This course focuses on cutting-edge Deep Learning techniques					
	for computer graphics. After a brief review of CNNs the focus						
	will be laid on autoencoders, generative models and the						
	extension of these methods to graph- and manifold-structured						
	data. Applicat	tions discu	sed will	include inve	erse problems ir	1	
	computer grap	ohics and t	ne synthe	sis of mode	els including dat	ta	
	completion an	d super-res	olution.		<u> </u>		
Prerequisites	Recommended	:					
	The course wil	ll build up	on the ba	sics of mach	nine learning as	well	
	as fundamenta	als and bas	ic archite	ctures of ne	eural networks.		
	Therefore, it is	s highly re	commend	ed to have	taken Deep		
	Learning for Visual Recognition or a similar course as a						
	prerequisite. I	Exercises w	ill be a n	ix of theor	y and practical		
	(Python).						
	Teaching forms	at	Group siz	e 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 = inc	lependent s	tudy		
Exam achievements	Written exam		,,			ded)	
Study achievements	Successful exe	rcise partic	ipation		(not gra		
Forms of media			-		, 0		
Literature	No required to	ext, supple	nental re	adings will	be given in clas	SS.	

Module MA-INF 2218	Video Anal	ytics					
Workload	Credit points	Duration	Frequer	ncv			
180 h	6 CP	1 semester	_	every 2	vears		
Module	Prof. Dr. Jürg	Prof. Dr. Jürgen Gall					
coordinator	O .						
Lecturer(s)	Prof. Dr. Jürg	gen Gall					
	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	iter Science	Optional	1 2-3.			
Technical skills	Students will l	earn advanc	ed techniq	ues for an	alyzing video o	lata.	
Soft skills	Productive work in small teams, development and realization of						
	a state-of-the-	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 exam	nple, video	clip class	sification, temp	oral	
	video segment	ation, spatic	-temporal	action de	etection, video		
	context, spatio	o-temporal n	nodeling of	f humans	and objects,		
	anticipation, a segmentation.	ffordance, v	deo summ	narization	, semantic vide	eo	
Prerequisites	Required:						
•	MA-INF 2201	– Computer	Vision				
	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	Oral exam				(gra	ded)	
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)	
Forms of media							
Literature							

Module	Seminar Vi	sualizatio	and Me	edical Ir	nage Analys	sis	
MA-INF 2219							
Workload	Credit points	Duration	Frequer	ncy			
120 h	4 CP	CP 1 semester   every semester					
Module	Prof. Dr. Tho	mas Schultz					
coordinator							
Lecturer(s)	Prof. Dr. Tho	mas Schultz					
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	Optional	$\lfloor 2.$				
Technical skills	_	Ability to understand new research results presented in original scientific papers.					
Soft skills	Ability to pres	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	independent search for relevant scientific literature.					
Contents	Current confer	ence and jo	urnal pape	ers			
Prerequisites	Recommended	:					
	At least one of	f the followi	ng:				
	• MA-INF 222	22 - Visual	Data Analy	ysis			
	• MA-INF 231	12 - Image  A	$\Lambda_{ m cquisition}$	and Ana	lysis in		
	Neuroscience						
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	$\overline{\operatorname{ded}}$	
Forms of media							
Literature							

Module	Lab Visuali	zation and	d Medic	al Imag	e Analysis		
MA-INF 2220							
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semeste	r every	every semester			
Module	Prof. Dr. Tho	mas Schultz	i				
coordinator							
Lecturer(s)	Prof. Dr. Thomas Schultz						
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Option	al 2.			
Technical skills	The students	will carry ou	ıt a pract	ical task (	(project) in the		
	context of data	a visualizati	on and vi	sual analy	ytics or medical		
	image analysis	s, including	test and o	documenta	ation of the		
		implemented software/system.					
Soft skills	Ability to properly present and defend design decisions, to						
	prepare readable documentation of software; skills in						
			_		nall teams over		
	0 .	,		ssify ones	own results into	o the	
	state-of-the-ar	t of the resp	o. area				
Contents							
Prerequisites	Recommended						
	At least one of	f the followi	ng:				
	• MA-INF 222	22 - Visual	Data Ana	lysis			
	• MA-INF 231	12 - Image	Acquisitio	n and An	alysis in		
	Neuroscience						
Format	Teaching forms	at Gı	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	ded	
Study achievements					(not gra	ded	
Forms of media							
Literature							

Module	Seminar Vis	sual Comp	$\mathbf{uting}$				
MA-INF 2221							
Workload	Credit points	Duration	Freque	•			
120 h	4 CP	1 semester	er at least every year				
Module	JunProf. Dr.	Florian Ber	rnard				
coordinator							
Lecturer(s)	JunProf. Dr.	JunProf. Dr. Florian Bernard					
Classification	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optiona	l 2. or 3	3.		
Technical skills	Ability to und	erstand new	research	esults pro	esented in origin	nal	
	scientific paper	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	Current conference and journal papers.					
Prerequisites	Required:						
	No formal requ	uirements. F	articipant	s are exp	ected to have se	ome	
	previous expos	sure to at lea	ast one of	the follow	ving:		
	- visual compu	iting (e.g. co	omputer vi	ision, com	puter graphics.	, 3D	
	shape analysis	, image anal	ysis, etc.),				
	- mathematica	l optimisation	on (e.g. co	mbinator	ial/continuous,		
	convex/non-co	onvex, etc.),	or		,		
	- machine lear	ning.					
D .	Teaching forms	at G	roup size	h/week	Workload[h]	$\mathbf{CP}$	
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		(grad	ded)	
Study achievements					(not grad	ded)	
Forms of media							
Literature							

Module MA-INF 2222	Visual Data	Analysis					
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semester	ster every year				
Module	Prof. Dr. Tho	mas Schultz					
coordinator							
Lecturer(s)	Prof. Dr. Tho	mas Schultz					
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	M. Sc. Computer Science   Optional   1-4.					
Technical skills	for visual data techniques for	Ability to design, implement, and make proper use of systems for visual data analysis. Knowledge of algorithms and techniques for the visualization of multi-dimensional data,					
Soft skills	Productive wo practical proble reflection on v	graphs, as well as scalar, vector, and tensor fields.  Productive work in small teams, self-dependent solution of practical problems in the area of visual data analysis, critical reflection on visualization design, presentation of solution strategies and implementations, self management					
Contents	This class provides a broad overview of principles and algorithms for data analysis via interactive visualization.  Specific topics include perceptual principles, luminance and color, visualization analysis and design, integration of visual with statistical data analysis and machine learning, as well as specific algorithms and techniques for the display of multidimensional data, dimensionality reduction, graphs, direct and indirect volume visualization, vector field and flow visualization, as well as tensor field visualization.						
Prerequisites	Recommended Students are r	: ecommended dculus, as we	to have	a basic k	nowledge in line n programming. Workload[h]		
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	ee vaaeg, ,	3 11140	Politicality		ded)	
Study achievements	Successful exer	rcise particip	ation		(not gra		
Forms of media					(	/	
Literature	Press, Second M. Ward et al Techniques, ar	A.C. Telea, Data Visualization: Principles and Practice. CRC Press, Second Edition, 2015  M. Ward et al., Interactive Data Visualization: Foundations, Techniques, and Applications. CRC Press, 2010  T. Munzner, Visualization Analysis and Design, A K Peters,					

Module	Seminar Ad	vances i	n Multim	odal Lea	arning		
MA-INF 2223		.,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		.0 01012 2201			
Workload	Credit points	Duration	Freque	ncy			
120 h	4 CP	1 semest	_	semester			
Module	Prof. Dr. Hild	egard Kül	ne				
coordinator							
Lecturer(s)	Prof. Dr. Hild	Prof. Dr. Hildegard Kühne					
Cl:64:	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	M. Sc. Computer Science   Optional   2.					
Technical skills	Presentation o	f selected	advanced to	opics in co	mputer vision	and	
	multimodal learning and various applications						
Soft skills	Ability to perform individual literature search, critical reading,						
		understanding, and clear didactic presentation					
Contents		This seminar will cover most recent advancements and					
	publications in multimodal learning, which is the integration of						
	multiple data	sources or	multiple m	odalities f	or more comple	ex	
	machine learni	ing applica	tions. This	can also i	include reviews	of	
	emerging tech	niques, inc	luding unsu	pervised a	approaches, de	ep	
	learning, trans	fer learnin	g, and rein	forcement	learning to		
	combine multi	ple modali	ties such as	images, a	audio, video, jo	int	
	feature learnin	g, and nat	ural langua	ge process	sing. It can fur	ther	
	cover techniqu	es for data	fusion and	the role	they play in		
	successful app	lications of	multimod	al learning	g. Students will	l	
	have an oppor	tunity to $\epsilon$	valuate and	d experime	ent with public	;	
	code if availab	le. Goel is	to develop	a better ı	understanding	of	
	the possibilities and challenges of multimodal learning.						
Prerequisites	Required:						
	none						
Format	Teaching forms	at	Group size	h/week	Workload[h]	CP	
rormat	Seminar		10	2	30 T / 90 S	4	
	T = face-to-fa	ce teaching	S = inde	pendent st	tudy		
Exam achievements	Oral presentat			-		ded)	
Study achievements	Erfolgreiche Ü				(not gra		
Forms of media							
Literature	The relevant li	iterature w	The relevant literature will be announced in time.				

Module MA-INF 2224	Lab Challer	nges in Co	mputer	Vision			
Workload	Credit points	Duration	Freque	ncy			
270 h	9 CP	1 semester		emester			
Module	Prof. Dr. Hild	legard Kühne					
coordinator		O					
Lecturer(s)	Prof. Dr. Hildegard Kühne						
	Programme	_	Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Optiona	l 2.			
Technical skills	Students will o	carry out a p	ractical ta	ask (proj	ect) in the cont	ext	
	of computer v	ision and/or	$\operatorname{multimod}$	lal learni	ng, including		
	evaluation and	•					
	software/system.						
Soft skills	, ,		valuate a	scientifi	c approach; abi	lity	
	-				the-art of the re	-	
	area; skills in	constructively	y collabor	ating wi	th others in sm	$\overline{\mathrm{all}}$	
		teams over a longer period of time.					
Contents	This Programming Project focuses on exploring the challeng						
	modern Computer Vision algorithms and model development.						
	The project will track the latest progress in the field and the						
	associated challenges in different application areas, such as video						
	understanding as well as general computer vision topics. The						
	project will in	_		_	=		
	techniques in o	current comp	uter visio	n system	ns to identify an	nd	
	=	_		-	comparison to p		
	=				standing of the		
			-		ch as generaliza		
					insights on the		
				-	ology in respons	e to	
	upcoming chal	_					
Prerequisites	Required:						
	Practical expe	rience in dee	p learning	r S			
T	Teaching forms	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	'	
Exam achievements	Oral presentat					ded)	
Study achievements	Erfolgreiche Ü				(not gra		
Forms of media	0	<u> </u>			( 8	/	
Literature							

Module MA-INF 2307	Lab Vision							
Workload	Credit points	Duration	n	Freque	ency			
270 h	9 CP	1 semes	ster	-	semester			
Module	Prof. Dr. Jürg	Prof. Dr. Jürgen Gall						
coordinator		G .						
Lecturer(s)	Prof. Dr. Jürg	Prof. Dr. Jürgen Gall						
Classification	Programme		I	Mode	Seme	ster		
Classification	M. Sc. Compu	ter Scien	ce (	Option	al   2. or	3.		
Technical skills	The students v	will carry	out a	a pract:	ical 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: research	ch top	pics and	d applicat	ions		
Prerequisites	Required:							
	MA-INF 2201	– Compu	iter V	ision				
	Good C++ pr	ogrammi	ng sk	ills				
Format	Teaching forma	at	Grou	p size	h/week	Workload[h]	CP	
roimat	Lab		8	8	4	60 T / 210 S	9	
	T = face-to-fa		<u> </u>		pendent s	study		
Exam achievements	Oral presentat	ion, writt	en re	port		(gra	ded	
Study achievements						(not gra	ded	
Forms of media								
	A. Fossati, J. Gall, H. Grabner, X. Ren, K. Konolige. Consumer						ımer	
Literature	Depth Cameras for Computer Vision: Research Topics and							
	Applications							

Module MA-INF 2308	Lab Graphi	cs					
Workload	Credit points	Duration		Freque	ncy		
270 h	9 CP 1 semester   every semest			semester			
Module	Prof. Dr. Reinhard Klein						
coordinator							
Lecturer(s)	Prof. Dr. Reir	hard Klei	n				
Classification	Programme		]	Mode	Seme	ster	
Classification	M. Sc. Compu	iter Scienc	е (	Optiona	.l 3.		
Technical skills		·		•		(project) in the	
		context of geometry processing, rendering, scientific visualization					
	or human com	or human computer interaction, including test and					
	documentation	of the im	pler	mented s	software/	system.	
Soft skills	Ability to prop	perly prese	nt a	and defe	nd design	n decisions, to	
	prepare readal				· · · · · · · · · · · · · · · · · · ·		
			_			nall teams over	
		,			sify ones	own results into	the the
	state-of-the-ar		•				
Contents	Varying selected topics close to current research in the area of						
	geometry processing, rendering, scientific visualization or human						man
	computer inter	raction.					
Prerequisites	none					I	
Format	Teaching forms	at C		p size	h/week	Workload[h]	CP
	Lab		Č	8	4	60 T / 210 S	9
	T = face-to-fa	ce teaching	g; S	= indep	pendent s	study	
Exam achievements	Oral presentat	ion, writte	n re	eport		(gra	ded)
Study achievements						(not gra	ded)
Forms of media							
Literature							

Module	Lab Audio					
MA-INF 2309						
Workload	Credit points	Duration	Frequ	ency		
270 h	9 CP	1 semest	er   every	year		
Module	apl. Prof. Dr.	Frank Ku	rth			
coordinator						
Lecturer(s)	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen					
Classification	Programme		Mode	Seme	ster	
Classification	M. Sc. Compu	iter Science	e Option	al 3.		
Technical skills	The students will carry out a practical task (project) in the					
	context of audio and music processing, including test and					
	documentation of the implemented software/system.					
Soft skills	Ability to prop	perly prese	nt and def	end design	n decisions, to	
	prepare readal	ole docume	ntation of	software;	skills in	
	constructively	collaborat	ing with o	thers in sr	mall teams over	a
	longer period	of time; ab	ility 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 s	study	
Exam achievements	Oral presentat	ion, writte	n report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
Literature						

Module MA-INF 2310	Advanced T	Copics in C	Compute	er Graph	nics II			
Workload	Credit points	Duration	Freque	ncy				
270 h	9 CP	1 semester	every ye					
Module	Prof. Dr. Reinh	ard Klein						
coordinator								
Lecturer(s)	Prof. Dr. Reinh	ard Klein						
Cl. 10 11	Programme	]	Mode	Semester				
Classification	M. Sc. Comput	er Science	Optional	3.				
Technical skills	Analytical form	Analytical formulation of problems related to geometry processing:						
	<ul><li>apply basic coreal world appli</li><li>Design and in</li></ul>	<ul> <li>apply methods of geometry processing</li> <li>apply basic concepts of statistical shape analysis and shape spaces to real world applications</li> <li>Design and implement novel application software in this area</li> </ul>						
Soft skills	Based on the kr	nowledge and	skills acqu	uired stude	nts should be able to			
	<ul><li>processing and</li><li>identify the m</li><li>geometry proces</li><li>present, propo</li></ul>	<ul> <li>read and judge current scientific literature in the area of geometry processing and gain an overview of the current state of the art</li> <li>identify the major literature relevant for solving a given problem in geometry processing</li> <li>present, propose and communicate different solutions and work in a team to solve geometry processing problems</li> </ul>						
	• discuss geome	try processin	g problem:	s with resea	archers from different			
	application field							
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							
	<ul> <li>classical and discrete differential geometry of curves and surfa</li> <li>mesh data structures and generation of meshes from point clo</li> <li>Laplacian operator and optimization techniques with applicat denoising, smoothing, decimation, shape fitting, shape descriptor geodesic distances</li> <li>parameterization and editing of surfaces</li> <li>point cloud registration</li> <li>correspondences</li> <li>shape spaces and statistical shape analysis</li> </ul>							
					will be presented.			
Prerequisites	none	uros mom stat	C-O1-011E-al	i i research	win be bresented.			
1 rerequisites	Teaching forma	at C	roup size	h/week	Workload[h] CP			
Format	Lecture Lecture	G	roup size	11/ week	60 T / 105 S 5.5			
Tormat	Exercises			2	30 T / 75 S   3.5			
		1. 0	. 1	1	00 1 / 10 5   0.0			
-	T = face-to-face	e teaching; S	= indepen	ident study	/ 1 1			
Exam achievements	Oral exam	· · · · ·	•		(graded)			
Study achievements	Successful exerc	ise participat	ion		(not graded)			
Forms of media	- M D-4 1 T	Volatab M	Dar-1 D	111: <sub>5</sub> D T	over Dol Mr. 1			
Literature	<ul> <li>M. Botsch, L. Kobbelt, M. Pauly, P. Alliez, B. Levy, Polygon Processing, A K Peters, 2010</li> <li>Laga, Hamid, Yulan Guo, Hedi Tabia, Robert B. Fisher, and Mohammed Bennamoun. 3D Shape analysis: fundamentals, the and applications. John Wiley &amp; Sons, 2018.</li> </ul>							
	• Solomon, Just Peters/CRC Pre		ıı Algorith	ms. Textbo	ook published by AK			

Module	Image Acqu	uisition and	l Analys	sis in N	euroscience			
MA-INF 2312		T	T_					
Workload	Credit points	Duration	Frequer	-				
180 h	6 CP   1 semester   at least every 2 years							
Module	Prof. Dr. Tho	omas Schultz						
coordinator	- A	~						
Lecturer(s)		Prof. Dr. Thomas Schultz						
Classification	Programme		Mode	Semes	ter			
	M. Sc. Compu		Optional					
Technical skills		Students will learn about image acquisition and analysis						
					y will understa			
	_	_			removal, image			
	_	_			ant statistical			
			_		us will be on d			
	from Magnetic Resonance Imaging and on mathematical models							
	for functional							
Soft skills	Productive work in small teams, self-dependent solution of							
	practical problems in the area of biomedical image processing,							
	presentation of solution strategies and implementations, self							
	management, critical reflection of conclusions drawn from							
	complex exper							
Contents			_		nd analysis pip	eline		
	that is typical			,	_			
	acquisition to		sing and	statistical	l analysis.			
Prerequisites	Recommended		,			`		
	Mathematical background (calculus, linear algebra, statistics);							
	imperative pro				I			
	Teaching form	at Gr	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	udy			
Exam achievements	Oral exam				(gra	ded)		
Study achievements	Successful exe	rcise particip	ation		(not gra			
Forms of media								
	• B. Preim, C. Botha: Visual Computing for Medicine: Theory,							
	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							
	• D.K. Jones:	Diffusion MI	RI: Theor	y, Method	d, and			
	Applications, Oxford University Press, 2011							

Module	Deep Learn	ing for '	Visi	ual Rec	ognitio	n		
MA-INF 2313		ı		ı				
Workload	Credit points	Duration		Frequency				
180 h	6 CP   1 semester   every year							
Module	Prof. Dr. Rein	nhard Klei	n					
coordinator								
Lecturer(s)	Dr. Michael V	Veinmann						
Classification	Programme			$\mathbf{Mode}$	Semes	ter		
Classification	M. Sc. Compu	ıter Scienc	e	Optional	1-4.			
Technical skills	Students will	be introdu	ced	to the th	neory of n	eural networks	s and	
	study various	application	ns ir	n comput	er vision	and other topi	ics in	
	AI.							
Soft skills	Productive wo	ork in sma	ll te	ams, dev	elopment	and realizatio	n of	
	individual approaches and solutions, critical reflection of							
	competing methods, discussion in groups.							
Contents	Deep learning has taken over the machine learning community							
	by storm, with success both in research and commercially. Deep							
	learning is applicable over a range of fields such as computer							
	vision, speech recognition, natural language processing, robotics,							
	etc. This course will introduce the fundamentals of neural							
	networks and then progress to state-of-the-art convolutional and							
	recurrent neural networks as well as their use in applications for							
	visual recognition. Students will get a chance to learn how to							
	implement and train their own network for visual recognition							
	tasks such as object recognition, image segmentation and							
	caption generation.							
Prerequisites	Recommended	l <b>:</b>						
	Students are r					=		
	probability an				_			
	proficiency in	programm	ning	(python	or Matla	b  or  C++).		
	Teaching form	at	Gro	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 teachin	g; S	= index	endent st	tudy		
Exam achievements	Oral exam		J, .5	^ <b>r</b>			ided)	
Study achievements	Successful exe	rcise parti	cipa	tion		(not gra		
Forms of media		F	r			( 11 8-4	)	
	No required to	ext. Suppl	eme	ntal read	ings will	be provided in	the	
Literature	lecture.	э эчррг		1111 1000	-0~ …11	r-s/raca III		

Module MA-INF 2314	Image Proc	essing, Se	earch an	d Analy	rsis I			
Workload	Credit points	Duration	Freque	ency				
270 h	9 CP	1 semeste	er every	year				
Module	Prof. Dr. Chri	istian Bauc	khage					
coordinator								
Lecturer(s)	Prof. Dr. Chri	istian Bauc	khage					
Classification	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	ter Science	Option	al   2. or	3.			
Technical skills	Upon complete	ion, studen	s should	be able to	1			
	<ul> <li>implement basic and advanced methods for digital image processing</li> <li>implement simple and advanced algorithms for image filtering</li> <li>implement algorithms for creating artistic image effects</li> <li>implement algorithms for image warping</li> <li>implement algorithms for image morphing</li> <li>implement algorithms for color and intensity manipulation</li> </ul>							
	• design and implement their own algorithms for image							
Soft skills  Contents	<ul> <li>design and implement their own algorithms for image processing</li> <li>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.</li> <li>technical foundations / hardware aspects of digital photography</li> <li>mathematical representations of digital images</li> <li>coordinate systems and coordinate transformations</li> <li>Fourier transforms and convolutions</li> <li>low- band-, and high pass filtering</li> <li>mean- and Gaussian filtering</li> <li>median filtering and morphological operations</li> <li>efficient implementations of various kinds of filters</li> <li>interpolation methods</li> <li>artistic image effects</li> <li>image warping</li> <li>image morphing</li> <li>physiological foundations of color perception</li> </ul>							
	• color manipu	ılation						
Prerequisites	none	ı		l	T	1		
Format	$\frac{\text{Teaching forms}}{\text{Lecture}}$ $\text{Exercises}$ $T = \text{face-to-fa}$		S = inde	h/week 4 2 ependent s	Workload[h]   60 T / 105 S   30 T / 75 S   study	5.5 3.5		
Exam achievements	Written exam			•		ided)		
Study achievements	Successful exer	rcise partici	pation		(not gra			
Forms of media	• lecture slides			online	( 810			
					are made availa	ble		
Literature	<ul><li>Gonzales and</li><li>Jähne, "Digi</li></ul>				essing"			

Module MA-INF 2315	Seminar Computational Photography						
Workload	Credit points	Duration	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	Optiona	al 2. or	3.		
Technical skills	Ability to und	Ability to understand new research results presented in original					
	scientific pape	scientific papers.					
Soft skills	Ability to pres	sent and to c	ritically of	discuss th	ese results in th	ne	
	framework of	the correspon	nding are	a.			
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	Appeara	ance			
MA-INF 2316							
Workload	Credit points	Duration	Freque	ncy			
270 h	9 CP	1 semester	ester every year				
Module	Prof. Dr. Mat	thias Hullin	·				
coordinator							
Lecturer(s)	Prof. Dr. Mat	thias Hullin					
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Optiona	d 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	documentation of the implemented software/system.					
Soft skills	Ability to prop	perly present	and defe	nd design	n decisions, to		
	prepare readal	ole document	ation of	software;	skills in		
	constructively	collaboratin	g with ot	hers in sr	nall teams over	a	
	longer period	of time; abili	ty to clas	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 = inde	pendent s	study		
Exam achievements	Oral presentat	ion, written	report		(gra	ded	
Study achievements					(not gra	$\overline{\operatorname{ded}}$	
Forms of media							
Literature							

Module MA-INF 2317	Numerical	_	s for Vis	sual Cor	nputing and		
		Duration	Freque				
Workload 180 h	Credit points 6 CP	uoora					
Module		6 CP   1 semester   at least every 2 years JunProf. Dr. Florian Bernard					
coordinator	Jun1 101. D1.	rionan be	maru				
	JunProf. Dr.	Florian Bo	rnord				
Lecturer(s)		rionan be	Mode	Semest	L		
Classification	Programme M. Sc. Compu	M. Sc. Computer Science Optional 2. or 3					
Technical skills	• ability to im		_				
Technical skins	understanding	-		_	,		
					roblems in visual		
	computing and	_	_	autonat p	robicilis ili visuai		
			_	is best an	plied for which		
	problem in vis		_	_	=		
	practical prob	_	_		= '		
Soft skills					d utilise analogies		
	-	_	•	·	_		
	<ul> <li>between new problems and previously seen ones</li> <li>analytical and abstract thinking: develop a general intuition of</li> </ul>						
	computational problems, being able to adopt different						
	perspectives of particular concepts						
Contents	This module focuses on numerical methods that frequently occur						
	in the fields visual computing (VC) and machine learning (ML).						
	In addition to algorithms, this module will also cover modelling						
	aspects that are relevant for solving practical problems in VC						
	and ML. The	contents inc	lude:				
	• Error analys	is and condi	itioning of	problems			
	• Linear systems (solvability, algorithms, stability,						
	regularisation), and applications and modelling in VC and ML						
	(e.g. linear regression, image alignment, deconvolution)						
	• Spectral methods (eigenvalue decomposition, singular value						
	decomposition, respective algorithms), and their applications						
	and modelling in VC and ML (e.g. clustering, Procrustes						
	analysis, point-cloud alignment, principal components analysis)						
	• Numerical optimisation (gradient-based methods, second-order						
	methods, large-scale optimisation) and applications and						
	modelling in VC and ML.						
Prerequisites	Required:						
	No formal prerequisites.						
	Recommended:						
	Participants are expected to have a high level of mathematical						
	maturity (in particular, a good working knowledge of linear						
	algebra and calculus is essential). A basic understanding of						
	mathematical						
_	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			
Exam achievements	Written exam				(graded)		
Study achievements	Successful exe	rcise particij	pation		(not graded)		
Forms of media							
Literature							

## 3 Information and Communication Management

MA-INF 3108	L2E2	6 CP	Secure Software Engineering	72
MA-INF 3109	L2E2	6  CP	Quantum Algorithms: Introduction and Data Fusion	
			Examples	73
MA-INF 3140	L2E2	6  CP	Advanced Computer Forensics	74
MA-INF 3202	L2E2	6 CP	Mobile Communication	75
MA-INF 3209	Sem2	4  CP	Seminar Selected Topics in Communication	
			Management	. 76
MA-INF 3216	Sem2	4  CP	Seminar Sensor Data Fusion	77
MA-INF 3229	Lab4	9 CP	Lab IT-Security	. 78
MA-INF 3233	L2E2	6 CP	Advanced Sensor Data Fusion in Distributed Systems	<b>7</b> 9
MA-INF 3236	L2E2	6 CP	IT Security	80
MA-INF 3237	L2E2	6 CP	Array Signal and Multi-channel Processing	. 81
MA-INF 3238	L2E2	6  CP	Side Channel Attacks	82
MA-INF 3239	L2E2	6 CP	Malware Analysis	. 83
MA-INF 3241	L3E1	6 CP	Practical Challenges in Human Factors of Security and	
			Privacy	84
MA-INF 3242	L2E2	6 CP	Security of Distributed and Resource-constrained	
			Systems	85
MA-INF 3304	Lab4	9 CP	Lab Communication and Communicating Devices	86
MA-INF 3305	Lab4	9 CP	Lab Information Systems	87
MA-INF 3309	Lab4	9 CP	Lab Malware Analysis	88
MA-INF 3310	L2E2	6 CP	Introduction to Sensor Data Fusion - Methods and	
			Applications	89
MA-INF 3312	Lab4	9 CP	Lab Sensor Data Fusion	. 90
MA-INF 3317	Sem2	4 CP	Seminar Selected Topics in IT Security	. 91
MA-INF 3319	Lab4	9 CP	Lab Usable Security and Privacy	. 92
MA-INF 3320	Lab4	9 CP	Lab Security in Distributed Systems	93
MA-INF 3321	Sem2	4  CP	Seminar Usable Security and Privacy	. 94
MA-INF 3322	L2E2	6 CP	Applied Binary Exploitation	95
MA-INF 3323	Lab4	9 CP	Lab Fuzzing Bootcamp	96
<b>MA-INF 3324</b>	Lab4	9 CP	Lab Design of Usable Security Mechanisms	. 97

Module MA-INF 3108	Secure Software Engineering						
Workload	Credit points	Duration	Freque	ncy			
180 h	6 CP 1 semester   every year						
Module	Dr. Christian	Tiefenau					
coordinator							
Lecturer(s)	Dr. Christian	Tiefenau, M	ischa Meie	er			
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	iter Science	Optiona	$1 \mid 2$ . or $3$	3.		
Technical skills	software-engin including secur presented and	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	eling					
	• Risk analysis	_					
	-	chitectural security					
	• Secure coding						
	• Applied Cryptography						
	• Secure configuration and deployment						
	• Updates and maintenance						
Prerequisites	Recommended	:					
	Fundamental l concepts.	knowledge in	software-	engineerii	ng and IT-secu	rity	
	Teaching forma	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	endent st	,	1	
Exam achievements	Written exam	cc ocacining,		,		ded)	
	(0 )				acaj		
Study achievements	Successful exe	rcise particir	ation		(not gra	ded)	
Study achievements Forms of media	Successful exer	rcise particip	oation		(not gra	ded)	

Module MA-INF 3109	Quantum A Fusion Exa	•	s: Introd	uction a	and Data	
Workload	Credit points	Duration	Freque	ncv		
180 h	6 CP	1 semeste				
Module	Prof. Dr. Wol	fgang Koch				
coordinator		8. 8				
Lecturer(s)		fgang Koch			Dr. Martin Ul	mke
Classification	Programme		Mode	Semest		
Classification	M. Sc. Compu		_		3. ome game chan	
Technical skills	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 data fusion has just begun to be realized. While the implementation of quantum algorithms is to be considered on classical as well as on quantum computers, the latter are anticipated as well-adapted "analog computers" for					
Soft skills	management p computers can nonetheless rea	unprecedentedly fast solving data fusion and resources management problems. While the development of quantum computers cannot be taken for granted, their potential is nonetheless real and has to be considered by the international information fusion community.				
	• Adaptability	_				
	• Critical thin					
Contents  Prerequisites	<ul> <li>Introduction</li> <li>Short introd</li> <li>Introduction</li> <li>Quantum co</li> <li>Quantum ins</li> <li>Particle filte</li> <li>The data ass</li> <li>Track extract</li> </ul>	with Examuction to quantum imputing has spired track ring and fer sociation pretion and semputing for any particle als :	uantum me in computing ardware sing rmionic targoblem nsor manager r multi targer r resources e systems a	get tracki gement get tracki managem nd boson	ng data associa nent sampling	ation
		10 – Introdu			a Fusion - Met	hods
	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
		co tooching	$\cdot$ S $=$ index		,	I
T. 1.	T = face-to-fa	ce reaching	, o — maep	endent st		ال مار
Exam achievements	Oral exam	1	1			ded)
Study achievements	Erfolgreiche Ü	bungsteilna	hme		(not gra	ded)
Forms of media						
Literature						
	1					

Module MA-INF 3140	Advanced C	Advanced Computer Forensics						
Workload	Credit points	Duration	uration Frequency					
180 h	6 CP 1 semester every year							
Module	Dr. Christian	Tiefenau						
coordinator								
Lecturer(s)	Dr. Christian	Dr. Christian Tiefenau						
Classification	Programme		Mode	Semes	ter			
Classification	M. Sc. Compu	iter Science	Optiona	l   1., 2. d	or 3.			
Technical skills	The course co	The course covers advanced research topics in computer						
	forensics and s	secure softwa	are engine	ering.				
Soft skills								
Contents	Theoretical an	d practical	aspects of	computer	forensics and			
	secure softwar	e engineerin	g are cover	red.				
Prerequisites	none							
	Teaching form	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 exer	cise particip	ation		(not gra	ded)		
Forms of media								
Literature								

Module	Mobile Com	municatio	$\mathbf{n}$					
MA-INF 3202								
Workload	Credit points	Duration	Freque	-				
180 h	6 CP	1 semester	every y	rear				
Module	Prof. Dr. Peter	r Martini						
coordinator	2 4 2 2							
Lecturer(s)	Prof. Dr. Peter	r Martini, Di						
Classification	Programme M. Sc. Comput	ter Science	Mode Optiona	Semest				
Technical skills	Knowledge abo	ut key conce	epts of m	obile com	munication			
	including mobil	lity manager	nent (bot	h technol	ogy independe	$\operatorname{nt}$		
	and technology	and technology dependent), knowledge about wireless						
	technologies an	d their inter	action wi	th other j	protocol layers			
	and/or other ne	etwork techn	ologies, a	ability to	evaluate and a	ssess		
	scenarios with	communicati	on of mo	bile devic	es. In-depth			
	understanding	of communic	ation par	radigms o	f wireless/mob	$_{ m ile}$		
	systems and ne	twork eleme	nts, prod	uctive wo	rk in small gro	ups,		
	strengthening skills on presentation and discussion of soluti to current challenges							
Soft skills	Theoretical exe	rcises to sup	port in-c	lepth und	erstanding of			
	lecture topics and to stimulate discussions, practical exercises in							
	teamwork to support time management, targeted organisation of							
	practical work	and critical	discussion	n of own a	and others' res	ults		
Contents	Mobility Mana	gement in th	e Interne	t, Wireles	ss Communicat	ion		
	Basics, Wireless Networking Technologies, Cellular/Mobile							
	Communication	n Networks (	voice and	data cor	nmunication),			
	Ad-hoc and Ser	nsor Networl	ĸs.		,			
Prerequisites	Recommended:							
	Bachelor level l	knowledge of	basics of	f commun	ication system	$\mathbf{s}$		
	(e.g. BA-INF 1	.01 "Kommu	nikation	in Verteilt	ten Systemen"			
	(German Bachelor Programme Informatik, English lecture slides							
	available)							
	Teaching forma	t 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	e teaching: S	S = inder	oendent st	udv	•		
Exam achievements	Written exam	3				ded)		
Study achievements	Successful exer	cise participa	ation		(not gra			
Forms of media		. I			( 610	)		
	• Jochen Schiller: Mobile Communications, Addison-Wesley,							
	2003			, 11	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,			
	• William Stall	ings: Wirele	ss Comm	unication	s and Network	ing.		
Literature	Prentice Hall, 2	_			and monwork	61		
	• Further up-to		ure will l	oe annour	nced in due con	ırse		
	before the begin			o wiiiOul	icca in auc cot	1100		

Module	Seminar Selected Topics in Communication									
MA-INF 3209	Management									
Workload	Credit points	Duration	n Frequency							
120 h	4 CP	1 semester at least every year								
Module	Prof. Dr. Peter Martini									
coordinator										
Lecturer(s)	Prof. Dr. Pete	er Martini, I	rof. Dr. N	Iichael M	leier					
Classification	Programme		Mode	Semest	ter					
Classification	M. Sc. Compu	iter Science	Optional	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	framework of the corresponding area.								
Contents		rence and jo	urnal pape	ers, curren	nt standardizat	ion				
	drafts									
Prerequisites	Required:									
		-			llowing lecture	s:				
	Principles of I		- '		, ·					
	,			nmunicati	ion (MA-INF3:	202),				
	IT Security (N		)							
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 literature will be announced towards the end of the									
Diterature	previous semes	ster			previous semester					

Module	Seminar Sensor Data Fusion						
MA-INF 3216							
Workload	Credit points	Duration	n Frequency				
120 h	4 CP	1 semester	every y	ear			
Module	P.D. Dr. Wolfgang Koch						
coordinator							
Lecturer(s)	P.D. Dr. Wolf	gang Koch,	Dr. Felix (	Govaers			
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	iter Science	Optional	$\lfloor 2.$			
Technical skills	Ability to und	erstand new	research i	esults pre	esented in origi	inal	
	scientific paper	rs.					
Soft skills	Ability to present and to critically discuss these results in the						
	framework of	framework of the corresponding area.					
Contents	Current confer	ence and jo	ırnal pape	ers			
Prerequisites	none						
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	ion, written	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature	The relevant li seminar.	terature wil	be annou	nced at the	he beginning o	f the	

Module MA-INF 3229	Lab IT-Secu	urity					
Workload	Credit points	Duration	Frequ	ency			
270 h	9 CP 1 semester every semester						
Module	Prof. Dr. Mic	Prof. Dr. Michael Meier					
coordinator							
Lecturer(s)	Prof. Dr. Mic	Prof. Dr. Michael Meier					
Classification	Programme		Mode	Seme	ester		
Classification	M. Sc. Compu	iter Science	Option	al   2. or	3.		
Technical skills	The students will carry out a practical task (project) in the						
	context of IT Security, including test and documentation of the						
	implemented software/system.						
Soft skills	Ability to prop	perly prese	nt and def	end design	n decisions, to		
	prepare readal	ble docume	ntation of	software;	skills in		
	constructively	collaborati	ng with o	thers in si	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 s	study		
Exam achievements	Oral presentat	tion, writte	ı report		(gra	ided)	
Study achievements					(not gra	ded	
Forms of media							
Literature							

Module	Advanced Sensor Data Fusion in Distributed							
MA-INF 3233	Systems							
Workload	Credit points	Duration	Freque	ncy				
180 h	6 CP   1 semester   every year							
Module	PD Dr. Wolfg	ang Koch						
coordinator								
Lecturer(s)	Dr. Felix Gova	Dr. Felix Govaers						
Classification	Programme		Mode	Semes	ter			
Classification	M. Sc. Compu	iter Science	Optiona	l   2.				
Technical skills	_	_		. –	hms which enh	ance		
	the situational		-					
		-			ular to improve			
	_	performance of systems by linking multiple sensors. This implies some challenges to the sensor data fusion methodologies such as						
					_			
	_	,		. ,	d correlations			
		-			nication links			
		,		-	have to be ap	-		
		at the sensor sites, that is local tracks have to be computed. Once recieved at a fusion center (FC), the tracks then are fus						
			,	* *				
	to reconstruct a global estimate. In this lecture, method							
	to a achieve a distributed state estimation are considered.							
	Among these are tracklet fusion, the Bar-Shalom-Campo formula, the Federated Kalman Filter, naive fusion, the							
	distributed Ka							
Soft skills	Mathematical							
Soft skills	mathematical		_	,				
Contents					ıla, the Federat	ed		
Contents		,		-	Kalman filter ai			
	the least squar	,	*					
	Decorrlated fu				,			
Prerequisites	Recommended		1					
•	At least 1 of t		ς:					
	BA-INF 137 –	Einführun	r in die Ser	sordaten	fusion			
					Fusion - Metho	ode		
	and Application		non to ben	soi Data	rusion - Meth	Jus		
	Teaching forms		Group size	h/week	Workload[h]	СР		
Format	Lecture	at (	aroup size	2	30 T / 45 S	2.5		
Tornico	Exercises			$\frac{2}{2}$	30 T / 75 S	3.5		
		an tonahira	. C _ :nda=		·	1 0.0		
Every ashi	T = face-to-fa Oral exam	ce teacning	s = mae	endent st		404)		
Exam achievements		raiga partici	nation			$\frac{\text{ded}}{\text{dod}}$		
Study achievements  Forms of modio	Successful exer Power Point	reise partie.	раноп		(not gra	ueu)		
Forms of media		pelving and	Songor Dat	a Fugion:	Methodologica	n1		
	Framework an	_			_	aı		
Literature						<b>.</b> .		
	D. Hall, CY. Chong, J. Llinas, and M. L. II: "Distributed Data							
	Fusion for Network-Centric Operations", CRC Press, 2014.							

Module	IT Security								
MA-INF 3236	G 111	ъ							
Workload	Credit points 6 CP	Duration	Frequency						
180 h	6 CP   1 semester   every year Prof. Dr. Michael Meier								
Module	Prof. Dr. Mic.	nael Meier							
coordinator	Prof. Dr. Michael Meier								
Lecturer(s)		nael Meier							
Classification	Programme		Mode	Semest					
	M. Sc. Compu		Optiona						
Technical skills			v		research fields				
	IT security. St				,				
	objectives in these fields. Additionally								
	fundamental knowledge and methods helping them to deepen								
G 0 1 11		their knowledge in their upcoming studies.  working in small groups on exercises, critical discussion of own							
Soft skills	_	· .		•					
	and others' results, time management, transfering theoretical								
<b>C</b>		knowledge to practical scenarios  The contents vary but usually include							
Contents	The contents	vary but usua	any mend	ıe					
	• Privacy								
	• Cryptograph	nic Protocols							
	• Network Sec	urity							
	• Supply Chai	n Attacks							
	• Management								
	• Low-level so	ftware analys	sis						
	• Software tes	$_{ m ting}$							
	• Side Channe	el Attacks							
	• Anomaly De	etection							
	• Human Fact	or in Securit	y						
Prerequisites	Required:								
	Fundamental l	knowledge in	the follow	ving areas	s: operating				
	systems, netwo	orks, security							
	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	Written exam	3/	-1			ded)			
Study achievements	Successful exe	rcise particip	ation		(not gra				
Forms of media	(Hot Studed)								
Literature									

Module MA-INF 3237	Array Signa	al and Mu	lti-chanr	nel Proc	essing		
Workload	Credit points	Duration	Freque	nev			
180 h	6 CP	1 semeste:					
Module	Prof. Dr. Wol		every y	cai			
coordinator	1 101. D1. W01	igang Roch					
Lecturer(s)	Dr. Marc Oist	Dr. Marc Oispuu					
(-)	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optiona				
Technical skills	Localization of		urces usin	g passive	sensors is a		
	fundamental t	ask encount	ered in var	ious field	s like wireless		
	communication, radar, sonar, and seismology. In this lecture, a						
	unified framev	unified framework for electromagnetic and acoustic signals and					
	signal processi	ignal processing techniques are presented. Furthermore, the					
	sensor calibrat	ion, directio	n finding,	and bear	ings-only		
	localization pr	oblem are c	onsidered.	Special a	applications are	9	
	emphasized, li	ke small airl	orne arra	ys for unr	manned aerial		
	vehicles (UAV	s).					
Soft skills	Mathematical	derivation of	f algorithr	ns, applic	cations of		
	mathematical						
Contents	Estimation the	· ,	,		. ,		
	conventional b	_		0			
	, , , , , , , , , , , , , , , , , , , ,			_	calization, Dir	ect	
	Position Deter	`	PD), App	lications			
Prerequisites	Recommended	-					
	Recommended			ions of Au	idio Signal		
	Processing" (N		,		l		
	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			
Exam achievements	Oral Exam					ided)	
Study achievements	Successful exe	rcise particij	oation		(not gra	ded)	
Forms of media	Power Point						
	H. L. van Tree		-	_			
Literature	Detection, Est		d Modulat	ion Theor	ry. New York:		
	Wiley-Interscie	ence, $2002$ .					

Module MA-INF 3238	Side Channel Attacks							
Workload	Credit points	Duration	Freque	ncy				
180 h	6 CP	1 semeste	every year					
Module	Dr. Felix Boes	3						
coordinator								
Lecturer(s)	Dr. Felix Boes	3						
Classification	Programme		Mode	Semes	ter			
Classification	M. Sc. Compu	iter Science	Optiona	$1 \mid 2$ . or $3$	3.			
Technical skills	• Students are	introduced	to theoret	ical and p	practical side			
	channel effects	of modern	hardware.					
	• Students lea	rn techniqu	es to utiliz	e these eff	fects to circum	vent		
	security mechanisms.							
	• This includes covert channels as well as side channel attacks							
	and microarch	itectural at	tacks on m	odern CP	Us.			
Soft skills	Theoretical ex	ercises to s	ipport in-c	lepth und	erstanding of			
	lecture topics and to stimulate discussions, practical exercises in							
	teamwork to support time management, targeted organization of							
	practical work	ractical work and critical discussion of own and others' results.						
Contents	• Theoretical	foundations	of side cha	annel effec	cts and attacks	as		
	well as	rell as						
	• covert chann	iels,						
	• differential p	ower analy	sis,					
	• padding orac	cle,						
	• RSA timing	attacks,						
	• cache based	side channe	el effects,					
	• microarchite	ctural atta	eks (Spectr	e)				
Prerequisites	Recommended	:						
	Fundamental l	knowledge a	bout IT S	ecurity, op	perating systen	ns		
	and statistics	is advantag	eous but ne	ot mandat	tory.			
	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 = inder	endent st	udy			
Exam achievements	Written Exam					ded)		
Study achievements	Successful exe	rcise partic	pation		(not gra	$\overline{\operatorname{ded})}$		
Forms of media		=			. 3			
Literature								

Module MA-INF 3239	Malware A	nalysis					
Workload	Credit points	Duration	Freque	ency			
180 h	6 CP 1 semester   every year						
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	addition, the st	pendently an udents shoul	d to descr	ibe its dama to carry out	onal scope of a age potential. In detailed analyz h the help of scr	es of	
Soft skills	Presentation of methods and te		d methods	s, critical dis	scussion of appli	ed	
Contents	deepened and a Different malwa malware author	dapted to the are samples are. These price	e peculiar re used to orities incl	ities of malw explain the	*		
Prerequisites	students to wor students will we analysis during	munication ware analysis ofuscation sis environme e analysis obfuscation of common ar on of binary a ns with sever k independen or of praction the semester , it is necessar	ents  nalysis step algorithms al lectures atly later. cal topics . Since the	that provid In the cours from the fielese subject a villing to dea		ut to	
Frerequisites	_						
	none						
	Recommended: Basic knowledge of operating systems (kernel, threads, virtual						
	_	•	U .	,		27.7	
	memory), netwo		\ <u>-</u>		, .	ry	
	analysis (assem				-, -		
	development (p				<del> </del>	CD	
Farmat	Teaching formate Lecture	at C	Group size	h/week	Workload[h] 30 T / 45 S	2.5	
Format	Exercises			$\frac{2}{2}$	30 T / 75 S	$\begin{vmatrix} 2.5 \\ 3.5 \end{vmatrix}$	
		~		1	'	5.5	
	T = face-to-face	e teaching; S	= indepe	ndent study			
Exam achievements	Oral exam				10	aded)	
Study achievements	Successful exerc	cise participa	tion		(not gra	aded)	
Forms of media							
Literature	The relevant lit lecture	erature will	be announ	ced at the b	beginning of the		

Module	Practical Challenges in Human Factors of Security								
MA-INF 3241	and Privacy	and Privacy							
Workload	Credit points	Credit points Duration Frequency							
180 h	6 CP	6 CP 1 semester   every year							
Module	Prof. Dr. Mat	Prof. Dr. Matthew Smith							
coordinator									
Lecturer(s)	Prof. Dr. Mat	thew Smitl	1						
Classification	Programme		Mode	Semes	ter				
Classification	M. Sc. Compu	iter Science	Optiona	ıl 2.					
Technical skills	After complete	After completing the unit students will be able to conduct							
	related work s	related work searchers to get a deep understanding into the state							
	of the art. Th	of the art. They will be able to design, run and evaluate							
	scientific studi	es in this a	rea.						
Soft skills									
Contents	In this course	we will lear	n about a	nd develop	solutions for a	a			
	specific challer	nge concern	ing human	factors in	security and				
	privacy.								
Prerequisites	none								
	Teaching forms	at (	Group 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 = inder	pendent st	tudy				
Exam achievements	Project work				(gra	ded)			
Study achievements	Successful exe	rcise partic	ipation		(not gra	ded)			
Forms of media									
Literature									

Module	Security of	Distribut	ed and R	esource	e-constrained	ł	
MA-INF 3242	Systems						
Workload	Credit points	Duration	Frequer	ıcy			
180 h	6 CP	1 semeste	r every y	every year			
Module	Prof. Dr. Mic.	hael Meier	·				
coordinator							
Lecturer(s)	Dr. Thorsten	Aurisch					
Classification	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optional	2.			
Technical skills	Ability to und	lerstand and	l analyse th	eoretical	and practical		
	cyber security	challenges	of distribut	ed and			
	ressource-cons	trained syst	ems, as we	ll as the a	ability to select	and	
	apply appropr	iate solution	ns.				
Soft skills							
Contents	• Group communication with IP multicast						
	• Group key n	_					
	• Broadcast ei						
	• Public key in		е				
	• Web of trust						
	• Multicast in						
	• Distributed						
	• Cyber resilie	0					
	• Security in t		o networks				
	• Security for	Io'I'					
Prerequisites	none				1	ı	
	Teaching forms	at C	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	Written exam				(gra	ded)	
Study achievements	Successful exe	rcise partici	pation		(not gra	$\overline{\mathrm{ded}}$	
Forms of media			<u> </u>				
Literature							

Module	Lab Comm	unication	and Co	mmunic	ating Devices	S	
MA-INF 3304							
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semeste	er every	semester			
Module	Prof. Dr. Pete	er Martini	•				
coordinator							
Lecturer(s)	Prof. Dr. Pete	er Martini,	Prof. Dr.	Michael I	Meier		
Classification	Programme M. Sc. Compu	ıter Science	Mode Option	Seme 2. or			
Technical skills	context of con	The students will carry out a practical task (project) in the context of communication systems, including test and documentation of the implemented software/system.					
Soft skills	ability to mak discuss (interi	Work in small teams and cooperate with other teams in a group; ability to make design decisions in a practical task; present and discuss (interim and final) results in the team/group and to other students; prepare written documentation of the work carried out.					
Contents	Selected topics	s close to c	irrent rese	earch in th	ne area of		
	communication	n systems,	network se	ecurity, m	obile		
	communication	n and comr	nunicating	devices.			
Prerequisites	Principles of I	Distributed INF3201),	Systems ( Mobile Co	MA-INF3	ollowing lecture 105), Network tion (MA-INF32		
	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	S = inde	pendent s	study	1	
Exam achievements	Oral presentat		-			ded)	
Study achievements	*	,			(not gra		
Forms of media					, 5		
T	The relevant literature will be announced towards the end of the						
Literature	previous seme	ster.					

Module	Lab Inform	ation Syst	ems				
MA-INF 3305							
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semester	at leas	st every y	ear		
Module	Dr. Thomas E	Bode					
coordinator							
Lecturer(s)	Dr. Thomas E	Bode					
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Optiona	al 2. or	3.		
Technical skills	The students	The students will carry out a practical task (project) in the					
	context of info	context of information systems, including test and					
	documentation	ocumentation of the implemented software/system.					
Soft skills	Ability to prop	Ability to properly present and defend design decisions, to					
	prepare readal	ble documen	tation of	software;	skills in		
	constructively	collaboratin	g with ot	hers in sr	nall teams over	a	
	longer period	of time; abili	ty 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 curi	rent resea	rch in the area	of	
	database- and	information	systems.				
Prerequisites	none						
D 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	pendent s	study		
Exam achievements	Oral presentat	tion, written	report		(gra	ded)	
Study achievements					(not gra	ded	
Forms of media							
Literature	The relevant literature will be announced towards the end of the						
Diterature	previous seme	ster.					

Module	Lab Malwai	re Analysi	S					
MA-INF 3309								
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 N	Meier			
Classification	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	iter Science	Optiona	al   3.				
Technical skills	The students	will carry ou	t a practi	ical task (	(project) in the			
				_	ecific topic focu			
	Malware Anal	ysis and Cor	nputer/N	etwork Se	ecurity, includir	ng		
	test and docur	sest and documentation of the implemented software/system.						
Soft skills	Work in small	Work in small teams and cooperate with other teams in a group; ability to make design decisions in a practical task; present and						
	discuss (interi	m and final)	results in	the tean	n/group and to			
		; prepare wr	itten doc	umentatio	on of the work			
	carried out							
Contents	Selected topics							
	communication		nalware a	nalysis, co	omputer and			
	network securi	ity.						
Prerequisites	Required:							
		•			ollowing lecture	es:		
	Principles of I		• (		, ,			
	,	, ,		mmunica	tion (MA-INF3	202),		
	IT Security (M							
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP		
Tornat	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	aded)		
Study achievements					(not gra	aded)		
Forms of media								
Literature								

Module			Data 1	Fusion -	Methods as	nd	
MA-INF 3310	Application		T				
Workload	Credit points	Duration	Freque	-			
180 h	6 CP	1 semester	every y	ear			
Module	Prof. Dr. Wol	tgang Koch					
coordinator							
Lecturer(s)	Prof. Dr. Wol	fgang Koch					
Classification	Programme		Mode	Semes	ter		
	M. Sc. Compu		Optiona				
Technical skills		_			theory of senso		
	data fusion. The lecture starts with preliminaries on how to						
	handle uncerta	ain data and	knowledg	e within a	analytical calcı	ılus.	
	Then, the fund	damental and	well-kno	wn Kalm	an filter is deri	ved.	
	Based on this	tracking sche	me, furth	er approa	aches to a wide	;	
	spectrum of a	pplications wi	ll be sho	wn. All al	lgorithms will	be	
	motivated by	examples fror	n ongoing	g research	projects,		
	industrial coop		l impress	ions of cu	rrent		
	demonstration	hardware.					
	Because of inherent practical issues, every sensor measures						
		-			shows how to		
		=			ion of theoretic		
	tools such as I						
		-			ions, maneuver	ing	
	phases, and m				,	0	
Soft skills	Mathematical				ation of		
	mathematical						
Contents	Gaussian prob				an filter		
	_	-	-		ole Model Filte	r.	
	Retrodiction,					-,	
Prerequisites	none	<u> </u>	101100101		)		
Toroquisites	Teaching forms	at Gr	oup size	h/week	Workload[h]	СР	
Format	Lecture	GI	cap size	2	30 T / 45 S	2.5	
rormat	Exercises			$\frac{2}{2}$	30 T / 75 S	$\begin{vmatrix} 2.5 \\ 3.5 \end{vmatrix}$	
					,	5.5	
	T = face-to-fa	ce teaching; S	S = indep	endent st		>	
Exam achievements	Written exam					ded)	
Study achievements	Successful exe	rcise participa	ation		(not gra	ded)	
Forms of media							
	W. Koch: "Tra	acking and Se	ensor Dat	a Fusion:	Methodologica	al	
T *4	Framework an	d Selected A <sub>l</sub>	oplication	ns", Spring	ger, 2014.		
Literature	Y. Bar-Shalon	n: "Estimatio	n with A	pplication	s to Tracking	and	
	Navigation", V						

Module	Lab Sensor	Data Fu	sion				
MA-INF 3312							
Workload	Credit points	Duration	Fre	equenc	<b>y</b>		
270 h	9 CP	1 semest	er ev	ery yea	ar		
Module	Prof. Dr. Wol	fgang Kocl	1				
coordinator							
Lecturer(s)	Prof. Dr. Wol	Prof. Dr. Wolfgang Koch					
Classification	Programme		Mod	de	Semes	ster	
Classification	M. Sc. Compu	iter Science	Opt	tional	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	information from several nodes will be implemented.					
Soft skills	The students s	shall work	togethe	er in a	team.	Everyone is	
	responsible for	a specific	part in	the co	ontext	of a main goal.	
	Results will be	e exchange	d and i	ntegra	ted via	software interfa	aces.
Contents	Varying select	ed topics o	n sensc	or data	fusion		
Prerequisites	none						
Format	Teaching forms	at G	roup si	ize h	/week	Workload[h]	CP
rormat	Lab		8		4	60 T / 210 S	9
	T = face-to-fa	ce teaching	S = i	indepe	ndent s	study	
Exam achievements	Oral presentat	ion, writte	n repoi	rt		(gra	ded)
Study achievements						(not gra	ded)
Forms of media							
Literature	The relevant literature will be announced at the beginning of the						
Literature	lab.						

Module MA-INF 3317	Seminar Sel	ected Top	ics in IT	Securi	ty		
Workload	Credit points	Duration	Frequen	cy			
120 h	4 CP	1 semester   every year					
Module	Prof. Dr. Mich	Prof. Dr. Michael Meier					
coordinator							
Lecturer(s)	Prof. Dr. Mich	Prof. Dr. Michael Meier, Prof. Dr. Peter Martini					
Classification	Programme		Mode	Semest	Semester		
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 dis	scuss the	se results in th	ne	
	framework of t	he correspon	iding area.				
Contents	Current confer	ence and jou	rnal paper	s			
Prerequisites	none						
Format	Teaching forma	at G	oup size	h/week	Workload[h]	CP	
Format	Seminar		10	2	30 T / 90 S	4	
	T = face-to-face	ce teaching;	S = indepe	endent st	udy		
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra	ded	
Forms of media	_						
Literature							

Module	Lab Usable	Security	and Pri	vacy			
MA-INF 3319							
Workload	Credit points	Duration	Frequ	ency			
270 h	9 CP	1 semest	er every	year			
Module	Prof. Dr. Mat	thew Smit	h				
coordinator							
Lecturer(s)	Prof. Dr. Mat	thew Smit	h				
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Computer Science		e Option	al $2$ .			
Technical skills	The students v	will carry of	out a pract	ical task	(project) in the		
	context of usa	ble securit	y and priva	acy, includ	ding user studie	s.	
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	the context	of human	aspects o	of security and		
	privacy.						
Prerequisites	Required:						
	Vorkenntnisse	zur Durch	führung uı	nd Auswei	rtung von		
	Benutzerstudie	en sind no	wendig. V	Vie sie z.B	in BA-INF145	<b>5</b> -	
	Usable Securit	y and Priv	acy gelehr	t werden.			
	Knowledge on	how to ru	n and eval	uate user	studies are requ	ired.	
	For example a	s it is taug	ht in BA-l	NF145 - 1	Usable Security	and	
	Privacy.						
D .	Teaching forma	at (	Froup 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	ided)	
Study achievements					(not gra	ided)	
Forms of media							
Literature							

Module MA-INF 3320	Lab Securit	y in Dist	ributed	Systems	<b>3</b>		
Workload	Credit points	Duration	Frequ	onav			
270 h	9 CP	1 semest	_	-			
Module	Prof. Dr. Mat		-	year			
coordinator	1 101. D1. Mac	onew Simo	11				
Lecturer(s)	Prof. Dr. Mat	thow Smit	h				
Lecturer (s)	Programme	onew Simo	Mode	Seme	stor		
Classification	M. Sc. Compu	iter Science			ster		
Technical skills	The students	will carry o	ut a pract	ical task (	(project) in the		
	context of dist			uding doc	umentation of t	he	
	Strong program	mming skil	ls required	l.			
Soft skills	Ability to proprepare 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	Security in dis	stributed sy	stems, inc	cluding an	nongst others:		
	<ul> <li>Secure Mess</li> <li>App Security</li> <li>SSL/HTTPS</li> <li>API Security</li> <li>Machine Lea</li> <li>Passwords</li> <li>Intrusion Design</li> <li>Anomaly Design</li> <li>Security Vis</li> </ul>	y S S y arning for S etection Systection	Č				
Prerequisites	none						
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
Tormat	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching	S = inde	ependent s	study		
Exam achievements	Oral presentat		* *	-	•	ded)	
Study achievements	_	,	•		(not gra		
Forms of media					( 0		
Literature							

Module MA-INF 3321	Seminar Us	able Secur	ity and	Privacy			
Workload	Credit points	Duration	Frequen	cy			
120 h	4 CP	1 semester	emester every year				
Module	Prof. Dr. Matthew Smith						
coordinator							
Lecturer(s)	Prof. Dr. Mat	Prof. Dr. Matthew Smith					
Classification	Programme		Mode	Semester			
Classification	M. Sc. Compu	ter Science	Optional	2.	2.		
Technical skills	Ability to und	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 the	ne	
	framework of t	he correspon	nding area				
Contents	Current confer	ence and jou	ırnal papeı	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-fa	ce teaching;	S = independent	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 Expl	oitation				
Workload	Credit points	Duration	Fraguer	1077			
180 h	6 CP	1 semester	Frequer every ye				
Module	Prof. Dr. Peter		every ye	aı			
coordinator	Tion. Dr. Teter	wai um					
Lecturer(s)	Prof. Dr. Elma	r Padilla					
Lecturer (s)	Programme	1 1 adina	Mode	Semester			
Classification	M. Sc. Comput	er Science	Optional	2. or 3.			
Technical skills	Static and dyna	mic progran	n analysis, I	Exploitation	(Stack-based B	uffer	
	Overflows, Form	nat String E	xploits, Hea	p Exploita	tion, Use-After-I	ree	
	Exploits) and C	Countermeas	ures (Stack	Cookies, N	X, ASLR, RELF	RO)	
Soft skills	Frustration tole	erance when	working wit	h binary re	epresentations ar	$\operatorname{id}$	
	trying to apply taught techniques, focussed working on technically						
	challenging pro	blems, simul	taneously a	pplying kno	owledge from		
	different areas of computer science						
Contents	Our computers	run a lot of	closed sour	ce binary p	rograms meaning	g	
	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 tech	niques (stack	cookies, N	X, ASLR, I	RELRO,) as v	ve	
	progress and ex	ploit them a	s well. Afte	er we finishe	ed the topic of		
	stack-based buf	fer overflows	we move of	n to more a	advanced topics	such	
	as heap exploits	ation, use-aft	ter-free expl	oits and ot	hers. The lectur	e	
	ends with an in	troduction to	o fuzzing ar	nd an analy	sis of a sophistic	atec	
	real-world explo	oit.					
Duana suriait	Required:						
rrerequisites	Required:						
rerequisites	none						
Frerequisites	none Recommended	:					
Frerequisites	Recommended		cture: "Apr	olied Binary	/ Analysis" BA-l	NF	
Frerequisites	Recommended • Binary Analy		cture: "App	blied Binary	/ Analysis" BA-l	NF	
Frerequisites	Recommended • Binary Analy 155)	sis skills (Le		·	/ Analysis" BA-l	NF	
Frerequisites	Recommended  • Binary Analy 155)  • Basic knowled	sis skills (Le	nux operati	ng system	·	NF	
Frerequisites	Recommended  • Binary Analy 155)  • Basic knowled  • System Progr	sis skills (Le lge of the Li amming skil	nux operati	ng system	·	NF	
rerequisites	Recommended  • Binary Analy 155)  • Basic knowled  • System Progr Programmierum	sis skills (Le lge of the Li amming skil g")	nux operati ls in C (Lec	ng system	·	NF	
rerequisites	Recommended  • Binary Analy 155)  • Basic knowled  • System Progr Programmierum  • Basic Python	sis skills (Le lge of the Li amming skil g") programmir	nux operati ls in C (Lec	ng system ture: "Syst	emnahe		
	Recommended  • Binary Analy 155)  • Basic knowled  • System Progr Programmierum  • Basic Python  Teaching forms	sis skills (Le lge of the Li amming skil g") programmir	nux operati ls in C (Lec	ng system	emnahe  Workload[h]	CF	
	Recommended  • Binary Analy 155)  • Basic knowled  • System Programmierum  • Basic Python  Teaching forms  Lecture	sis skills (Le lge of the Li amming skil g") programmir	nux operati ls in C (Lec	ng system ture: "Syst	workload[h]	CF 2.5	
	Recommended  • Binary Analy 155)  • Basic knowled  • System Programmierum  • Basic Python  Teaching formate  Exercises	sis skills (Ledlge of the Liamming skilg") programming t	nux operati ls in C (Lec ng skills Group size	ng system ture: "Syst  h/week  2 2	emnahe  Workload[h]	CF 2.5	
Format	Recommended  • Binary Analy 155)  • Basic knowled  • System Programmierum  • Basic Python  Teaching formate  Exercises  T = face-to-face	sis skills (Ledge of the Liamming skilg") programming at Control Contr	nux operati ls in C (Lec ng skills Group size	ng system ture: "Syst  h/week  2 2	Workload[h] 30 T / 45 S 30 T / 75 S	2.5 3.5	
Format  Exam achievements	Recommended  • Binary Analy 155)  • Basic knowled  • System Progr Programmierum  • Basic Python  Teaching formate Lecture Exercises  T = face-to-face Oral Examination	sis skills (Ledlge of the Liamming skilleg") programming at e teaching; Son	nux operati ls in C (Lec ag skills  Group size  = indepen	ng system ture: "Syst  h/week  2 2	workload[h] 30 T / 45 S 30 T / 75 S  (gra	2.5 3.5	
Format  Exam achievements  Study achievements	Recommended  • Binary Analy 155)  • Basic knowled  • System Programmierum  • Basic Python  Teaching formate  Exercises  T = face-to-face	sis skills (Ledlge of the Liamming skilleg") programming at e teaching; Son	nux operati ls in C (Lec ag skills  Group size  = indepen	ng system ture: "Syst  h/week  2 2	Workload[h] 30 T / 45 S 30 T / 75 S	2.5 3.5	
Format  Exam achievements Study achievements Forms of media	Recommended  • Binary Analy 155)  • Basic knowled  • System Progr Programmierum  • Basic Python  Teaching formate Lecture Exercises  T = face-to-face Oral Examination	sis skills (Leddge of the Liamming skilg") programming at Control Cont	nux operati ls in C (Lec ng skills Group size  = indepen tion	ng system ture: "Syst  h/week  2 2 dent study	Workload[h]   30 T / 45 S   30 T / 75 S   (gra (not gra	CF 2.5 3.5	

Module	Lab Fuzzing	g Bootcan	ıp				
MA-INF 3323							
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semeste:	every	year			
Module	Prof. Dr. Mat	thew Smith					
coordinator							
Lecturer(s)	Dr. Christian	Tiefenau					
Classification	Programme		Mode	Seme	Semester		
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 testing, including test and documentation of the						
	implemented software/system.						
Soft skills	Ability to prop	perly presen	and defe	end design	n decisions, to		
	prepare readal	ole documen	tation of	software;	skills in		
	constructively	collaboratin	g with ot	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 = 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 Usable Security Mechanisms						
Workload	Credit points	Duratio	n	Freque	encv		
270 h	9 CP	1 seme		every	•		
Module	Prof. Dr. Mat			CVCIY	ycar		
coordinator	1101. D1. Mac	1 101. D1. Matthew Shiftin					
Lecturer(s)	Dr. Emmanue	el von Zez	schw	itz			
	Programme			Mode	Seme	ster	
Classification	M. Sc. Compu	ıter Scien	ice	Optiona	al 2. or	3.	
Technical skills	The students	will carry	out	a practi	ical task	(project) in the	
	context of usa	ble securi	ity m	echanis	ms, inclu	ding test and	
	documentation	documentation of the implemented software/system.					
Soft skills	Ability to prop	perly pres	sent a	nd defe	end design	n decisions, to	
	prepare readal	ble docun	nenta	tion of	software;	skills in	
						mall teams over	a
	longer period	of time; a	bility	to clas	sify ones	own results into	o the
	state-of-the-ar	t of the r	esp. a	area			
Contents							
Prerequisites	none						
Format	Teaching forms	at	Grou	p size	h/week	Workload[h]	CP
rormat	Lab			8	4	60 T / 210 S	9
	T = face-to-fa	ce teachi	ng; S	= inde	pendent s	study	
Exam achievements	Oral presentat	tion, writ	ten re	port		(gra	ided)
Study achievements	(not graded)					ided)	
Forms of media							
Literature							

## 4 Intelligent Systems

MA-INF 4111	L2E2	6  CP	Principles of Machine Learning	99
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	. 113
MA-INF 4213	Sem2	4  CP	Seminar Humanoid Robots	. 114
MA-INF 4214	Lab4	9 CP	Lab Humanoid Robots	. 115
MA-INF 4215	L2E2	6 CP	Humanoid Robotics	. 116
MA-INF 4216	L2E2	6 CP	Biomedical Data Science & AI	. 117
MA-INF 4217	Sem2	4  CP	Seminar Machine Learning Methods in the Life Sciences	. 118
MA-INF 4226	Lab4	9 CP	Lab Parallel Computing for Mobile Robotics	. 119
MA-INF 4228	L4E2	9 CP	Foundations of Data Science	. 120
MA-INF 4229	L4E2	9 CP	Pattern Recognition I	. 121
MA-INF 4230	L2E2	6 CP	Advanced Methods of Information Retrieval	. 122
MA-INF 4231	Sem2	4 CP	Seminar Advanced Topics in Information Retrieval	. 123
MA-INF 4232	Lab4	9 CP	Lab Information Retrieval in Practice	. 124
MA-INF 4302	L2E2	6 CP	Advanced Learning Systems	. 125
MA-INF 4303	L2E2	6 CP	Learning from Non-Standard Data	
MA-INF 4304	Lab4	9 CP	Lab Cognitive Robotics	
MA-INF 4306	Lab4	9 CP	Lab Development and Application of Data Mining and Learning	g
			Systems	. 128
			Lab Field Programmable Gate Arrays	
MA-INF 4308	Lab4	9 CP	Lab Vision Systems	. 130
MA-INF 4309	Lab4	9 CP	Lab Sensor Data Interpretation	131
MA-INF 4310	Lab4	9 CP	Lab Mobile Robots	. 132
MA-INF 4312	L2E2	6 CP	Semantic Data Web Technologies	
MA-INF 4313	Sem2	4 CP	Seminar Semantic Data Web Technologies	
MA-INF 4314	Lab4	9 CP	Lab Semantic Data Web Technologies	. 135
MA-INF 4316	L2E2	6 CP	Graph Representation Learning	. 136
MA-INF 4318	Sem2	4 CP	Seminar Representation Learning for Big Data Analytics	. 137
			Game AI	
MA-INF 4322	L4E2	9 CP	Lab Machine Learning on Encrypted Data	139
			Pattern Recognition II	
			Seminar Advanced Topics in Data Science	
			Lab Data Science in Practice	
			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	Principles o	of Machine	Learnir	ng					
MA-INF 4111									
Workload	Credit points	Duration	Freque	ncy					
180 h	6 CP	6 CP   1 semester   every year							
Module									
coordinator									
Lecturer(s)	Prof. DrIng.	Prof. DrIng. Christian Bauckhage							
Classification	Programme M. Sc. Compu	iter Science	Mode Optiona	Semest					
Technical skills	able to describe of machine leasupervised and and skills acqu	Upon successful completion of this module, students should be able to describe fundamental methods, algorithms, and use cases of machine learning. Students acquire knowledge about supervised and unsupervised learning; based on the knowledge and skills acquired, students should be able to							
	estimation in a  • Adopt the fu	<ul> <li>Implement, algorithms for optimization and parameter estimation in model training and machine learning tasks.</li> <li>Adopt the fundamental methods they learned about to a wirrange of problems in automated intelligent data analysis.</li> </ul>							
Soft skills	In the exercise theoretical cor approaches int implementatio This requires t	In the exercises, students can put their knowledge about theoretical concepts, mathematical methods, and algorithmic approaches into practice and realize small projects involving the implementation and evaluation of machine learning algorithms. This requires teamwork; upon successful completion of the module, students should be able to							
	<ul> <li>draft and implement basic machine learning algorithms for various practical problem settings</li> <li>prepare and give oral presentations about their work in front of an audience</li> </ul>								
Contents	Fundamental machine learning models for classification and clustering, model training via minimization of loss functions, fundamental optimization algorithms, model regularization, kernel methods for supervised and unsupervised learning, probabilistic modeling and inference, dimensionality reduction and latent factor models, the basic theory behind neural networks and neural network training; This course is intended to lay the foundation for more advanced courses on modern deep								
Prerequisites	learning and re		learning.						
Trerequisites	Linear algebra programming		orobability	theory, o	calculus, pytho	n			
	Teaching forms	at G	oup size	h/week	Workload[h]	CP			
Format	Lecture Exercises			2 2	30 T / 45 S 30 T / 75 S	2.5 3.5			
T. 1.	T = face-to-fa		s = indep	enaent st		ال ا			
Exam achievements	Schriftliche Pr		mo		, –	$\frac{\mathrm{ded}}{\mathrm{ded}}$			
Study achievements	Erfolgreiche Ü			ada 2****	(not gra	uea)			
Forms of media	<ul><li>lecture slides</li><li>notebooks wonline</li></ul>	ith program	ming exan	aples are	made available				
Literature	Algorithms, C • C.M. Bishop Springer, 2006	ambridge Ur e: Pattern R	niversity P ecognition	ress, 2003 and Mac	nce and Learning hine Learning, Machines, Pears				

Module MA-INF 4113	Cognitive R	Robotics							
Workload	Credit points	Duration		Freque	ncy				
180 h	6 CP	1 semest	ter	every year					
Module	Prof. Dr. Sver	Prof. Dr. Sven Behnke							
coordinator									
Lecturer(s)	Prof. Dr. Sver	n Behnke							
Classification	Programme			Mode	Semest	ter			
Classification	M. Sc. Compu	iter Scienc	e	Optiona	l   1. or 2	2.			
Technical skills	This lecture is	one of tw	o in	troducto	ry lecture	es of the intellig	gent		
	systems track.	The lectu	ire c	covers co	gnitive ca	pabilities of			
	robots, like sel	f-localizat	ion,	mappin	g, object j	perception, and	d		
	action-plannin	g in comp	lex (	environn	nents.				
	This module c	omplemen	ts N	IA-INF	4114 and	can be taken			
	before or after	-							
Soft skills	Communicativ	e skills (or	ral a	and writt	en presen	ntation of solut	ions,		
		,			-	(ability to acce	,		
	and formulate					•	•		
Contents						,			
		Probabilistic approaches to state estimation (Bayes Filters, Kalman Filter, Particle Filter), motion models, sensor models,							
	self-localization	n, mappin	g wi	ith know	n poses, s	simultaneous			
	mapping and l	localization	n (S	LAM), i	terated cl	osest-point			
	matching, patl	h planning	, pla	ace- and	person re	ecognition, obje	$\operatorname{ect}$		
	recognition.								
Prerequisites	Required:								
	MA-INF 4101	- Theory	of S	ensorimo	otor Syste	ems has not been	en		
	passed.								
	Teaching forms	at	Gro	up 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	Written exam					,	ded)		
Study achievements	Successful exe	rcise parti	cipa	tion		(not gra	ded)		
Forms of media									
	• S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics.								
	MIT Press, 2005.								
Litorature	• B. Siciliano,	O. Khatik	) (E	ds.): Spi	ringer Hai	ndbook of			
Literature	Robotics, 2008	3.							
	• R. Szeliski:	Computer	Vis	ion: Alg	orithms a	nd Application	ıs,		
	• R. Szeliski: Computer Vision: Algorithms and Applications, Springer 2010.								

Module	Robot Lear	ning							
MA-INF 4114	<u> </u>		T =						
Workload	Credit points	Duration	Freque	-					
180 h	6 CP	1 semester	every y	ear					
Module	Prof. Dr. Sven Behnke								
coordinator									
Lecturer(s)	Prof. Dr. Svei	n Behnke, Dr							
Classification	Programme	~ .	Mode	Semest					
	M. Sc. Compu		Optiona						
Technical skills				·	es of the intellig	_			
	1 -	_			hat can learn t				
			_		scinating challe	_			
				·	ingredients for				
	-		_		towards human				
	-				t learning, lear	ning			
	models for cor	-	_		_				
	demonstration	s and imitati	on learnii	ng, and in	nteractive learn	ing.			
	This module of	complements	MA-INF	4113 and	can be taken				
	before or after	before or after that module.							
Soft skills	Communicativ	ve skills (oral	and writt	en presen	ntation of solut	ions,			
	discussions in	small teams)	, self com	petences	(ability to acce	ept			
	and formulate	criticism, ab	ility to ar	alyze pro	blems)				
Contents	Reinforcement	learning, Ma	arkov deci	ision proc	esses, dynamic	;			
	programming,	Monte Carlo	methods	, tempora	al-difference				
	methods, func	tion approximation	nation, lie	ear quadr	atic regulation,	,			
	differential dy	namic progra	mming, p	artially o	bservable MDI	$P_{\mathbf{S}}$ ,			
	policy gradien	t methods, in	verse rein	ıforcemen	t learning,				
	imitation learn	ning, learning	kinemati	ic models	, perceiving an	d			
	handling of ob	jects.							
Prerequisites	none								
	Teaching form	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 teaching: S	S = index	endent st	tudy				
Exam achievements	Written exam		<b>T</b>			$\overline{\operatorname{ded}}$			
Study achievements	Successful exe	rcise particip	ation		(not gra				
Forms of media					( 0				
	• R. Sutton an	nd A. Barto:	Reinforce	ement Lea	arning, MIT-Pr	ess,			
	1998.				Ο,	- ,			
Literature	• O. Sigaud an	nd J. Peters (	Eds.): Fr	om Moto	r Learning to				
	Interaction Le		,		_				

Module	Introduction to Natural Language Processing						
MA-INF 4115	Introduction to Ivatural Language I rocessing						
Workload	Credit points Duration Frequency						
180 h	6 CP 1 semester every year	6 CP 1 semester every year					
Module	Prof. Dr. Lucie Flek						
coordinator							
Lecturer(s)	Prof. Dr. Lucie Flek						
Classification	Programme Mode Semester						
Classification	M. Sc. Computer Science   Optional   1. or 2.						
Technical skills	This class provides a technical perspective on NLP ? met						
	building computer software that understands and manip						
	human language. Contemporary data-driven approaches						
	emphasized, focusing on machine learning techniques. The						
	covered applications vary in complexity, including for exa	_					
Soft skills	Entity Recognition, Argument Mining, or Emotion Analy Group work during programming exercises will allow stu						
Soft Skills	work on real-world NLP application projects. The final p						
	offers you the chance to apply your newly acquired skills						
	an in-depth application using different frameworks such						
	PyTorch and spaCy and present it in a poster session.						
Contents	Through lectures, exercises, and a final project, you will	gain a					
	thorough introduction to cutting-edge research in NLP, f	from the					
	linguistic basis of computational language methods to re-						
	advances in deep learning and large language models. The	nis					
	course provides:						
	• An overview of NLP goals, challenges, and applications	3					
	• Text representation (Words, sentences, paragraphs,						
	documents), word embeddings, word2vec, BERT, word si	milarity					
	• Machine learning / deep learning algorithms for text						
	classification, Transformers  • Basics of neural language modeling						
	Basics of neural language modeling     Basics of computational linguistics						
	- Transforming words to their base forms (tokenization, stemming, lemmatization)						
	,	1					
	- Syntactic analysis (part of speech tagging, chunking, ar	nd					
	parsing)						
	- Techniques for extracting meaning from text (semantic						
	analysis), use of lexical resources in NLP						
	• NLP applications and projects (e.g., Sentiment Analysis	is,					
	Named Entity Recognition, Question Answering,						
	Summarization, Fake news detection, Plagiarism detection	on,					
Prerequisites	Abusive language detection, Opinion mining)  Recommended:						
r rerequisites	Basics of statistics recommended.						
	Basic programming knowledge in Python is of advanta	ge.					
	• Basics of machine learning are of advantage.	0					
	Teaching format Group size h/week Workload	[h] CP					
Format	Lecture 3 45 T / 45						
	Exercises   1   15 T / 75	$5 S \mid 3$					
	T = face-to-face teaching; $S = independent study$						
Exam achievements	Klausur (60 %); Projektarbeit (40 %)	(graded)					
Study achievements	9 0	graded)					
Forms of media	• Lecture slides						
	• Exercise slides						
	• Notebooks with programming examples	• Notebooks with programming examples					

Module	AI Ethics Seminar								
MA-INF 4116									
Workload	Credit points	Duration	Frequency						
120 h	4 CP	1 semester	er every year						
Module	Prof. Dr. Lucie Flek								
coordinator									
Lecturer(s)	Prof. Dr. Luci	ie Flek							
Classification	Programme M. Sc. Compu	Programme Mode Semester M. Sc. Computer Science Optional 1. or 2.							
Technical skills	of artificial int AI systems, id	elligence. St entifying eth ugh ethical	udents wil ical dilem	l develop mas and	e ethical dilemmas skills in assessing social impacts, and communicating				
Soft skills	Students will l responsible sys multidisciplina science. At the essay on one o	Students will learn about the design of ethical and socially responsible systems. They will gain practice engaging with multidisciplinary perspectives from behavioral and social science. At the end of the course, students will write a final term essay on one of the course topics.							
Contents	We study artif associated with interaction with Six broad mod	h the research th AI system	ch, design, s.	deploym					
	<ul> <li>Foundations</li> <li>Bias &amp; fairne</li> <li>Privacy &amp; da</li> <li>Social netwo</li> <li>Politics &amp; pe</li> <li>AI for "social</li> </ul>	ess ata privacy rks & civilit olicy		unication	n				
	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 engineering.								
Prerequisites	Required: No previous ki	nowledge is	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 must.								
Format	Teaching forms Seminar	at G	roup size	h/week	Workload[h]   CP     30 T / 90 S   4				
	T = face-to-fa	ce teaching;	S = indep	endent st	tudy				
Exam achievements	Schriftliche Pr	üfung			(graded)				
Study achievements	Erfolgreiche Ü	bungsteilnal	ime		(not graded)				
Forms of media									
Literature									

Module	Artificial Life								
MA-INF 4201									
Workload	Credit points	Duration	Freque	ncy					
180 h	6 CP	1 semester	every y	rear					
Module	Prof. Dr. Sven Behnke								
coordinator									
Lecturer(s)	Prof. Dr. Sver	Behnke, Dr	. Nils Go	erke					
Classification	Programme		Mode	Semes	ter				
Classification	M. Sc. Compu	ter Science	Optiona	l 1-3.					
Technical skills	Detailed under	rstanding of	the most	important	t approaches a	nd			
	principles of a	rtificial life.	Knowledg	e and und	derstanding of	the			
	current state of	of research in	the field	of artifici	al life				
Soft skills		•			rtificial life, an				
	present and de	efend the fou	nd solution	ns within	the exercises	in			
	front of a grou	p of students	s. Critical	l discussion	on of the result	s of			
	the homework.	•							
Contents	Foundations of								
	of Life"; mecha	anisms for st	ructural c	developme	ent; foundation	s of			
	nonlinear dyna	amical systen	ns, Linder	nmeyer-sy	stems,				
	evolutionary m	nethods and	genetic al	gorithms,	reinforcement				
	learning, artific		-	_					
	self-organising		_	-	, and swarm				
	intelligence, pa	article swarm	optimiza	tion.					
Prerequisites	none								
	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 = indep	endent st	cudy				
Exam achievements	Written exam				(gra	ded)			
Study achievements	Successful exer	rcise particip	ation		(not gra	ded)			
Forms of media	Pencil and pap	er work, exp	lain solut	ions in fr	ont of athe exe	rcise			
	group, implem	entation of s	mall prog	rams, use	of simple				
	simulation too	ls.							
	• Christoph A	dami: Introd	uction to	Artificial	Life, The				
	Electronic Library of Science, TELOS, Springer-Verlag								
	• Eric Bonabeau, Marco Dorigo, Guy Theraulaz: Swarm								
	Intelligence: From Natural to Artificial Systems, Oxford								
T:tomotumo	University Pre	ss, Santa Fe	Institute	Studies in	n the Science o	f			
Literature	Complexity.								
	• Andrzej Osy	czka: Evolut	ionary Al	gorithms	for Single and				
	Multicriteria I	Design Optim	ization, S	Studies in	Fuzzyness and	[			
	Soft Computin	ng, Physica-V	erlag, A	Springer-	Verlag Compar	ıy,			
	Heidelberg								

Module	Autonomous	Mobile	Systems					
MA-INF 4203								
Workload	•	Duration	Freque	-				
180 h		6 CP   1 semester   every year						
Module	Prof. Dr. Sven	Prof. Dr. Sven Behnke						
coordinator								
Lecturer(s)	Dr. Dirk Schulz	z, Prof. Dr		nke				
Classification	Programme		Mode	Semest	ter			
	M. Sc. Comput		Optiona					
Technical skills	Profound know	_	-			cture		
	and function of					,		
	Knowledge of t	_						
	requirements fo	_		-	_	fic		
	applications and							
Soft skills	The students w	_						
	autonomous mo			-				
	what part of th		_	_				
	of the art devel	_			_	and		
	implement a so							
Contents	Requirements for	_						
	systems, e.g. fo	_			<del>-</del> '			
	SLAM-methods	-	_	_				
	methods for act	_	_	arison of c	imerent learnii	ıg		
D	paradigms for s  Recommended:	specific app	ilcations.					
Prerequisites	all of the follow	ing:						
		_	· C	- 4 · C4 ·				
	MA-INF 4101 -	_		otor Syste	ems			
	MA-INF 4113 -					ı		
	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: Mobile Robots: Moving Intelligence, Published by							
	Advanced Robo							
Literature	• Sebastian Th		_	d, Dieter	Fox: Probabili	$\operatorname{stic}$		
Liverandie	Robotics, MIT							
	• Howie Choset	t et al.: Pri	nciples of	Robot Mo	otion, MIT-Pre	ess,		
	2005							

Module MA-INF 4204	Technical Neural Nets								
Workload	Credit points	Duration	Freque	2017					
180 h	6 CP	1 semester	_	-					
Module			every y	Cai					
coordinator	1 101. D1. 30ac	Prof. Dr. Joachim K. Anlauf							
	Doof Do Issa								
Lecturer(s)		Prof. Dr. Joachim K. Anlauf, Dr. Nils Goerke							
Classification	Programme M. C. C. C.	C.:	Mode	Semest	ter				
	M. Sc. Compu		Optiona		1 , 1				
Technical skills	Detailed knowledge of the most important neural network approaches and learning algorithms and its fields of applications.								
		_	_						
	_		_		ural networks a				
		-			nilar to concep	ots of			
	brain function								
Soft skills		•			al paradigms f				
			-	_	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	maps (Koho	nen), ada	ptive resc	onance theory,				
	learning vector	r quantizatio	n, recurre	nt networ	·ks,				
	back-propagat	ion of error,	reinforcen	nent learn	ning, Q-learning	g,			
	support vector	machines, p	ulse proce	essing neu	ıral networks.				
	Exemplary app	plications of	neural ne	ts: function	on approximati	ion,			
	prediction, qua	ality control,	image pro	ocessing,	speech process	ing,			
	action plannin	g, control of	technical	processes	and robots.				
	Implementation	on of neural r	etworks i	n hardwa	re and software	e:			
	tools, simulate	ors, analog ar	d digital	neural ha	rdware.				
Prerequisites	none								
	Teaching forma	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:	ا S — inder	endent st	'	1			
Exam achievements	Written exam	ec teaching,		CHacht St		ded)			
Study achievements	Successful exe	rcise particip	ation		(not gra				
Forms of media	Successiui exe	reise particip	a 01011		(not gra	aea)			
rorms of media	• Christopher M. Bishop: Neural Networks for Pattern								
		•							
T*/	Recognition, Oxford University Press, ISBN-10: 0198538642, ISBN-13: 978-0198538646								
Literature			) A1 . •	l_ f_ D :	D				
		•	_		ttern Recogniti	ion,			
	Springer, ISBN-10: 1852334401, ISBN-13: 978-1852334406								

Module MA-INF 4207	Dynamicall	Dynamically Reconfigurable Systems					
Workload	Credit points	Duration	Freque	encv			
180 h	6 CP	1 semest	_	st every 2	vears		
Module	Prof. Dr. Joac			J.	U		
coordinator							
Lecturer(s)	Prof. Dr. Joac	Prof. Dr. Joachim K. Anlauf					
CI 'C '	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	e Options	al 2.			
Technical skills	to select appro	Knowledge of the most important FPGA architectures, ability to select appropriate FPGAs for a given application, overview of programming tools					
Soft skills	solutions), soc discussions of	Communicative skills (oral and written presentation of solutions), social skills (ability to solve problems in small teams, discussions of solution concepts) self competences (ability to accept and formulate criticism, ability to analyze problems)					
Contents	Architecture o	,		0	, 0		
				_	tion Language	s,	
	Synthesis, Tec				oute, FPGA		
	Computing, P	artial Reco	nfigurabili	ty			
Prerequisites	none			1			
	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 = inde	pendent st	tudy		
Exam achievements	Oral exam				(gra	ded)	
Study achievements	Successful exe	rcise partic	ipation		(not gra	ided)	
Forms of media							
Literature	Current resear	ch papers	and techni	cal docum	entation		

Module MA-INF 4208	Seminar Vis	sion System	ms						
Workload	Credit points	Duration	Frequen	ıcy					
120 h	4 CP	1 semester	every se	emester					
Module	Prof. Dr. Sver	n Behnke	1						
coordinator									
Lecturer(s)	Prof. Dr. Sver Dr. Nils Goerl	,	of. Dr. Jo	achim K.	Anlauf,				
Classification	Programme		Mode	Semest	ter				
Classification	M. Sc. Compu	ter Science	Optional	2. or 3	3.				
Technical skills	• Knowledge i	n advanced t	opics in tl	ne area o	f technical vision	on			
	systems, such	as image seg	mentation	, feature	extraction, and	d			
	object recognit	tion.							
	• Ability to ur	• Ability to understand new research results presented in							
	original scienti	fic papers ar	d to prese	ent them	in a research t	alk			
	as well as in a	as well as in a seminar report.							
Soft skills	_	Self-competences (time management, literature search,							
	self-study), con	self-study), communication skills (preparation and clear didactic							
	presentation of		*		, , , , , , , , , , , , , , , , , , ,				
	writing of sem			,		and			
	accept criticism	<u> </u>							
Contents	Current resear				-	e			
	field of vision	systems cove	ring funda	mental t	echniques and				
	applications.								
Prerequisites	Recommended								
	At least 1 of the	0							
	MA-INF 4111		Learning	and Ana	lysis Systems:				
	Machine Learr	$_{ m ning}$							
	MA-INF 4204	- Technical	Neural Ne	ts					
Format	Teaching forma	at Gı	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									
	• R. Szeliski: Computer Vision: Algorithms and Applications,								
	Springer 2010.								
Literature	• C. M. Bishop: Pattern Recognition and Machine Learning,								
	Springer 2006.		~						
	• D. A. Forsyt			uter Visi	on: A Modern				
	Approach, Pre	ntice Hall, 2	JU3.						

Module		inciples o	of Da	ata M	ining a	nd Learning	
MA-INF 4209	Algorithms	<b>—</b>					
Workload	Credit points	Duration		Frequency			
120 h	4 CP	1 semest	er	every ye	ear		
Module	Prof. Dr. Stef	an Wrobel					
coordinator							
Lecturer(s)	Prof. Dr. Stef	an Wrobel					
Classification	Programme			Iode			
	M. Sc. Compu			ptional			
Technical skills		-		_	-	zed topics in th	ıe
	area of machin	ne learning	and	data m	ining, acc	quiring the	
	competence to	independe	ntly	study s	cientific 1	literature, pres	$\operatorname{ent}$
	it to others an	to others and discuss it with a knowledgeable scientific					
	auditorium. L	earn how t	o scie	entifical	lly presen	t prior work by	У
	others, in writ	others, in writing and in presentations.					
Soft skills	Communicative skills (preparing and presenting talks, written						
	presentation o	f contents i	n a l	longer d	locument	), self compete	nces
	(time manager	ment with	ong-	ranging	deadline	es, ability to ac	cept
	and formulate	and formulate criticism, ability to analyse, creativity).					
Contents	Theoretical, st	atistical ar	ıd alg	gorithm	ical princ	ciples of data	
	mining and lea	arning algo	rithn	ns. Sear	ch and o	ptimization	
	algorithms. Sp	ecialized le	earni	ng algo	rithms fr	om the frontier	of
	research. Fund	damental re	sults	s from r	neighbour	ring areas.	
Prerequisites	Recommended	:					
	At least 1 of the	he followin	g:				
	MA-INF 4111	– Intelliger	nt Le	earning	and Ana	lvsis Systems:	
	Machine Learn	_		O			
	MA-INF 4112	_	nt Le	arning	and Ana	lysis Systems	
	Data Mining a	_		_		lybib bybucins.	
	Teaching forms			p size	$\frac{\mathbf{h}_{y}}{\mathbf{h}_{week}}$	Workload[h]	СР
Format	Seminar			0	2	30 T / 90 S	4
		. 1:		1		,	1
	T = face-to-fa				endent st		1 1\
Exam achievements	Oral presentat	ion, writte	n rep	ort		,,,	$\frac{\text{ded}}{1}$
Study achievements	G : 1:0	1 1	• ,	• .	. •	(not gra	<u>ded)</u>
Forms of media	Scientific pape			<u>′</u>			
Literature			ill be	e annou	nced tow	ards the end of	f the
	previous semes	ster.					

Module	Seminar Ad	lvanced T	opics in	Technic	al Informati	$\mathbf{c}\mathbf{s}$	
MA-INF 4210							
Workload	Credit points	Duration	Freque	ncy			
120 h	4 CP	1 semest	emester at least every 2 years				
Module	Prof. Dr. Joac	chim K. Ar	lauf				
coordinator							
Lecturer(s)	Prof. Dr. Joachim K. Anlauf						
Classification	Programme		Mode	Semes	Semester		
Classification	M. Sc. Compu	iter Science	e Optiona	1 2. or 3	3.		
Technical skills	Current Topic	Current Topics in Technical Informatics					
Soft skills	Communicativ	Communicative skills (preparing and presenting talks, preparing					
	a structured w	a structured written document), social skills (ability to accept					
	and formulate	and formulate criticism, discussions of current content) self					
	competences (	time mana	gement wit	h long-rar	nging deadlines	3,	
	understanding	of research	topics from	m original	literature)		
Contents	Current topics	such as: n	ew archited	ctures of c	omputers or		
	FPGAs (field	programma	ble gate ar	rays) or n	ew application	s of	
	dynamically re	econfigurab	le systems				
Prerequisites	none						
Format	Teaching forms	at	Group size	h/week	Workload[h]	CP	
rormat	Seminar		10	2	30 T / 90 S	4	
	T = face-to-fa	ce teaching	S = I = I = I = I = I = I = I = I = I =	endent st	udy	•	
Exam achievements	Oral presentat	ion, writte	n report		(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	Frequen					
120 h	4 CP	1 semester	ster   every semester					
Module	Prof. Dr. Sver	n Behnke						
coordinator								
Lecturer(s)	Prof. Dr. Sver	n Behnke, Dr						
Classification	Programme		Mode Semester					
	M. Sc. Compu		Optional					
Technical skills	Knowledge in	_			_			
	such as robot	perception, a	ction plan	ning, and	d robot learnin	g.		
	Ability to und	erstand new	research r	esults pre	esented in original	$_{ m inal}$		
	scientific pape	rs and to pres	sent them	in a rese	arch talk as we	ell as		
	in a seminar re	eport.						
Soft skills	Self-competen	ces (time mai	nagement,	literatur	e search,			
	self-study), co	mmunication	skills (pre	paration	and clear dida	actic		
	presentation of research talk, scientific discussion, structured							
	writing of sem	inar report),	social skil	ls (ability	y to formulate	and		
	accept criticisi	accept criticism, critical examination of research results).						
Contents	Current resear	ch papers fro	m confere	nces and	journals in th	e.e		
	field of cogniti	ve robotics co	overing fu	ndament	al techniques a	$\operatorname{ind}$		
	applications.							
Prerequisites	Recommended	:						
	At least 1 of t	he following:						
	MA-INF 4113	- Cognitive 1	Robotics					
	MA-INF 4114	9						
	Teaching forms		oup size	h/week	Workload[h]	CP		
Format	Seminar		10	2	30 T / 90 S	4		
	T = face-to-fa	ce teaching: 9	1	andont et	,	I		
Exam achievements	Oral presentat					ded)		
Study achievements	orar prosentate	ion, whiteen i	СРОГС		(not gra			
Forms of media					(1100 810			
	• S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics.							
	MIT Press, 2005.							
Literature	• B. Siciliano,		Eds.): Spr	inger Hai	ndbook of			
· · · · · · · · · · · · · ·	1	`	/ ~ P	G				
	Robotics, 2008.  • Selected papers.							

Module MA-INF 4213	Seminar Hu	ımanoid I	Robots					
Workload	Credit points	Duration	Freque	ncy				
120 h	4 CP	1 semeste	ter every semester					
Module	Prof. Dr. Mar	en Bennewi	tz					
coordinator								
Lecturer(s)	Prof. Dr. Mar	en Bennewi	tz					
Classification	Programme		Mode	Semes	ter			
Classification	M. Sc. Computer Science   Optional   2.							
Technical skills	Knowledge in	advanced to	pics in the	area of h	numanoid robe	tics,		
	motion planni scientific pape self-written su	such as environment perception, state estimation, navigation, or motion planning. Ability to understand new research results of scientific papers and to present them in a talk as well as in a self-written summary.						
Soft skills	Self-competen	`	_	,	,			
		self-study), communication skills (preparation of the talk, clear didactic presentation of techniques and experimental results,						
	_							
	scientific discu							
	` "		-		ical examinati	on of		
	_	algorithms and experimental results).  Current research papers from conferences and journals in the						
Contents					-			
	field of human	old robotics	covering	undamen	tai techniques	and		
D	applications.  Recommended	_						
Prerequisites								
	At least 1 of t							
	MA-INF 4215							
	MA-INF 4113							
Format	Teaching forms	at C	roup size	h/week	Workload[h]	CP		
	Seminar		10	2	30 T / 90 S	4		
	T = face-to-fa	ce teaching	S = indep	endent st	tudy			
Exam achievements	Oral presentat	ion, writter	report		(gra	aded)		
Study achievements					(not gra	aded)		
Forms of media								
	- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press							
	- B. Siciliano,	O. Khatib	Eds.): Spr	inger Har	ndbook of Rob	otics		
Literature	- K. Harada, I Humanoid Ro	,	`	Eds.), Mo	otion Planning	for		
	- Selected pan	ers.						
	- Selected papers.							

Module	Lab Human	oid Robot	S					
MA-INF 4214								
Workload	Credit points	Duration	Freque	-				
270 h	9 CP 1 semester   every semester							
Module	Prof. Dr. Mar	en Bennewitz	Z					
coordinator								
Lecturer(s)	Prof. Dr. Mar	en Bennewitz						
Classification	Programme	~ .	Mode	Semes	ster			
	M. Sc. Computer Science   Optional   2.							
Technical skills	_		-	_	in the design a			
	_		,		on, environment			
	_			_	ing techniques			
				-	cipants analyze	a		
	problem, realize	ze a solution,	and per	form an e	experimental			
	evaluation.							
Soft skills	_	elf-competences (time management, goal-oriented work, ability						
		o analyze problems theoretically and to find practical						
			•		on in small tean			
		-	on of solu	itions, cr	itical examinati	on		
	-	of implementations).						
Contents		,	,		ion, environmen			
	_	s, navigation	, and mo	tion plan	ning for human	oid		
	robots.							
Prerequisites	Recommended							
	At least 1 of t	_						
	MA-INF 4215	– Humanoid	Robotic	8				
	MA-INF 4113	- Cognitive	Robotics					
Format	Teaching forms	at Gro	up size	h/week	Workload[h]	CP		
Tornat	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					· · · · · · · · · · · · · · · · · · ·			
	- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press							
Litaratura	- B. Siciliano,	O. Khatib (E	Eds.): Sp	ringer Ha	ndbook of Rob	otics		
Literature	- K. Harada, I Humanoid Ro			(Eds.), M	otion Planning	for		
	- Selected pap	ers.						

Module	Humanoid Robotics						
MA-INF 4215							
Workload	Credit points	Duration	Freque	Frequency			
180 h	6 CP	1 semeste	r at least	at least every 2 years			
Module	Prof. Dr. Mar	en Bennewi	tz				
coordinator							
Lecturer(s)	Prof. Dr. Mar	Prof. Dr. Maren Bennewitz					
Classification	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optional	l 2-3.			
Technical skills	This lecture co	overs technic	ques for hu	manoid r	obots such as		
	perception, na	perception, navigation, and motion planning.					
Soft skills	Communicativ	Communicative skills (oral and written presentation of solutions,					
	discussions in	liscussions in small teams), ability to analyze problems.					
Contents	Self-calibration	Self-calibration with least squares, 3D environment					
	representation	epresentations, self-localization with particle filters, footstep					
	planning, inve	rse kinemat	cs, whole-l	body mot	ion planning w	$^{\mathrm{rith}}$	
	rapidly explor	ing random	trees, stati	istical tes	ting.		
Prerequisites	Recommended						
	MA-INF 4113						
	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	Oral exam				(gra	ded)	
Study achievements	Successful exe	rcise partici	oation		(not gra	ded	
Forms of media							
	• S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics.						
	MIT Press, 2005.						
Literature	• B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics						
Disciaraic	· ·		,	Eds.), Mo	otion Planning	for	
	Humanoid Ro	,					
	• Selected rese	earch papers					

Module	Biomedical Data S	cience \&{	} AI				
MA-INF 4216	G 111 1 1 D 11						
<b>Workload</b> 180 h	Credit points Duratio 6 CP 1 seme	_	-				
	6 CP   1 seme Dr. Holger Fröhlich	ster   every y	ear				
Module coordinator	Dr. noiger Fromici						
Lecturer(s)	Dr. Holger Fröhlich						
Lecturer(s)	Programme	Mode	Semes	tor			
Classification	M. Sc. Computer Scier			re1			
Technical skills	- understanding and kr machine learning meth	nowledge of fu ods	ndamenta	J	and		
Soft skills	<ul><li>understanding of thei</li><li>communication: oral</li><li>exercises</li><li>self-competences: abi</li></ul>	and written p	resentatio	on of solutions			
	to formulate possible so	olutions			ard		
	- practical skills: ability	•	-				
Contents	This lecture gives a brostatistical techniques as learning algorithms. The problems in bioinformation understand the explain correctly and partially	- social skills: working in a small team with other students  This lecture gives a broad overview about frequently used 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 explained methods, being able to apply them correctly and partially implement them. More detailed, the following topics are covered in the context of their application in bioinformatics:					
	- Short introduction to	Bioinformatio	cs and Bi	omedicine			
	- Statistical Basics: Proinference, statistical hy regression, Principal Co	pothesis testii	ng, linear	•	ic		
	- Clustering						
	- Hidden Markov Mode	els					
	- Principles of Supervis	sed Machine L	earning				
	- Elastic Net		J				
Duono estate	- Basics of deep learning	ıg					
Prerequisites	none Teaching format	Cnown -!	h /	Worlder 10-1	CP		
Format	Teaching format Lecture	Group size	h/week	Workload[h]   30 T / 45 S	2.5		
1 Of Hat	Exercises		$\frac{2}{2}$	30 T / 45 S 30 T / 75 S	3.5		
				,	0.0		
D	T = face-to-face teachi	ng; S = ndep	enaent st		4.4/		
Exam achievements	Written exam	igination		,-	$\frac{\text{ded}}{\text{ded}}$		
Study achievements	Successful exercise part	леграноп		(not gra	ueu)		
Forms of media	,	T. Hastie, R. Tibshirani, J. Friedman, The Elements of tatistical Learning, Springer, 2008					
Literature	S.Boslaugh, P. Watters, Statistics in a Nutshell, O'Reilly, 2008						
		P. Pevzner, An Introduction to Bioinformatics					

Module	Seminar Ma	achine I	ear	ning M	lethods	in the Life	
MA-INF 4217	Sciences						
Workload	Credit points	Duration	n	Freque	ncy		
120 h	4 CP	1 semes	ster	every y	rear		
Module	Dr. Holger Frö	ihlich					
coordinator							
Lecturer(s)	Dr. Holger Frö	<u>ihlich</u>					
Classification	Programme			Mode	Semes	ter	
	M. Sc. Compu			Optiona		• 1 1	
Technical skills	- understandin						
Soft skills	and their apple						
Soft Skills				-		•	
	- self-competer		-				
	given topic; ab	ollity to re	ead,	understa	nd and a	nalyze scientin	c
	publications						
	- social skills:	-	disc	cuss a sci	entific top	pic with other	
<b>Q</b>	students and the staff  Machine learning techniques play a crucial role in modern li						
Contents		_	-				
	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 learning						
	- Survival and disease progression models						
	- Bayesian Networks						
	- Stochastic processes, e.g. Gaussian Processes, Dirichlet Process						
	- Stocnastic pr Mixture Mode		e.g. (	Gaussian	Proceses	s, Dirichlet Pro	cess
	- MCMC methods						
	- Deep learning methods, e.g. DNNs, CNNs, Deep Belief Networks						
	- feature selection and non-linear embedding methods						
	- multi-modal data fusion techniques						
	Attendees will be asked to perform research about their topic in						
	a self-responsible manner.						
Prerequisites	Recommended						
	MA-INF 4216	– Data M	Iinir	ng and M	achine Le	earning Metho	ds in
	Bioinformatics						
Format	Teaching forma	at	Gro	oup size	h/week	Workload[h]	CP
1 01 HIM	Seminar			10	2	30 T / 90 S	4
	T = face-to-face	ce teachir	ng; S	S = indep	endent st	tudy	
Exam achievements	Oral presentat	ion, writt	en r	eport		(gra	ded)
Study achievements						(not gra	ded
Forms of media	powerpoint						
Literature	selected journa	al and cor	nfere	nce pape	ers		

Module	Lab Paralle	l Computi	ng for I	Mobile 1	Robotics			
MA-INF 4226								
Workload	Credit points	Duration	_	Frequency				
270 h	9 CP	1 semester		at least every 2 years				
Module	Prof. Dr. Mar	en Bennewit	$\mathbf{Z}$					
coordinator								
Lecturer(s)	Prof. Dr. Mar	en Bennewit	Z					
Classification	Programme		$\mathbf{Mode}$	Semes	ster			
Classification	M. Sc. Compu	iter Science	Optiona	al 2.				
Technical skills	Students will i	make practic	al experie	ence with	the design and			
	implementatio	n of paralleli	zed algor	rithms in	the context of			
	motion planni	ng and navig	ation.					
Soft skills	Ability to prop	perly present	and defe	end design	n decisions, to			
	prepare readal	ble document	ation of	software;	skills in			
	constructively	constructively collaborating with others in small teams over a						
	longer period	of time; abili	ty to clas	sify ones	own results into	the 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	g, 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	: Autonomou	ıs Mobile	Systems				
	MA-INF 4113	: Cognitive I	Robotics					
	MA-INF 4310	: Lab Mobile	Robots					
Format	Teaching forms	at Gro	oup size	h/week	Workload[h]	CP		
ruimat	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	Foundations	s of Data 9	Science				
MA-INF 4228	Toundation	or Data i	belefice				
Workload	Credit points	Duration	Freque	ncv			
270 h	9 CP	1 semester	_	-			
Module	Dr. Michael N		0 0				
coordinator							
Lecturer(s)	Dr. Michael N	Tüsken					
CI :C .:	Programme		Mode	Semes	ster		
Classification	M. Sc. Compu	iter Science	Optiona	1 2. or	3.		
Technical skills	Knowledge: P	eculiarities o	f high din	nensional	spaces in geom	netry	
	and probabilit	ies. Singular	vector de	ecomposi	tion. Basics in		
	machine learn	ing and clust	ering.				
	Skills: Unders	tanding of m	athematic	cal tools.			
Soft skills		Competences: Application to data science problems and ability					
		o assess similar methods.					
Contents	Data science a	ims at maki	ng sense o	of big dat	a. To that end,	,	
	various tools h	arious tools have to be understood for helping in analyzing the					
	arising structu	rising structures.					
	Often data con	Often data comes as a collection of vectors with a large number					
					structure is th		
	_				a. The geometr		
	and the linear			_	_	·	
		_			ensional space t	urns	
	out to be often	n misleading	We need	l to be av	ware of the		
	particular proj	perties of hig	h-dimens	ional spa	ces when worki	ng	
	with such data	a. Fruitful m	ethods for	r the ana	lysis include		
	singular vector	r decomposit	ion from	linear alg	gebra and		
	supervised and	d unsupervise	ed machir	ne learnin	ng. If time perm	nits,	
	we also consid	er random g	caphs, wh	ich are tl	he second most	used	
	model for real	world pheno	mena.				
Prerequisites	none						
	Teaching forms	at Gre	oup size	h/week	Workload[h]		
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	endent s	study		
Exam achievements	Schriftliche Pr	rüfung			(gra	ded)	
Study achievements	Erfolgreiche Ü	bungsteilnah	me		(not gra	ded	
Forms of media							
Literature				avindran	Kannan (2018-	⊦)	
Discrasure	Foundations o	f Data Scien	ce.				

Module	Pattern Red	cognitio	n I					
MA-INF 4229								
Workload	Credit points	Duration		Frequer	ıcy			
270 h	9 CP	1 semest		every ye	ar			
Module	Prof. Dr. Chris	tian Bauck	hag	ge .				
coordinator								
Lecturer(s)	Prof. Dr. Chris	tian Bauck	hag	ge				
Classification	Programme		N	Iode	Semester			
Classification	M. Sc. Comput			ptional	2.			
Technical skills	Upon completion	n, students	s sh	ould be a	ble to			
	clustering, and • implement ba optimization	ullet implement basic and advanced algorithms for data clustering and						
	• implement ba						n	
Soft skills	Students will lea							
		foundations of machine learning for pattern recognition. They will						
	learn about bas							
Contents	• fundamental of						ice.	
	recognition  basic and adv  basic and adv  least squares  maximum like  maximum a-p  Bayesian infer  fundamental a  the curse of d  methods and  Gaussian mix  the method of  quadratic and  algorithms for  support vecto  the kernel tric  neural networ  Hebbian learn	anced conceanced conceanced conceanced conceanced conceanced conceanced conceanced constrained constra	cepts for hnicechnods earn ity for mucrimed odds.	s in linear s in proba model fit ques tiques data clus ltipliers a tinant ana	r algebra ability theoreting  ry and the retering  and the KK alysis	ry and statistics		
Prerequisites	Recommended							
	Students should						oility	
	theory, and stat							
	Teaching forms	at	Gr	oup size	h/week	Workload[h]	СР	
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	Schriftliche Prü					(gra	aded)	
Study achievements	Erfolgreiche Üb	ungsteilnal	hme	<b>)</b>		(not gra		
Forms of media	• lecture slides				ne	, , , , , , , , , , , , , , , , , , , ,		
	• lecture notes	with progra	amr	ning exan	nples are m	ade available on	line	
	Bishop, "Patter:							
Literature	Duda, Stork, Ha	_				_		
Diterature						· A1 · · 1	,	
	MacKay, "Inform	mation The	eory	, Interenc	e, and Lear	rning Algorithm	S"	

Module MA-INF 4230	Advanced M	Iethods	of	Inform	ation Re	etrieval	
Workload	C1:4:4-	D		T			
180 h	Credit points 6 CP	Duration 1 semest		Frequer every y	-		
Module	Prof. Dr. Elen			every y	eai		
coordinator	Tion. Dr. Elem	a Dellildo	va				
Lecturer(s)	Prof. Dr. Elen	a Demido	179				
Decturer(s)	Programme Mode Semester						
Classification	_	M. Sc. Computer Science   Optional   2. or 3.					
Technical skills	This module in data structures structured and knowledge grap	troduces s, and algo semi-stru	the orith	students hms of in red data	to the action to the action to the action to the action of the action to	n retrieval for g, for example	
	choosing appro specific applica machine learning	At the end of the module, the students will be capable of choosing appropriate data structures and retrieval algorithms for specific applications and correctly apply relevant statistical and machine learning-based information retrieval procedures.					
Soft skills	discussion of so	Communication skills: oral and written presentation and discussion of solutions.					
Contents	Self-competence The module to						
	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						
	Teaching forma	t	Gro	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		g; S	= indep	endent st	-	
Exam achievements	Schriftliche Pri					,,,	ded)
Study achievements	Erfolgreiche Üb	oungsteiln	ahn	ne		(not gra	ded)
Forms of media							
	Selected chapte	ers from:					
	<ul> <li>Christopher I Schütze, Introd</li> <li>University Pres</li> <li>Bhaskar Mitr</li> <li>Neural Information Re</li> </ul>	luction to ss. 2008. ra and Nic ation Retr	Inf ck (	formation Craswell al ", Four	n Retrieva (2018), "Andations a	d, Cambridge An Introduction and Trendső in	n to
Literature	- Ridho Reinan "Knowledge Gr Foundations an 4, pp 289-444.	aphs: An	Inf	formation	n Retrieva	al Perspective",	
	- Jeffrey Xu Yu Databases. Syr Claypool Publi	nthesis Le	ctui				an &
	Further referenthe lecture.	ices to rele	evar	nt materi	ial will be	provided duri	ng

Module MA-INF 4231	Seminar Ad	lvanced To	pics in I	nforma	tion Retriev	/al		
	G 1:4 : 4	D	ъ					
Workload	Credit points	Duration	Frequen	-				
120 h	4 CP	1 semester	2 2					
Module	Prof. Dr. Eler	na Demidova						
coordinator	D 4 D EI							
Lecturer(s)	Prof. Dr. Eler	na Demidova						
Classification	Programme	~ .	Mode	Semest				
	M. Sc. Compu		Optional					
Technical skills	This module of		-	_				
	retrieval. The				-	-		
	study of state-				_			
	discussion with their peers and presentation to the scientific							
	audience.							
Soft skills	Communication	Communication skills: oral and written presentation of scientific						
	content. Self-competences: the ability to analyze problems, time							
	management, creativity.							
Contents	Statistical and machine learning-based information retrieval							
	methods, including typical steps of the information retrieval							
	process: data collection, feature extraction, indexing, retrieval,							
	ranking, and evaluation. Specialized data representation and							
		retrieval methods for selected data types and applications in						
	specific domai		v	1	11			
Prerequisites	Recommended							
1	MA-INF 4230	- Advanced	Methods o	of Informa	ation Retrieval			
	Teaching forms		oup size	h/week	Workload[h]	СР		
Format	Seminar		10	2	30 T / 90 S	4		
		1 1	I		,	1 -		
	T = face-to-fa	<u> </u>		endent st		1 1\		
Exam achievements	Oral presentat	tion, written	report		,,,	ded)		
Study achievements	None				(not gra	ided)		
Forms of media								
	Selected chapters from:							
	• Christopher D. Manning, Prabhakar Raghavan and Hinrich							
	Schütze, Introduction to Information Retrieval, Cambridge							
	University Press. 2008.							
Literature								
Literature	• Bhaskar Mitra and Nick Craswell (2018), "An Introduction to							
	Neural Information Retrieval ", Foundations and Trendső in							
	Information Retrieval: Vol. 13: No. 1, pp 1-126.							
	Further relevant literature will be announced at the beginning of							
	the seminar.							

Module	Lab Informa	ation Retri	eval in	Practio	ce				
MA-INF 4232	G 114	D 41	ъ						
Workload 270 h	Credit points 9 CP	Duration	Frequency						
_, , ,		1 semester   every year							
Module	Prof. Dr. Elen	na Demidova							
coordinator	D C D EI	D ( D FI D )							
Lecturer(s)	Prof. Dr. Elen	na Demidova							
Classification	Programme		Mode	Seme					
	M. Sc. Compu		Optiona						
Technical skills			-	_	ience in informa				
					ge and practica				
	_		_	_	formation retrie	eval			
		ystems 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.				U / 1				
Contents	Practical appl	Practical application of information retrieval methods to solve							
					aluate proposed				
	solutions.								
Prerequisites	Recommended	Recommended:							
-	MA-INF 4230	- Advanced M	Methods	of Inforn	nation Retrieva	l			
	MA-INF 4231	- Seminar Ac	lvanced '	Topics in	Information				
	Retrieval	201111101 110		10 proc 111	1111011110001011				
	Teaching forms	at Gro	up size	h/week	Workload[h]	CP			
Format	$\frac{1}{Lab}$		8	4	60 T / 210 S	9			
			-	- 	,	1			
T 1.	T = face-to-fa			pendent s		11\			
Exam achievements	Oral presentat	Jon, written i	eport		,-	aded)			
Study achievements	None				(not gra	adea)			
Forms of media	C 1 . 1 1	C							
	Selected chapt	ers from:							
	• Christopher D. Manning, Prabhakar Raghavan and Hinrich								
	Schütze, Introduction to Information Retrieval, Cambridge								
	University Press. 2008.								
Literature	• Bhaskar Mitra and Nick Craswell (2018), "An Introduction to								
	Neural Information Retrieval ", Foundations and Trendső in								
	Information Retrieval: Vol. 13: No. 1, pp 1-126.								
	Further references to relevant material will be provided during								
	the lab.					J			
	1220 2000.								

Module	Advanced L	earning S	stems						
MA-INF 4302									
Workload	Credit points	Duration	Frequer	ncy					
180 h	6 CP	1 semester	r every 2 years						
Module	Prof. Dr. Stef	an Wrobel							
coordinator									
Lecturer(s)	Prof. Dr. Stef	Prof. Dr. Stefan Wrobel							
Classification	Programme		Mode	Semes	ter				
Classification	M. Sc. Compu	iter Science	Optional	2. or 3	3.				
Technical skills		•	-	-	nowledge of on	e			
	particular clas	_	_	, .	-				
	necessary know	_							
	construct their own within the given class, all the way u								
		research frontier on the topic.							
Soft skills	In group work	*	-	v					
	communication								
					projects to other	ers.			
Contents	The module ea		centrates of	on one or	more specific				
	algorithm clas	ses, e.g.							
	• kernel machines								
	• neural networks								
	• probabilistic and statistical learning approaches								
	• logic-based l		oaches						
	• reinforcemen								
Prerequisites	Recommended								
	all of the following:								
	MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning								
	MA-INF 4112	- Intelligent	Learning	and Ana	lysis Systems:				
	Data Mining a	and Knowled	ge Discove	ery					
	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	udv				
Exam achievements	Written exam	8)	- · · · · ·			ded)			
Study achievements	Successful exe	rcise particip	ation		(not gra				
Forms of media	lectures, exerc				( 0				
	,	<u> </u>		g with K	Ternels, The Mi	ΙΤ			
	• 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								
T	• Christopher Bishop, Pattern Recognition and Machine								
Literature	Learning, The University of Edinburgh, 2006								
	<u> </u>	•		_ ,	ice, and Learni	ing			
	Algorithms, 20	= :							
	• Richard Duda, Peter Hart, David Stork, Pattern								
	• Richard Duda, Peter Hart, David Stork, Pattern Classification, John Wiley and Sons, 2001								

Module MA-INF 4303	Learning from Non-Standard Data								
Workload	Credit points	Duration	Freque	ncy					
180 h	6 CP	1 semeste	1						
Module	Prof. Dr. Stefa	Prof. Dr. Stefan Wrobel							
coordinator									
Lecturer(s)	Prof. Dr. Stefan Wrobel, Dr. Tamas Horvath								
CI IO II	Programme	<u> </u>	Mode	Semest	ter				
Classification	M. Sc. Compu	M. Sc. Computer Science   Optional   2. or 3.							
Technical skills	Participants de	epen their	knowledge	of learning	ng systems wit	h			
	respect to one	respect to one particular non-standard data type, i.e.,							
	non-tabular da	non-tabular data, as they are becoming increasingly important							
	in many applic	in many applications. Each type of data not only requires							
	specialized algo			_	,	g			
	pre- and postp	_	_						
	participants in					the			
	necessary socia								
	work and proje	-	g, and lear	n how to j	present softwar	e			
	projects to other		1 1						
Soft skills	Communicative	`		-		,			
	discussions in t	* *	_	,					
	formulate critic		y to anaiys	e, creativi	ity in the conte	ext			
C		of an "open end" task)							
Contents		The module will offered every year, concentrating on one particular non-standard data type each time, including: Text							
	Mining, Multin				_	.6			
	structured data			_	Learning Ironi				
Prerequisites	Recommended:		Java Willin	ь					
Trerequisites	all of the follow								
	MA-INF 4111	0	t Learning	and Anal	lysis Systems:				
	Machine Learn		i Learning	and min	iyolo bybucillo.				
	MA-INF 4112	_	t Loorning	and Anal	lveie Svetome:				
	Data Mining a				iysis bystems.				
	Teaching forma		Group size	h/week	Workload[h]	CP			
Format	Lecture		aroup size	2	30 T / 45 S	2.5			
Tormat	Exercises			$\frac{2}{2}$	30 T / 75 S	3.5			
		 	. C indom			0.0			
Even eshiovements	T = face-to-fac Written exam	e teaching	$s = mae_{\mathbf{k}}$	endent st		dod)			
Exam achievements	Successful exer	aigo portia	nation		(not gra	$\frac{\text{ded}}{\text{ded}}$			
Study achievements Forms of media	lectures, exerci		-		(not gra	ueuj			
Forms of media	• Gennady And	-			nloratory Anal	lveie			
	of Spatial and				= -	1 y 515			
	• Diane J. Coo	_							
	Wiley & Sons,		oc B. Holac	, , , , , , , , , , , , , , , , , , , ,	Graph Dava,				
Literature	• Saso Dzerosk		vrac. Relat	ional Dat	a Mining.				
	Springer, 2001	, =			o;				
	• Sholom M. V	Veiss, Nitir	Indurkhva	, Tong Zl	nang, Fred J.				
	Damerau, Text		_	_					
	Unstructured I				v G				
			, pringer,	<b>2</b> 001					

Module	Lab Cogniti	ive Roboti	cs						
MA-INF 4304									
Workload	Credit points	Duration	Frequen	ıcy					
270 h	9 CP	1 semester	every se	emester					
Module	Prof. Dr. Sver	n Behnke							
coordinator									
Lecturer(s)	Prof. Dr. Sver	n Behnke							
Classification	Programme		$\mathbf{Mode}$	Seme	ster				
Classification	M. Sc. Compu		Optional						
Technical skills	Participants a		•		•	_			
	_	_	_		of perception a	and			
	control algorit		_	-					
	group, they ar				e-ot-the-art				
G 6 1 11	· ·	solution, and evaluate its performance.							
Soft skills	_	Self-competences (time management, goal-oriented work, ability							
		to analyze problems and to find practical solutions), communication skills (Work together in small teams, oral and							
	written presen	`	_		,	Iu			
	implementatio		1010115, СП	near exa					
Contents	Robot middleware (ROS), simultaneous localization and								
	mapping (SLA	, , ,							
	\	,		_	on, person dete	ction			
	and tracking,	action recogn	nition, acti	on plan	ning and contro	ol,			
	mobile manipu	ulation, huma	an-robot ii	nteractio	on.				
Prerequisites	Recommended	:							
	At least 1 of t	he following:							
	MA-INF 4113	- Cognitive	Robotics						
	MA-INF 4114	– Robot Lea	rning						
Format	Teaching forms	at Gro	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					ided)			
Study achievements					(not gra				
Forms of media									
	,		nd D. Fox:	Probab	oilistic Robotics				
	MIT Press, 2005.								
Literature	• B. Siciliano, O. Khatib (Eds.): Springer Handbook of								
	Robotics, 2008								
	• Selected rese	earch papers.							

Module				ation o	f Data Minii	ng			
MA-INF 4306	and Learnin	ng Systems	}						
Workload	Credit points	Duration	Freque	ncy					
270 h	9 CP	1 semester	every y	vear					
Module	Prof. Dr. Stef	an Wrobel							
coordinator									
Lecturer(s)	Prof. Dr. Stef	Prof. Dr. Stefan Wrobel							
Classification	Programme		$\mathbf{Mode}$	Semes	ster				
Classification	M. Sc. Compu		Optiona						
Technical skills		•	•	0	the construction				
	_	_		0 0	ms for machine				
	learning and d	learning and data mining. They learn how to work with existing							
		state-of-the-art systems and apply them to application							
	-	problems, usually extending them for the requirements of their							
	particular task								
Soft skills		Communicative skills (appropriate oral presentation and written							
		documentation of project results), social skills (ability to work in							
	teams), self-co	- \		,	_	_			
		long-range goals under limited ressources, ability to work under							
		pressure, ability to accept/formulate ciriticsm)							
Contents		•			lysis. Common				
	_				of data analysi				
			_	_	-processing too				
				_	ation. Search a	na			
					isualization for	. al			
					or embedded ar	ıa			
Prerequisites	distributed sys		nous disc	overy sy	stems.				
Frerequisites	At least 1 of t								
		O	т		-1:- C+				
		_	Learning	, and Ana	alysis Systems:				
	Machine Learn	0	т .	1 4	1				
		0	_	•	alysis Systems:				
	Data Mining a					T			
Format	Teaching forms	at Gro	oup size	h/week	Workload[h]	CP			
	Lab		8	4	60 T / 210 S	9			
	T = face-to-fa			pendent s	study				
Exam achievements	Oral presentat	tion, written	report		(gra	ided)			
Study achievements					(not gra	ided)			
Forms of media		Computer Software, Documentation, Research Papers.							
Literature	The relevant l	iterature will	be annot	unced tov	vards the end c	f the			
Liverature	previous semester.								

Module	Lab Field P	rogramm	able Ga	te Arra	ys				
MA-INF 4307									
Workload	Credit points	Duration	Freque	ency					
270 h	9 CP	1 semeste	r   at leas	at least every 2 years					
Module	Prof. Dr. Joac	chim K. An	auf						
coordinator									
Lecturer(s)	Prof. Dr. Joac	Prof. Dr. Joachim K. Anlauf							
Classification	Programme		Mode	Seme	ster				
Classification	M. Sc. Compu	iter Science	Option	al   2. or	3.				
Technical skills	Development a	and simulat	on of dig	ital circui	ts in VHDL and	d			
	SystemC, expe	SystemC, experience with synthesizable subsets, knowledge of							
	the design pat	the design path from the idea to a realized circuit implemented							
	in an FPGA (	in an FPGA (field programmable gate array)							
Soft skills	Communicativ	Communicative skills (oral and written presentation of results),							
	,	· ·	•		ms, discussions	of			
	solution conce	. /	•		•				
	formulate criti	,	to analy	ze and fir	nd practical				
	solutions to pr								
Contents			- '		, and Synthesis				
	•		_		on, and Synthes	sis,			
	Synthesizable	,	st of Impl	ementatio	ons on FPGA				
	Evaluation Bo	ards							
Prerequisites	Recommended	-							
	MA-INF 4207	- Dynamica	lly Recor	figurable					
Format	Teaching forms	at G	oup size	h/week	Workload[h]	CP			
Tormat	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	ided)			
Study achievements					(not gra	ided)			
Forms of media									
Literature	Technical docu	umentation							

Module	Lab Vision	Systems							
MA-INF 4308		I							
Workload	Credit points	Duration	Freque	-					
270 h	9 CP	1 semester	er every semester						
Module	Prof. Dr. Svei	n Behnke							
coordinator									
Lecturer(s)	Dr. Nils Goerl	ke							
Classification	Programme		Mode	Semes	ster				
	M. Sc. Compu		Optiona		1				
Technical skills	Students will a	•	_	_		1			
	_	_	_		Us. They will a	apply			
	these techniqu				_				
C (t 1 11		algorithms for data-intensive computer vision tasks.							
Soft skills	_	Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions),							
	communication skills (Work together in small teams, oral and								
	written presen	,	_			Iu			
	implementatio		tions, cr	ilitai exa.	illillation of				
Contents		Basic matrix and vector computations with GPUs (CUDA).							
Contents	Classification					•			
	support-vector			-	= -				
	linear-discrimi			_	*				
	handling. Qua		_		_				
	algorithms for	_			_				
Prerequisites	Recommended			0					
•	At least 1 of t	he following:							
	MA-INF 4111	- Intelligent	Learning	and Ana	alysis Systems:				
	Machine Learn			,					
	MA-INF 4204	0	Veural N	ets					
	Teaching forms		up size	h/week	Workload[h]	CP			
Format	Lab		8	4	60 T / 210 S	9			
	T = face-to-fa	ce teaching: S	S — inde	nendent s	,	1			
Exam achievements	Oral presentat			pendent b		aded)			
Study achievements	Jan prosentati		-P 010		(not gra				
Forms of media					(1100 810				
	• R. Szeliski: Computer Vision: Algorithms and Applications,								
	Springer 2010.								
Literature	• C. M. Bishop: Pattern Recognition and Machine Learning,								
	Springer 2006.								
	• NVidia CUDA Programming Guide, Version 4.0, 2011.								

Module MA-INF 4309	Lab Sensor Data Interpretation						
Workload	Credit points	Duratio	n	Freque	encv		
270 h	9 CP	1 seme		_	st every 2	2 vears	
Module	PD. Dr. Volker Steinhage						
coordinator							
Lecturer(s)	PD. Dr. Volke	r Steinha	age				
	Programme			Mode	Seme	ester	
Classification	M. Sc. Compu	iter Scier	nce	Optiona	al $2$ . or	3.	
Technical skills	Competence to	Competence to implement algorithms for sensor data					
	interpretation, efficient handling and testing, documentation.						
Soft skills	Efficient implementation of complex algorithms, abstract						
	thinking, docu	thinking, documentation of source code.					
Contents	Varying selecte	ed up-to-	-date	topics of	on sensor	data interpreta	tion
Prerequisites	Required:						
	All of the follo	owing:					
	MA-INF 2201	- Comp	uter	Vision			
	MA-INF 4206	- Selecte	ed To	opics in	Sensor D	ata Interpretati	on
	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 teachi	ng; S	S = inde	pendent	study	
Exam achievements	Oral presentat	ion, writ	ten i	report		(gra	ided)
Study achievements						(not gra	ided)
Forms of media							
Literature	Relevant litera	ture will	be a	announc	ed at sta	rt of the lab.	

Module MA-INF 4310	Lab Mobile	Robots							
Workload	Credit points	Duration	Frequenc	·v					
270 h	9 CP	1 semester	_	every year					
Module	Prof. Dr. Sver		ar reast	overy year					
coordinator	1101. 21. 2.01	2 20 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1							
Lecturer(s)	Prof. Dr. Sver	Prof. Dr. Sven Behnke, Dr. Nils Goerke							
	Programme	,	Mode	Semester					
Classification	M. Sc. Compu	ter Science	Optional	2. or 3.					
Technical skills	Participants ac	cquire basic k	nowledge	and practical expe	rience in				
	the design and	implementat	ion of con	trol algorithms for	simple				
	structured rob	otic systems	using real	mobile robots.					
	_	_		bots will be identi	fied and				
	implemented i								
Soft skills	_	,		goal-oriented work	k, ability				
	to analyze pro			The state of the s					
		communication skills (Work together in small teams, oral and							
	_		tions, criti	cal examination of					
<b>Q</b>	implementatio		(C) 1 4	. 1 1 1	•				
Contents		, -	, .	simulation tools, b	oasic				
	_			e control, SMPA					
	architecture, n		_	g (SLAM), visual	hagad				
	object detection			- ' ' '	Dased				
Prerequisites	Recommended		7500 COHOL	<i>5</i> 1.					
Trerequisites	At least 1 of the								
	BA-INF 132 –	_	der Robot	ik					
	BA-INF 131 –	<u> </u>							
			·						
	MA-INF 1314			ıng					
	MA-INF 2201	-							
	MA-INF 4113	0							
	MA-INF 4114		_						
	MA-INF 4203	- Autonomou	ıs Mobile	Systems					
Format	Teaching forma	at Gro		/week Workload					
	Lab		8	4   60 T / 21	0 S   9				
	T = face-to-fa	ce teaching; S	S = independent	ndent study					
Exam achievements	Oral presentat	ion, written r	eport		(graded)				
Study achievements				· · · · · · · · · · · · · · · · · · ·	t graded)				
Forms of media			*	ot control middlew	*				
	_	· =	_	ng, demonstration					
	_ `	_	,	esentation and wri	tten				
	report of appro			Drobobilistic Del	oties				
	MIT Press, 20	_	u D. гох:	Probabilistic Robo	Juics.				
	,		Moving 1	ntelligence Public	hed by				
Literature	J. Buchli: Mobile Robots: Moving Intelligence, Published by  Advanced Robotic Systems and Pro Literatur Verlag								
Liveravare	Advanced Robotic Systems and Pro Literatur Verlag  • B. Siciliano, O. Khatib (Eds.): Springer Handbook of								
	Robotics, 2008	,	). ~P11	3					
	• Additional S		t publicat	ions.					
			r	-					

Module	Semantic Data Web Technologies								
MA-INF 4312	Semantic D	Schlandic Bata Web Teelinologies							
Workload	Credit points	Duration	Freque	ncv					
180 h	6 CP	1 semeste	_	-					
Module	Prof. Dr. Jens Lehmann								
coordinator	Tion Bit gone Bommann								
Lecturer(s)	Prof. Dr. Jens	Prof. Dr. Jens Lehmann, Dr. Christoph Lange,							
20004202(0)		Dr. Maria Maleschkova							
Classification	Programme		Mode	Semes	ter				
Classification	M. Sc. Compu	M. Sc. Computer Science   Optional   1.							
Technical skills	The goal of th	is lecture is	to impart	knowledg	ge on the				
	fundamentals,	technologie	s and appl	ications o	of the Semantic				
	Web and infor	mation retr	ieval. As p	part of the	e lecture the ba	sic			
	concepts and s	standards fo	r semantic	technolog	gies are explair	ned.			
Soft skills									
Contents	As part of the	As part of the W3C Semantic Web initiative standards and							
	technologies h	technologies have been developed for machine-readable exchange							
	of data, inforn	nation and	knowledge	on the W	eb. These				
	standards and	technologie	s are incre	asingly be	eing used in				
	applications as	nd have alre	ady led to	a numbe	r of exciting				
	projects (e.g.		-		_				
	applications su	ich as scher	na.org, Op	enCalais,	or Google's				
					ly grounded an	.d			
	practically ori	_							
	discussed with				1				
	• RDF syntax	and data n	nodel						
	• RDF Schema			e of RDF	(S)				
	• ontologies in				` '				
	_				s, query langua	ന്മ			
	• Linked Data			_		ges			
	• Semantic tex								
Prerequisites	none	ti anaiysis e	ind inform	ation reti	ievai systems				
	Teaching forms	at (	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	ı	,	1 5.5			
Exam achievements	Written exam	8				ded)			
Study achievements	Successful exe	rcise partici	pation		(not gra				
Forms of media		Post viol	r		(1100 8100				
Literature									

Module	Seminar Semantic Data Web Technologies								
MA-INF 4313									
Workload	Credit points	Duration	Fre	quen	c <b>y</b>				
120 h	4 CP	1 semest	ter at l	r at least every year					
Module	Prof. Dr. Jens Lehmann								
coordinator									
Lecturer(s)	Dr. Christoph	Lange, D	r. Maria	Male	eshkova				
Classification	Programme		Mod	е	Semest	ter			
Classification	M. Sc. Compu	iter Scienc	e Opti	onal	2.				
Technical skills	Through the s	eminar, st	udents v	rill le	arn to w	ork with tools	and		
	technologies of	technologies of the Semantic Web as well as assess their							
	capabilities for	capabilities for given problems. They will gain the ability to							
	understand ne	w research	results	prese	ented in	original scienti	fic		
	papers.								
Soft skills	Ability to pres	sent and to	critical	y dis	scuss tec	hnologies and			
	research result	s in the fr	ameworl	of S	$\mathbf{f}$	Web technolog	gies.		
Contents	• technologies	such as tr	iple stor	es, lii	nk discov	very framework	κs,		
	NLP pipelines								
	• recent confer	rence and	journal p	aper	s				
Prerequisites	none								
Format	Teaching forms	at	Group s	ze	h/week	Workload[h]	CP		
Format	Seminar		10		2	30 T / 90 S	4		
	T = face-to-fa	ce teachin	g; S = ir	depe	endent st	udy			
Exam achievements	Oral presentat	ion, writte	en report			(gra	ded)		
Study achievements						(not gra	ded)		
Forms of media									
Literature									

Module MA-INF 4314	Lab Semant	Lab Semantic Data Web Technologies							
Workload	Credit points	Credit points Duration Frequency							
270 h	9 CP 1 semester every year								
Module	Prof. Dr. Jens	Prof. Dr. Jens Lehmann							
coordinator									
Lecturer(s)	Prof. Dr. Jens	Prof. Dr. Jens Lehmann, Dr. Maria Maleschkova							
Classification	Programme		Mode	;	Semes	ster			
Classification	M. Sc. Compu	iter Scienc	e Optio	$_{ m nal}$	2.				
Technical skills	The students will carry out a practical task (project) in the								
	context of Semantic Web technologies, including test and								
	documentation of the implemented software/system.								
Soft skills	Ability to prop	perly pres	ent and d	efenc	d design	n decisions, to			
	prepare readal	ble docum	entation	of sof	ftware;	skills in			
	constructively	collabora	ting with	othe	rs in sr	nall teams over	a		
	longer period	of time; al	oility to c	lassif	y own	results with reg	gard		
	to the state-of	-the-art							
Contents									
Prerequisites	none								
Format	Teaching forms	at	Group siz	e h	/week	Workload[h]	CP		
rormat	Lab		8		4	60 T / 210 S	9		
	T = face-to-fa	ce teachin	g; S = in	depe	ndent s	study			
Exam achievements	Oral presentat	ion, writt	en report			(gra	ided)		
Study achievements						(not gra	ded		
Forms of media									
Literature									

Module	Graph Representa	tion Learn	ing						
MA-INF 4316	Graph Representa	Jon Boarn	8						
Workload	Credit points Duration	n Freque	ncv						
180 h	6 CP 1 semester at least every 2 years								
Module	Dr. Pascal Welke								
coordinator									
Lecturer(s)	Dr. Pascal Welke								
. ,	Programme	Mode	Semester						
Classification	M. Sc. Computer Science	e Optional	1.						
Technical skills	representation and compound runtime of algorithms in - Ability to implement, p	<ul> <li>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.</li> <li>Ability to implement, practically apply, and theoretically analyze graph representation, graph kernels, and graph mining algorithms.</li> </ul>							
Soft skills	<ul> <li>Social, methodological, and analytical competences via communication, own development, and presentation of problem formulations, algorithms, and solutions.</li> <li>Learning to solve project tasks in a group.</li> <li>Learning to evaluate the trade-offs and limitations of existing methods.</li> </ul>								
Contents	We will discuss general approaches for machine learning (ML) on graph structured data. In particular, computational methods for graph representation learning such as graph neural networks (GNNs), graph 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 as triangles, or trees.  If time permits, we might venture into the realm of ranking on large-scale graphs, with applications such as recommender system. 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 I  MA-INF 4212 – Data S  MA-INF 1105 - Algorit  MA-INF 1102 - Combin	gent Learning gent Learning Discovery Science and Bi hms for Data	and Analys g Data Analysis	·					
	Teaching format	Group size	h/week	Workload[h]	CP				
Format	Lecture Exercises T = face-to-face teaching		2 2	30 T / 45 S 30 T / 75 S	2.5 3.5				
Exam achievements	Oral exam or written exa	-		(gra	aded)				
Study achievements	Successful exercise partic			(not gra					
Forms of media	• Lecture slides	<u> </u>		(-100 810					
	• Jupyter notebooks								
Literature	<ul> <li>William L. Hamilton: Of Lectures on Artificial Into Claypool.</li> <li>Nils M. Kriege, Fredrik on graph kernels, Applied N</li> </ul>	elligence and i	Machine Le	arning, Morgan	and				
				.1. C. 1.77	-1-				
	• Karsten M. Borgwardt,	M. Elisabett	a Ghisu et a	al.: Graph Kern	els:				
	State-of-the-Art and Futi	ure Challenges	s, Foundation	ons and Trends	in				
	Machine Learning 13(5-6	).							
	0(0 0	,							

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						
, ,	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  Format	Recommended: Open-minded for new problem settings, Programming in different languages (C++, Python, Java), Critical approach to existing solutions, Research curiosity  Teaching format Group size h/week Workload[h] CP 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							
	<ul> <li>[1] Sergey Ivanov, Evgeny Burnaev. "Anonymous Walk Embeddings" ICML, 2018.</li> <li>[2] Tsitsulin, Anton, Davide Mottin, Panagiotis Karras, and Emmanuel Müller "VERSE: Versatile Graph Embeddings from Similarity Measures." WWW, 2018.</li> </ul>						
	[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						
	Graph". KDD, 2018  [6] Nino Shervashidze, Pascal Schweitzer, Erik Jan van Leeuwen, Kurt Mehlhorn, Karsten M. Borgwardt "Weisfeiler-Lehman Graph Kernels".  JMLR, 2011						
	01111111111111111111111111111111111111						

MA-INF 4319   Service   Prof. Dr. Christian Bauckhage   Prof	Module	Game AI								
Module   Prof. Dr. Christian   Baucklage   Programme   M. Sc. Computer   Science   Optional   2. or 3.	MA-INF 4319									
Prof. Dr. Christian Bauckhage										
Decturer(s)	270 h									
Prof. Dr. Christian Bauckhage	Module	Prof. Dr. Chris	tian Bauckh	age						
Programme   Mode   Semester   M. Sc. Computer Science   Optional   2. or 3.	coordinator									
Technical skills    Vision completion, students should be able to	Lecturer(s)	Prof. Dr. Chris	tian Bauckh	age						
M. Sc. Computer Science   Optional   2. or 3.  Upon completion, students should be able to   know about fundamental concepts of artificial intelligence and how they apply to computer games   know about basic and advanced methods for planning, problem solving, and behavior modelling   implement basic and advanced algorithms for planning, problem solving, and behavior modelling   implement numerically robust data clustering and classification   Students will learn about mathematical and algorithmic foundations of artificial intelligence. They will learn about basic and more advanced techniques for planning, problem solving, and behavior modelling, how to implement them on their own, and how to put them into practice especially in the context of artificial computer game agents.    Contents	Classification	Programme		Mode	Semester					
• know about fundamental concepts of artificial intelligence and how they apply to computer games • know about basic and advanced methods for planning, problem solving, and behavior modelling • implement basic and advanced algorithms for planning, problem solving, and behavior modelling • implement numerically robust data clustering and classification  Students will learn about mathematical and algorithmic foundations of artificial intelligence. They will learn about basic and more advanced techniques for planning, problem solving, and behavior modelling, how to implement them on their own, and how to put them into practice especially in the context of artificial computer game agents.  Contents  • historical overview of game AI • basic terms and definitions for AI in games • backward induction and the minmax algorithm • alpha-beta pruning, depth restircted searches, features, and evaluation functions • (traditional, uninformed) tree search algorithms • Monte Carlo tree search • algorithms for path- and motion planning, A* search • mathematical models and computer algorithms for data clustering • self organizing maps • finite state machines for behavior modeling / programming • fuzzy logic / fuzzy control for behavior modeling / programming • probability theory and Bayesian networks  • Markov chains / Markov models • hidden Markov models for behavior modeling and analysis • Markov decision processes and reinforcement learning • the Bellman equations for reinforcement learning • temporal difference learning • Q learning • genetic algorithms and genetic programming experience.  Promat    Recommended:   Group size   hywek   Workload[h]   CP	Classification	M. Sc. Compute	M. Sc. Computer Science   Optional   2. or 3.							
they apply to computer games  • know about basic and advanced methods for planning, problem solving, and behavior modelling  • implement basic and advanced algorithms for planning, problem solving, and behavior modelling  • implement numerically robust data clustering and classification  Students will learn about mathematical and algorithmic foundations of artificial intelligence. They will learn about basic and more advanced techniques for planning, problem solving, and behavior modelling, how to implement them on their own, and how to put them into practice especially in the context of artificial computer game agents.  Contents  Contents  • historical overview of game AI  • basic terms and definitions for AI in games  • backward induction and the minmax algorithm  • alpha-beta pruning, depth restircted searches, features, and evaluation functions  • (traditional, uninformed) tree search algorithms  • Monte Carlo tree search  • algorithms for path- and motion planning, A* search  • algorithms for path- and motion planning, A* search  • algorithms for path- and motion planning, A* search  • algorithms for path- and motion planning, A* search  • algorithms for path- and motion planning, A* search  • algorithms for path- and motion planning, A* search  • algorithms for path- and motion planning, A* search  • algorithms for behavior modeling / programming  • finite state machines for behavior modeling / programming  • finite state machines for behavior modeling / programming  • probability theory and Bayesian networks  • Markov chains / Markov models for behavior modeling and analysis  • Markov decision processes and reinforcement learning  • the Bellman equations for reinforcement learning  • the Bellman eq	Technical skills	Upon completio	n, students	should be a	able to					
they apply to computer games  • know about basic and advanced methods for planning, problem solving, and behavior modelling  • implement basic and advanced algorithms for planning, problem solving, and behavior modelling  • implement numerically robust data clustering and classification  Students will learn about mathematical and algorithmic foundations of artificial intelligence. They will learn about basic and more advanced techniques for planning, problem solving, and behavior modelling, how to implement them on their own, and how to put them into practice especially in the context of artificial computer game agents.  Contents  Contents  • historical overview of game AI  • basic terms and definitions for AI in games  • backward induction and the minmax algorithm  • alpha-beta pruning, depth restircted searches, features, and evaluation functions  • (traditional, uninformed) tree search algorithms  • Monte Carlo tree search  • algorithms for path- and motion planning, A* search  • algorithms for path- and motion planning, A* search  • algorithms for path- and motion planning, A* search  • algorithms for path- and motion planning, A* search  • algorithms for path- and motion planning, A* search  • algorithms for path- and motion planning, A* search  • algorithms for path- and motion planning, A* search  • algorithms for behavior modeling / programming  • finite state machines for behavior modeling / programming  • finite state machines for behavior modeling / programming  • probability theory and Bayesian networks  • Markov chains / Markov models for behavior modeling and analysis  • Markov decision processes and reinforcement learning  • the Bellman equations for reinforcement learning  • the Bellman eq		• know about fi	ındamental	concepts of	artificial in	telligence and h	ow			
know about basic and advanced methods for planning, problem solving, and behavior modelling				-						
solving, and behavior modelling  • implement basic and advanced algorithms for planning, problem solving, and behavior modelling  • implement numerically robust data clustering and classification  Students will learn about mathematical and algorithmic foundations of artificial intelligence. They will learn about basic and more advanced techniques for planning, problem solving, and behavior modelling, how to implement them on their own, and how to put them into practice especially in the context of artificial computer game agents.  Contents  • historical overview of game AI • basic terms and definitions for AI in games • backward induction and the minmax algorithm • alpha-beta pruning, depth restircted searches, features, and evaluation functions • (traditional, uninformed) tree search algorithms for data clustering • self organizing maps • finite state machines for behavior modeling / programming • self organizing maps • finite state machines for behavior modeling / programming • probability theory and Bayesian networks • Markov chains / Markov models • hidden Markov models for behavior modeling and analysis • Markov decision processes and reinforcement learning • the Bellman equations for reinforcement learning • the Recommended:  Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.  Format    Facching format					hods for pla	nning, problem				
• implement basic and advanced algorithms for planning, problem solving, and behavior modelling					1	3/ I				
solving, and behavior modelling  • implement numerically robust data clustering and classification  Students will learn about mathematical and algorithmic foundations of artificial intelligence. They will learn about basic and more advanced techniques for planning, problem solving, and behavior modelling, how to implement them on their own, and how to put them into practice especially in the context of artificial computer game agents.  Contents  • historical overview of game AI • basic terms and definitions for AI in games • backward induction and the minmax algorithm • alpha-beta pruning, depth restircted searches, features, and evaluation functions • (traditional, uninformed) tree search algorithms • Monte Carlo tree search • algorithms for path- and motion planning, A* search • mathematical models and computer algorithms for data clustering • self organizing maps • finite state machines for behavior modeling / programming • fuzzy logic / fuzzy control for behavior modeling / programming • fuzzy logic / fuzzy control for behavior modeling / programming • fuzzy logic / fuzzy control for behavior modeling and analysis • Markov chains / Markov models • hidden Markov models for behavior modeling and analysis • Markov decision processes and reinforcement learning • the Bellman equations for reinforcement learning • the Bellman equations for reinforcement learning • temporal difference learning • Q learning • genetic algorithms and genetic programming  Prerequisites  Recommended:  Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming exercise.  Format    Facching format				-	thms for pl	anning, problem	L			
Soft skills  Soft skills  Sudents will learn about mathematical and algorithmic foundations of artificial intelligence. They will learn about basic and more advanced techniques for planning, problem solving, and behavior modelling, how to implement them on their own, and how to put them into practice especially in the context of artificial computer game agents.  Contents  • historical overview of game AI • basic terms and definitions for AI in games • backward induction and the minmax algorithm • alpha-beta pruning, depth restircted searches, features, and evaluation functions • (traditional, uninformed) tree search algorithms for data clustering • self organizing maps • finite state machines for behavior modeling / programming • fuzzy logic / fuzzy control for behavior modeling / programming • probability theory and Bayesian networks • Markov chains / Markov models for behavior modeling and analysis • Markov decision processes and reinforcement learning • the Bellman equations for reinforcement learning • temporal difference learning • Q learning • genetic algorithms and genetic programming experience.  Prornat  Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.  Prornat  Group size   Myewek   Workload h  CP  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   2 a) or 1 / 10 S S   5.5  Exercises   3 a) or 1 / 10 S S   5.5  Exercises   4 a) or 1 / 10 S S   5.5  Exe				_	1	O/ 1				
Soft skills    Students will learn about mathematical and algorithmic foundations of artificial intelligence. They will learn about basic and more advanced techniques for planning, problem solving, and behavior modelling, how to implement them on their own, and how to put them into practice especially in the context of artificial computer game agents.    Contents				-	lustering ar	nd classification				
techniques for planning, problem solving, and behavior modelling, how to implement them on their own, and how to put them into practice especially in the context of artificial computer game agents.  Contents  • historical overview of game AI • basic terms and definitions for AI in games • backward induction and the minmax algorithm • alpha-beta pruning, depth restircted searches, features, and evaluation functions • (traditional, uninformed) tree search algorithms of Monte Carlo tree search • algorithms for path- and motion planning, A* search • mathematical models and computer algorithms for data clustering • self organizing maps • finite state machines for behavior modeling / programming • fuzzy logic / fuzzy control for behavior modeling / programming • probability theory and Bayesian networks • harkov chains / Markov models • hidden Markov models for behavior modeling and analysis • Markov decision processes and reinforcement learning • the Bellman equations for reinforcement learning • temporal difference learning • Q learning • genetic algorithms and genetic programming  Prerequisites  Recommended:  Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.  Format  Group size   h/week   Workload[h]   CP    Ecture   4   60 T / 105 S   5.5    Exam achievements  T = face-to-face teaching; S = independent study  Exam achievements  Oral exam   Group size   h/week   Graded)  Study achievements  Forms of media  Petture 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	Soft skills	Students will lea	arn about n	athematica	l and algori	thmic foundatio	ns of			
to implement them on their own, and how to put them into practice especially in the context of artificial computer game agents.    historical overview of game AI   basic terms and definitions for AI in games   backward induction and the minmax algorithm   ealpha-beta pruning, depth restircted searches, features, and evaluation functions   (traditional, uninformed) tree search algorithms   Monte Carlo tree search   ealgorithms for path- and motion planning, A* search   emathematical models and computer algorithms for data clustering   self organizing maps   finite state machines for behavior modeling / programming   fuzzy logic / fuzzy control for behavior modeling / programming   probability theory and Bayesian networks   Markov chains / Markov models   hidden Markov models   hidden Markov models   hidden Markov models   hidden Markov decision processes and reinforcement learning   the Bellman equations for reinforcement learning   emporal difference learning   Q learning   egenetic algorithms and genetic programming		artificial intellig	ence. They	will learn a	bout basic	and more advan	$\operatorname{ced}$			
especially in the context of artificial computer game agents.    Contents		techniques for p	lanning, pro	oblem solvii	ng, and beh	avior modelling,	how			
Contents		to implement th	nem on their	own, and	how to put	them into practi	ice			
		especially in the	e context of	artificial co	mputer gan	ne agents.				
backward induction and the minmax algorithm   alpha-beta pruning, depth restircted searches, features, and evaluation functions   (traditional, uninformed) tree search algorithms   Monte Carlo tree search   algorithms for path- and motion planning, A* search   mathematical models and computer algorithms for data clustering   eself organizing maps   finite state machines for behavior modeling / programming   fuzzy logic / fuzzy control for behavior modeling / programming   probability theory and Bayesian networks   Markov chains / Markov models for behavior modeling and analysis   Markov decision processes and reinforcement learning   the Bellman equations for reinforcement learning   temporal difference learning   egenetic algorithms and genetic programming   egenetic algorithms and genetic programming   Prerequisites   Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.   Feaching format   Group size   h/week   Workload[h]   CP   Exercises   2   30 T / 75 S   3.5   T = face-to-face teaching; S = independent study   Exam achievements   Successful exercise participation   (not graded)   Study achievements   Successful exercise participation   (not graded)   Ecture notes with programming examples are made available online   electure notes with programming examples are made available online   Russell and Norvig, "Artificial Intelligence: A Modern Approach"   Literature   Millington, "Artificial Intelligence: For Games"   Literature   Millington, "Artificial Intelligence: A Modern Approach"   Literature   Millington, "Artificial Intelligence: A Modern Approach"   Literature   Millington, "Artificial Intelligence: A Modern Approach"   Literature   Millington, "Artificial Intelligence For Games"   Literature   Millington, "Artificial Intelligence For Games"   Literature   Literature   Millington, "Artificial Intelligence For Games   Literature   Literature   Literature   Literature   Literature   Literature   Literature   Lite	Contents	• historical over	view of gan	ne AI						
• alpha-beta pruning, depth restircted searches, features, and evaluation functions • (traditional, uninformed) tree search algorithms • Monte Carlo tree search • algorithms for path- and motion planning, A* search • mathematical models and computer algorithms for data clustering • self organizing maps • finite state machines for behavior modeling / programming • fuzzy logic / fuzzy control for behavior modeling / programming • probability theory and Bayesian networks • Markov chains / Markov models • hidden Markov models for behavior modeling and analysis • Markov decision processes and reinforcement learning • the Bellman equations for reinforcement learning • temporal difference learning • Q learning • Q learning • genetic algorithms and genetic programming  Prerequisites  Recommended:  Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.  Teaching format Group size h/week Workload[h] CP Lecture 4 60 T / 105 S 5.5  Exercises 7 2 30 T / 75 S 3.5  T = face-to-face teaching; S = independent study  Oral exam (graded)  Study achievements  Successful exercise participation (not graded)  Forms of media electure slides are made available online • lecture notes with programming examples are made available online • lecture notes with programming examples are made available online  Russell and Norvig, "Artificial Intelligence: A Modern Approach*  Literature		• basic terms ar	nd definition	ns for AI in	games					
evaluation functions  (traditional, uninformed) tree search algorithms  Monte Carlo tree search algorithms for path- and motion planning, A* search mathematical models and computer algorithms for data clustering self organizing maps finite state machines for behavior modeling / programming fuzzy logic / fuzzy control for behavior modeling / programming probability theory and Bayesian networks Markov chains / Markov models hidden Markov models for behavior modeling and analysis Markov decision processes and reinforcement learning the Bellman equations for reinforcement learning quering quering quering quering quering quering and statistics as well as programming experience.  Prerequisites  Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.  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  Successful exercise participation   (not graded)  Forms of media   electure slides are made available online   electure notes with programming examples are made available online   electure notes with programming examples are made available online   Russell and Norvig, "Artificial Intelligence: A Modern Approach"		• backward indu	uction and t	he minmax	algorithm					
• (traditional, uninformed) tree search algorithms • Monte Carlo tree search • algorithms for path- and motion planning, A* search • mathematical models and computer algorithms for data clustering • self organizing maps • finite state machines for behavior modeling / programming • fuzzy logic / fuzzy control for behavior modeling / programming • probability theory and Bayesian networks • Markov chains / Markov models • hidden Markov models for behavior modeling and analysis • Markov decision processes and reinforcement learning • the Bellman equations for reinforcement learning • temporal difference learning • Q learning • genetic algorithms and genetic programming  Prerequisites  Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.  Format    Teaching format   Group size   h/week   Workload[h]   CP		• alpha-beta pr	uning, deptl	n restircted	searches, fe	eatures, and				
Monte Carlo tree search     algorithms for path- and motion planning, A* search     mathematical models and computer algorithms for data clustering     self organizing maps     finite state machines for behavior modeling / programming     fuzzy logic / fuzzy control for behavior modeling / programming     probability theory and Bayesian networks     Markov chains / Markov models     hidden Markov models for behavior modeling and analysis     Markov decision processes and reinforcement learning     the Bellman equations for reinforcement learning     temporal difference learning     Q learning     genetic algorithms and genetic programming  Prerequisites  Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.  Taching 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  Oral exam (graded)  Study achievements  Successful exercise participation (not graded)  Forms of media electure slides are made available online     electure notes with programming examples are made available online     electure notes with programming examples are made available online  Russell and Norvig, "Artificial Intelligence: A Modern Approach"  Literature  Millington, "Artificial Intelligence: For Games"										
<ul> <li>• algorithms for path- and motion planning, A* search</li> <li>• mathematical models and computer algorithms for data clustering</li> <li>• self organizing maps</li> <li>• finite state machines for behavior modeling / programming</li> <li>• finite state machines for behavior modeling / programming</li> <li>• fuzzy logic / fuzzy control for behavior modeling / programming</li> <li>• probability theory and Bayesian networks</li> <li>• Markov chains / Markov models</li> <li>• hidden Markov models for behavior modeling and analysis</li> <li>• Markov decision processes and reinforcement learning</li> <li>• the Bellman equations for reinforcement learning</li> <li>• temporal difference learning</li> <li>• Q learning</li> <li>• genetic algorithms and genetic programming</li> <li>Prerequisites</li> <li>Recommended:</li> <li>Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.</li> <li>Format</li> <li>Group size</li> <li>h/week</li> <li>Workload[h]</li> <li>CP</li> <li>Lecture</li> <li>4</li> <li>4</li> <li>60 T / 105 S</li> <li>5.5</li> <li>5.5</li> <li>2</li> <li>30 T / 75 S</li> <li>3.5</li> <li>5.5</li> <li>5.6</li> <li>5.7</li> <li>5.7</li> <li>6</li> <li>6</li> <li>7</li> <li>7</li> <li>8</li> <li>9</li> <li>1</li> <li>1</li> <li>1</li> <li>1</li> <li>1</li> <li>2</li> <li>2</li> <li>30 T / 75 S</li> <li>3.5</li> <li>3.5</li> <li>3.5</li> <li>3.5</li> <li>3.5</li> <li>3.6</li> <li>3.0</li> <li>3.7</li> <li>3.5</li> <li>3.5</li> <li>3.6</li> <li>3.7</li> <li>3.7</li> <li>3.7</li> <li>3.7</li> <li>3.7</li> <li>3.7</li></ul>				tree search	${\it algorithms}$					
<ul> <li>mathematical models and computer algorithms for data clustering</li> <li>self organizing maps</li> <li>finite state machines for behavior modeling / programming</li> <li>fuzzy logic / fuzzy control for behavior modeling / programming</li> <li>probability theory and Bayesian networks</li> <li>Markov chains / Markov models</li> <li>hidden Markov models for behavior modeling and analysis</li> <li>Markov decision processes and reinforcement learning</li> <li>the Bellman equations for reinforcement learning</li> <li>temporal difference learning</li> <li>Q learning</li> <li>genetic algorithms and genetic programming</li> <li>Prerequisites</li> <li>Recommended:</li> <li>Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.</li> <li>Format</li> <li>Group size h/week Workload[h] CP</li> <li>Lecture</li></ul>										
• self organizing maps • finite state machines for behavior modeling / programming • fuzzy logic / fuzzy control for behavior modeling / programming • probability theory and Bayesian networks • Markov chains / Markov models • hidden Markov models for behavior modeling and analysis • Markov decision processes and reinforcement learning • the Bellman equations for reinforcement learning • temporal difference learning • Q learning • genetic algorithms and genetic programming  Prerequisites  Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.  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  Oral exam (graded)  Study achievements  Successful exercise participation (not graded)  Forms of media • lecture slides are made available online • lecture notes with programming examples are made available online Russell and Norvig, "Artificial Intelligence: A Modern Approach"  Literature  Millington, "Artificial Intelligence For Games"		_	-	-	-					
• finite state machines for behavior modeling / programming • fuzzy logic / fuzzy control for behavior modeling / programming • probability theory and Bayesian networks • Markov chains / Markov models • hidden Markov models for behavior modeling and analysis • Markov decision processes and reinforcement learning • the Bellman equations for reinforcement learning • temporal difference learning • Q learning • quentic algorithms and genetic programming  Prerequisites  Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.  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 Oral exam (graded)  Study achievements Successful exercise participation (not graded)  Forms of media electure slides are made available online • lecture notes with programming examples are made available online Russell and Norvig, "Artificial Intelligence: A Modern Approach"  Millington, "Artificial Intelligence For Games"				computer	algorithms	for data clusteri:	ng			
• fuzzy logic / fuzzy control for behavior modeling / programming • probability theory and Bayesian networks • Markov chains / Markov models • hidden Markov models for behavior modeling and analysis • Markov decision processes and reinforcement learning • the Bellman equations for reinforcement learning • temporal difference learning • Q learning • querning • genetic algorithms and genetic programming  Prerequisites  Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.  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  Oral exam (graded)  Study achievements  Successful exercise participation (not graded)  Forms of media • lecture slides are made available online • lecture notes with programming examples are made available online  Russell and Norvig, "Artificial Intelligence: A Modern Approach"  Millington, "Artificial Intelligence For Games"			-							
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<ul> <li>hidden Markov models for behavior modeling and analysis</li> <li>Markov decision processes and reinforcement learning</li> <li>the Bellman equations for reinforcement learning</li> <li>temporal difference learning</li> <li>Q learning</li> <li>genetic algorithms and genetic programming</li> <li>Recommended:</li> <li>Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.</li> <li>Teaching format Group size h/week Workload[h] CP</li> <li>Lecture 4 60 T / 105 S 5.5</li> <li>Exercises 2 30 T / 75 S 3.5</li> <li>T = face-to-face teaching; S = independent study</li> <li>Exam achievements</li> <li>Successful exercise participation (not graded)</li> <li>Forms of media</li> <li>lecture slides are made available online</li> <li>lecture notes with programming examples are made available online</li> <li>lecture notes with programming examples are made available online</li> <li>Russell and Norvig, "Artificial Intelligence: A Modern Approach"</li> <li>Literature</li> <li>Millington, "Artificial Intelligence For Games"</li> </ul>		- "	•	•	vorks					
• Markov decision processes and reinforcement learning • the Bellman equations for reinforcement learning • temporal difference learning • Q learning • genetic algorithms and genetic programming  Prerequisites  Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.  Permat  Teaching format Group size Independent study  Exercises Independent study  Exam achievements  Graup size Independent study  Exam achievements  Successful exercise participation Index graded)  Study achievements  Successful exercise participation Index graded)  Forms of media Intelligence: A Modern Approach  Russell and Norvig, "Artificial Intelligence For Games"					1 1.	1 1 .				
<ul> <li>the Bellman equations for reinforcement learning</li> <li>temporal difference learning</li> <li>Q learning</li> <li>genetic algorithms and genetic programming</li> <li>Recommended:         <ul> <li>Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.</li> </ul> </li> <li>Format</li> <li>Group size</li> <li>h/week</li> <li>Workload[h]</li> <li>CP</li> <li>Lecture</li> <li>4</li> <li>60 T / 105 S</li> <li>5.5</li> <li>Exercises</li> <li>2</li> <li>30 T / 75 S</li> <li>3.5</li> <li>Exam achievements</li> <li>Oral exam</li> <li>Study achievements</li> <li>Successful exercise participation</li> <li>lecture slides are made available online</li> <li>lecture notes with programming examples are made available online</li> <li>lecture notes with programming examples are made available online</li> <li>Russell and Norvig, "Artificial Intelligence: A Modern Approach"</li> <li>Literature</li> <li>Millington, "Artificial Intelligence For Games"</li> </ul>										
• temporal difference learning • Q learning • genetic algorithms and genetic programming  Prerequisites  Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.  Promat    Teaching format   Group size   h/week   Workload[h]   CP			-			9				
• Q learning • genetic algorithms and genetic programming  Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.    Teaching format   Group size   h/week   Workload[h]   CP					ient iearning	5				
Prerequisites Recommended: Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.  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 Oral exam (graded)  Study achievements Oral exam (graded)  Forms of media • lecture slides are made available online • lecture notes with programming examples are made available online  Russell and Norvig, "Artificial Intelligence: A Modern Approach"  Literature Millington, "Artificial Intelligence For Games"			rence learm	ng						
Recommended:   Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.   Teaching format   Group size   h/week   Workload[h]   CP			thme and go	notic progr	amming					
	Prerequisites			mene brogr	umming					
	1 rerequisites			ing knowled	lge in linear	algebra probak	oility			
			-	-	-		Jiiioy			
Format  Lecture Exercises Exercises  T = face-to-face teaching; S = independent study  Coral exam Study achievements  Coral exam Successful exercise participation Forms of media  • lecture slides are made available online • lecture notes with programming examples are made available online Russell and Norvig, "Artificial Intelligence: A Modern Approach"  Literature  Millington, "Artificial Intelligence For Games"		-					CP			
Exercises 2 30 T / 75 S 3.5  T = face-to-face teaching; S = independent study  Exam achievements Oral exam (graded)  Study achievements Successful exercise participation (not graded)  Forms of media • lecture slides are made available online • lecture notes with programming examples are made available online  Russell and Norvig, "Artificial Intelligence: A Modern Approach"  Literature Millington, "Artificial Intelligence For Games"	Format			aroup size	<del>                                     </del>					
Exam achievements Oral exam (graded)  Study achievements Successful exercise participation (not graded)  Forms of media • lecture slides are made available online • lecture notes with programming examples are made available online  Russell and Norvig, "Artificial Intelligence: A Modern Approach"  Literature Millington, "Artificial Intelligence For Games"	Tormat				1 -					
Exam achievementsOral exam(graded)Study achievementsSuccessful exercise participation(not graded)Forms of media• lecture slides are made available online• lecture notes with programming examples are made available onlineRussell and Norvig, "Artificial Intelligence: A Modern Approach"LiteratureMillington, "Artificial Intelligence For Games"			 	2 _ : d	_	1 00 1 / 100	1 3.3			
Study achievements       Successful exercise participation       (not graded)         Forms of media       • lecture slides are made available online         • lecture notes with programming examples are made available online         Russell and Norvig, "Artificial Intelligence: A Modern Approach"         Literature       Millington, "Artificial Intelligence For Games"	Every coli		e teaching; S	o = maeper	ident study	<i>(</i>	,dod)			
Forms of media       ● lecture slides are made available online         ● lecture notes with programming examples are made available online         Russell and Norvig, "Artificial Intelligence: A Modern Approach"         Literature       Millington, "Artificial Intelligence For Games"			igo pontici-	tion						
● lecture notes with programming examples are made available online Russell and Norvig, "Artificial Intelligence: A Modern Approach"  Literature Millington, "Artificial Intelligence For Games"					no	(not gra	iaea)			
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Literature Millington, "Artificial Intelligence For Games"							ше			
			_	_		ierii Approacn"				
MacKay, "Information Theory, Inference, and Learning Algorithms"	Literature	Millington, "Art	tificial Intell	igence For	Games"					
		MacKay, "Inform	mation The	ory, Inferen	ce, and Lear	rning Algorithm	s"			

Module	Lab Machin	Lab Machine Learning on Encrypted Data								
MA-INF 4322										
Workload	Credit points	Duration	Frequency							
270 h	9 CP	1 semester								
Module	Dr. Michael N	Dr. Michael Nüsken								
coordinator										
Lecturer(s)	Dr. Michael N	Dr. Michael Nüsken								
Classification	Programme		Mode	Seme	ster					
Classification	M. Sc. Compu	M. Sc. Computer Science   Optional   2. or 3.								
Technical skills	The students	The students will carry out a practical task (project) in the								
	context of Cry	context of Cryptography, including test and documentation of								
	the implement	ed software/	system.							
Soft skills	Ability to prop	Ability to properly present and defend								
	design decision	design decisions, to prepare readable documentation of software;								
		skills in constructively collaborating with others in small teams								
	skills in constr	ructively coll	aborating	g with oth	iers in small te	ams				
	over a longer p	period of tim	e; ability	to classif	fy ones own res	ults				
	into the state-	into the state-of-the-art of the resp. area								
Contents					and installatio	ns of				
	data science methodology to automatically analyze large amounts of possibly privacy infringing data we have to carefully									
	_			_	ore and more fa					
		_			listinguish fake					
	from trustable				_	u				
						ula: a				
			_		be possible. T					
					orts for unifyin	_				
	_	_	_		at least to son					
					See Munn et a	1.				
	(2019) for a re		0	-						
	_				omputations or					
		•	_		pplication that	we				
	are chosing to	gether. Ideal	ly, we can	n come uj	p with a novel					
	solution for pe	erforming an	unconsid	lered algo	rithm. We stud	ly				
	the tasks and	tools, select	algorithn	ns, find a	protocol, proto	type				
	an implemention, perform a security analysis, present an									
	evaluation,									
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		1				
Exam achievements	Schriftliche Pr			Politicili		aded)				
Study achievements	Erfolgreiche Ü		me		(not gra					
Forms of media		~ 41150001111A1			(1100 816	aca)				
Literature										
Literature										

Module MA-INF 4323	Pattern Recognition II								
Workload	Credit points	Duratio	n	Frequ	ency				
270 h	9 CP	1 semes		every	year				
Module	Prof. Dr. Christi	ian Bauck	hage						
Coordinator	Duof Du Chuisti	lan Danah	h a ma						
Lecturer(s)	Prof. Dr. Christi Programme	an Bauck		ode	Semester				
Classification	M. Sc. Computer Science				2. or 3.				
Technical skills		M. Sc. Computer Science   Optional   2. or 3.  Upon completion, students should be able to							
Soft skills	<ul> <li>know about aspractical implem algorithms</li> <li>know about ite with large data s</li> <li>implement num</li> <li>implement num</li> </ul>	<ul> <li>know about iterative algorithms for machine learning / pattern recognition with large data sets</li> <li>implement numerically robust algorithms for data dimensionality reduction</li> <li>implement numerically robust data clustering and classification</li> </ul>							
Soft skills	robust implemen pattern recogniti dynamical system	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	<ul> <li>advanced concepts from linear algebra</li> <li>QR-, spectral-, and singular value decompositions</li> <li>iterative algorithms for least squares optimization</li> <li>iterative algorithms for principal component analysis</li> <li>Hebbian learning and Oja's rule for principal compoentn analysis</li> <li>auto-encoder networks</li> <li>associative memory networks</li> <li>Hopfield networks</li> <li>Hopfield networks for pattern recognition</li> <li>Hopfield networks for problem solving</li> <li>energy minimization methods in machine learning and pattern recognition</li> <li>latent factor models for data analysis</li> <li>data matrix factorization techniques</li> <li>multidimensional scaling</li> <li>manifold learning</li> <li>basic graph theory</li> <li>graph cuts and graph clustering</li> <li>graph diffusion processes</li> <li>radial basis functions for interpolation</li> <li>radial basis functions for classification</li> </ul>								
Prerequisites	• radial basis fur Recommended Students should theory, and statis Recognition (1).	: good work stics. Idea	ing	knowled	ge in linear alge		ern		
	Teaching forms	at	G	roup si	ze 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		S =	indepen	dent study				
Exam achievements	Schriftliche Prüft					,-	aded)		
Study achievements	Erfolgreiche Übu					(not gr	aded)		
Forms of media						available anlin-			
Literature	<ul> <li>lecture slides are made available online</li> <li>lecture notes with programming examples are made available online</li> <li>MacKay, "Information Theory, Inference, and Learning Algorithms"</li> <li>Haykin, "Neural Networks and Learning Machines"</li> <li>Bishop, "Neural Networks for Pattern Recognition"</li> <li>Elden, "Matrix Methods in Data Mining and Pattern Recognition"</li> <li>Skillicorn, "Understanding Complex Datasets"</li> <li>Kirby, "Geometric Data Analysis"</li> </ul>								

Module	Seminar Advanced Topics in Data Science								
MA-INF 4324									
Workload	Credit points	Duration	Frequen	Frequency					
120 h	4 CP	1 semeste	every year						
Module	Prof. Dr. Eler	Prof. Dr. Elena Demidova							
coordinator									
Lecturer(s)	Prof. Dr. Eler	na Demidova	l						
Classification	Programme M. Sc. Compu	ProgrammeModeSemesterM. Sc. Computer ScienceOptional2. 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	<ul> <li>Communication skills: oral and written presentation of scientific content.</li> <li>Self-competences: the ability to analyze problems, time management, creativity.</li> </ul>								
Contents	data generation	uding typica on, integration. Specialize	l steps of the on, cleaning d data repr	he data s g, explora esentatio	science processation, modelling on and analytic	g			
Prerequisites	Recommended	:							
	BA-INF 150 -	Einführung	in die Data	a Science	•				
Format	Teaching forms	at G	roup size	h/week	Workload[h]	СР			
rormat	Seminar		10	2	30 T / 90 S	4			
	T = face-to-fa	ce teaching;	S = indepe	endent st	cudy				
Exam achievements	Oral presentat					ded)			
Study achievements	None	*	-		(not gra				
Forms of media									
Literature	Relevant litera seminar	ature will be	announced	at the k	peginning of th	е			

Module	Lab Data S	Lab Data Science in Practice							
MA-INF 4325									
Workload	Credit points	Duration	Freque	ency					
270 h	9 CP	1 semester	every	year					
Module	Prof. Dr. Eler	Prof. Dr. Elena Demidova							
coordinator									
Lecturer(s)	Prof. Dr. Eler	na Demidova							
Classification	Programme		Mode	Seme	ster				
Classification	M. Sc. Compu	ter Science	Optiona	al   2. or	3.				
Technical skills	This module c	oncentrates	on praction	cal experi	ience in data				
	analytics. Par	analytics. Participants acquire basic knowledge and practical							
	experience in t	experience in the design and implementation of data science							
	workflows for s	workflows for specific data types and applications.							
Soft skills	Communicat	tion skills: th	e ability	to work i	in teams.				
	• Self-compete	ences: the ab	ility to a	nalyse pro	oblems and find				
	practical solut	ions. Time r	nanageme	ent, creat	ivity, presentation				
	of results.								
Contents	Practical appli	ication of sta	tistical a	nd machi	ne learning-based				
	methods to so	lve data ana	ytics pro	blems on	real-world datasets				
	and evaluate p	proposed solu	tions.						
Prerequisites	Recommended	:							
	BA-INF 150 -	Einführung	in die Da	ta Scienc	e				
	MA-INF 4230	- Advanced	Methods	of Inform	nation Retrieval				
Format	Teaching forma	at Gro	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		(graded)				
Study achievements	None				(not graded)				
Forms of media									
Literature									

Module	Explainable	AI an	d Appl	icati	ions				
MA-INF 4326									
<b>Workload</b> 180 h	Credit points 6 CP	Duration 1 semes		<b>quenc</b> y year					
Module coordinator	Dr. Tiansi Dong		•						
Lecturer(s)	Dr. Tiansi Dong								
` ,	Programme		Mode	Se	emester				
Classification		M. Sc. Computer Science   Optional   3.							
Technical skills		• Know the dual-model functioning of the human mind, and two main AI							
Soft skills	<ul> <li>Understand the systems, and Knopeep-Learning systems.</li> <li>Know System of connectionist AI</li> <li>Develop neural symbolic AI and</li> <li>Know the limit self-driving. Knopeep</li> </ul>	<ul> <li>Develop white-box neural AI systems</li> <li>Understand the problems and limitations of Blackbox Deep-Learning systems, and Know the state-of-the-art Methods for Interpreting Deep-Learning systems (XAI)</li> <li>Know System 1 and 2 of the mind, prons and cons of symbolic AI and</li> </ul>							
Contents	Deep-Learning sy 1. Introduction:		rge Deep-l	Learni	ng systems,	e.g. Watson, Gl	PT,		
Prerequisites Format	2. Dual-system theories (System 1 and 2), nine laws of cognition, criteria of semantic models 3. The target and the state-of-art methods of XAI 4. Neural-symbolic AI 5. Cognitive maps, Collages, Mental Spatial Representation, Events 6. Qualitative Spatial Representation and Reasoning 7. Rotating Sphere Embedding: A New Wheel for Neural-Symbolic Unification 8. Neural Syllogistic Reasoning 9. Recognizing Variable Environments 10. Humor Understanding 11. Rotating Spheres as building-block semantic components for Language, Vision, and Action  none  Teaching format Group size h/week Workload[h] CP Lecture 2 30 T / 45 S 2.5								
	Exercises The face to face	too obimm.	 Cindon	on don	2	30 T / 75 S	3.5		
Exam achievements	T = face-to-face Written exam	reaching;	ь — шаер	enaeu	ı sıuuy	( m	aded)		
Study achievements	Successful exercis	se particip	ation			(not gr			
Forms of media									
Literature	<ul> <li>Kahneman, D. (2011). Thinking fast and slow. Farrar, Straus and Giroux</li> <li>Gaedenfors, P. (2017). The Geometry of Meaning. MIT Press.</li> <li>Attardo, Hempelmann, Maio (2003). Script Oppositions and Logical Mechanisms: Modeling Incongruities and their Resolutions, HUMOR 15(1)3-46</li> <li>Tversky, B. (2019). Mind in Motion. Basic Books, New York.</li> <li>Dong, et al. (2020). Learning Syllogism with Euler Neural-Networks. arXiv:2007.07320</li> <li>Dong, T. (2021). A Geometric Approach to the Unification of Symbolic Structure and Neural Networks. Springer.</li> <li>Knauff and Spohn (2021). Handbook of Rationality. MIT Press, Cambridge, MA, USA.</li> <li>Samek et.al. (2019), Explainable AI: Interpreting, Explaining and Visualizing Deep Learning. Springer.</li> <li>Greg Dean (2019). Step by Step to Stand-Up Comedy (Revised Edition).</li> </ul>								

Module	Lab Biomed	Lab Biomedical Data Science							
MA-INF 4327									
Workload	Credit points	Duration	Frequency						
270 h	9 CP	9 CP   1 semester   every year							
Module	Prof. Dr. Holg	Prof. Dr. Holger Fröhlich							
coordinator									
Lecturer(s)	Prof. Dr. Holg	ger Fröhlich							
Classification	Programme		Mode	Seme	ster				
Classification	M. Sc. Compu	iter Science	Options	al 3.					
Technical skills	The students	The students will carry out a practical task (project) in the							
	context of bior	context of biomedical data science, including test and							
	documentation of the implemented software/system.								
Soft skills	Ability to prop	perly presen	t and defe	end design	n decisions, to				
	prepare readal	ole docume	tation of	software;	skills in				
	constructively	collaborati	ng with ot	hers in sr	nall teams over	a			
	longer period	of time; abi	ity to clas	ssify ones	own results into	o the			
	state-of-the-ar	t of the resp	o. area						
Contents	Varying select	ed topics cl	se to cur	rent resea	rch in the area	of			
	biomedical dat	ta science.							
Prerequisites	none								
D	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, writter	report		(gra	ded)			
Study achievements		<del>.</del>			(not gra	ded			
Forms of media									
Literature									

Module	Spatio-Tem	poral Da	ta Analyt	ics			
MA-INF 4328							
Workload	Credit points	Duration	Freque	Frequency			
180 h	6 CP	1 semeste	r every year				
Module	Prof. Dr. Elena Demidova						
coordinator							
Lecturer(s)	Prof. Dr. Elena Demidova						
Classification	Programme M. Sc. Compu	Mode Optiona		Semester 2. or 3.			
Technical skills  Soft skills	This module introduces the students to the advanced methods, 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 skills: oral and written presentation and discussion of solutions. Self-competences: the ability to analyze and solve problems.						
Contents	The module topics include data structures, data representation and analysis methods, and algorithms that enable analyzing spatio-temporal data and building predictive models effectively and effectively. Furthermore, we will study the corresponding evaluation techniques and novel applications.						
Prerequisites	none						
	Teaching form	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 teaching; $S = independent study$						
Exam achievements	Schriftliche Prüfung (graded)						
Study achievements	Erfolgreiche Übungsteilnahme (not graded)				/		
Forms of media	Ŭ .					/_	
Literature							

Module MA-INF 4329	Seminar Biological Intelligence							
Workload	Credit points Duration Frequency							
120 h	4 CP							
Module	Prof. Dr. Dominik Bach							
coordinator								
Lecturer(s)	Prof. Dr. Dr. Dominik Bach							
Classification	Programme		Mode	Semester				
Classification	M. Sc. Compu	ter 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	Current conference and journal papers.							
Prerequisites	none							
Format	Teaching forms	ıt Gı	oup size	h/week	Workload[h]	CP		
	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	Master Thesis								
MA-INF 0401									
Workload	Credit points	Duration	Freque	ncy					
900 h	30 CP 1 semester every semester								
Module									
coordinator									
Lecturer(s)	All lecturers of computer science								
Classification	Programme		Mode	Se	Semester				
Classification	M. Sc. Compu	iter Science	Compul	sory 4.					
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								
	Teaching forms	at (	Froup size	h/week	Workload[h]	CP			
	Independent			0	900 S	30			
Format	preparation of a								
	scientific thesis with								
	individual coaching								
	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								
Diserature	relevant literature (depending on the topic of the thesis)								

Module MA-INF 0402	Master Seminar						
	G 114	D 41					
Workload	Credit points	Duration	Frequency				
60 h	2 CP   1 semester   every semester						
Module							
coordinator							
Lecturer(s)	All lecturers of computer science						
Classification	Programme		Mode Semester		emester		
Classification	M. Sc. Compu	iter Science	Compul	sory $4$ .			
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							
Literature Individual bibliographic research required for identifying							
Diterature	relevant literature (depending on the topic of the thesis)						