# Module Handbook

for the

## Master Programme "Computer Science"

at

### Rheinischen Friedrich-Wilhelms-Universität Bonn

revised version: April 16, 2020

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

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

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

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

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

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1	Algorithmics	2
2	Graphics, Vision, Audio	30
3	Information and Communication Management	68
4	Intelligent Systems	100
5	Master Thesis	140

## 1 Algorithmics

MA-INF 1102	L4E2	9 CP	Combinatorial Optimization	. 3
MA-INF 1103	L4E2	9 CP	Cryptography	. 4
MA-INF 1104	L4E2	9 CP	Advanced Algorithms	. 5
MA-INF 1201	L4E2	9 CP	Approximation Algorithms	. 6
MA-INF 1202	L4E2	9 CP	Chip Design	. 7
MA-INF 1203	L4E2	9 CP	Discrete and Computational Geometry	. 8
MA-INF 1205		6 CP	Graduate Seminar Discrete Optimization	. 9
MA-INF 1206	Sem2	4 CP	Seminar Randomized and Approximation Algorithms	10
MA-INF 1207	Lab4	9 CP	Lab Combinatorial Algorithms	11
MA-INF 1209	Sem2	4 CP	Seminar Advanced Topics in Cryptography	12
MA-INF 1213	L4E2	9 CP	Randomized Algorithms and Probabilistic Analysis $\ldots\ldots$	13
MA-INF 1217	Sem2	4 CP	Seminar Theoretical Foundations of Data Science	14
MA-INF 1218	L4E2	9 CP	Algorithms and Uncertainty	15
MA-INF 1219	Sem2	4 CP	Seminar Algorithmic Game Theory	16
MA-INF 1220	Sem2	4  CP	Seminar Algorithms for Computational Analytics	17
MA-INF 1221	Lab4	9 CP	Lab Computational Analytics	18
MA-INF 1222	Lab4	9 CP	Lab High Performance Optimization	19
MA-INF 1301	L4E2	9 CP	Algorithmic Game Theory	20
MA-INF 1304	Sem2	4 CP	Seminar Computational Geometry	21
MA-INF 1305		6 CP	Graduate Seminar Chip Design	22
MA-INF 1307	Sem2	4  CP	Seminar Advanced Algorithms	23
MA-INF 1308	Lab4	9 CP	Lab Algorithms for Chip Design	24
MA-INF 1309	Lab4	9 CP	Lab Efficient Algorithms: Design, Analysis and	
			Implementation	25
MA-INF 1312	L4E2	9 CP	The Art of Cryptography	26
MA-INF 1314	L4E2	9 CP	Online Motion Planning	27
MA-INF 1315	Lab4	9 CP	Lab Computational Geometry	28
MA-INF 1320	Lab4	9 CP	Lab Advanced Algorithms	29

Module	Combinator	rial Optim	ization				
MA-INF 1102							
Workload	Credit points	Duration	Frequency				
270 h	9 CP						
Module	Prof. Dr. Jens	s Vygen					
coordinator							
Lecturer(s)	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 developme	ent of solution	n strateg	gies for co	mbinatorial		
	optimization p	optimization problems					
Soft skills		Mathematical modelling of practical problems, abstract					
		thinking, presentation of solutions to exercises					
Contents	Matchings, b-matchings and T-joins, optimization over						
	matroids, sub	nodular fund	tion min	imization	, travelling		
	salesman prob	lem, polyhed	lral comb	inatorics,	NP-hard probl	ems	
Prerequisites	none						
	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP	
Format	Lecture			4	60 T / 105 S	5.5	
	Exercises			2	30 T / 75 S	3.5	
	T = face-to-fa	ce teaching;	S = inde	pendent s	study		
Exam achievements	Oral exam				(gra	ded)	
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)	
Forms of media							
	• B. Korte, J.	Vygen: Con	binatoria	al Optimi	zation: Theory	and	
	Algorithms. Springer, 6th edition, 2018						
	• A. Schrijver: Combinatorial Optimization: Polyhedra and						
Literature	Efficiency. Spr	ringer, 2003					
Literature	• W. Cook, W	. Cunningha	ım, W. P	ulleyblan	k, A. Schrijver:		
	Combinatorial	_	-				
	• A. Frank: C	onnections in	ı Combir	natorial O	ptimization. Ox	xford	
	University Pre	ss, 2011					

Module MA-INF 1103	Cryptography							
Workload	Credit points	Duration	Frequ	oncy				
270 h	9 CP 1 semester   every year							
Module	Dr. Michael Nüsken							
coordinator	Di. Wilchael IV	doken						
Lecturer(s)	Dr. Michael Nüsken							
	Programme	4,511011	Mode	Seme	ster			
Classification	M. Sc. Compu	iter Science						
Technical skills	-	Understanding of security concerns and measures, and of the						
		interplay between computing power and security requirements.						
	_ ~ ~	Mastery of the basic techniques for cryptosystems and						
	cryptanalysis							
Soft skills	0 2 0	Oral presentation (in tutorial groups), written presentation (of						
		•		,	ving homework	\		
	problems, criti	, ,			O			
Contents	- '			vptosyste	ms: AES, RSA,			
					nge, cryptograp			
	hash functions	, signature	, identific	ation; fac	toring integers a	and		
	discrete logari	thms; lower	bounds i	n structur	red models.			
Prerequisites	none							
	Teaching forms	at G	roup size	h/week	Workload[h]	CP		
Format	Lecture			4	60 T / 105 S	5.5		
	Exercises			2	30  T / 75  S	3.5		
	T = face-to-fa	ce teaching	S = inde	ependent s	study			
Exam achievements	Written exam				(gra	ded)		
Study achievements	Successful exer	rcise partic	pation		(not gra	ded)		
Forms of media								
Literature	<ul><li>Stinson, Cry</li><li>Course notes</li></ul>		Theory a	nd Practi	ce, 2nd edition			

Module MA-INF 1104	Advanced A	Algorithm	ns				
Workload	Credit points	Duration	Frequ	uenc	v		
270 h	9 CP	1 semest	_		-		
Module	Prof. Dr. Heil	ko Röglin					
coordinator							
Lecturer(s)	Prof. Dr. Ann	e Driemel,	Prof. Dr	. Th	omas l	Kesselheim,	
	Prof. Dr. Heil	Prof. Dr. Heiko Röglin, PD Dr. Elmar Langetepe,					
	Dr. Herman H	Dr. Herman Haverkort, Senior Prof. Dr. Marek Karpinski					
Classification	Programme		Mode		Semes	ster	
Classification	-	M. Sc. Computer Science   Optional   1.					
Technical skills		Deeper insights into selected methods and techniques of modern					
		algorithmics.					
Soft skills				$\operatorname{hods}$	, critic	al discussion of	
	applied metho		•				
Contents	Advanced algo		-		٠.		
			-		_	rithms. We will	
		sential top	ics such a	s lin	ear pro	ograms and net	work
	flows.						
Prerequisites	none			1 -			I
	Teaching forms	at G	roup size	h/	/week	Workload[h]	CP
Format	Lecture				4	60 T / 105 S	5.5
	Exercises				2	30  T / 75  S	3.5
	T = face-to-fa	ce teaching	g; S = inc	leper	ndent s		
Exam achievements	Written exam					(gra	ded)
Study achievements	Successful exe	rcise partic	ipation			(not gra	ded)
Forms of media							
Literature							

			. 1					
Module	Approximat	tion Algori	thms					
MA-INF 1201	~		T =					
Workload	Credit points	Duration	Freque	-				
270 h	9 CP 1 semester at least every year							
Module	Prof. Dr. Jens Vygen							
coordinator								
Lecturer(s)		All lecturers of Discrete Mathematics,						
		Senior Prof. Dr. Marek Karpinski						
Classification	Programme	-	Mode	Seme				
	M. Sc. Compu		Optiona					
Technical skills	Introduction t	_			-			
		approximation algorithms for NP-hard combinatorial						
	_			_	es for proving lo	ower		
	and upper bou							
Soft skills				ds, critic	cal discussion of			
	applied metho		-					
Contents					on Schemes. De			
					or selected NP-l	nard		
	problems, like			-				
	MAXSAT, TS	· –						
	Facility Locati			_	=			
	techniques (lik							
	Search, randor		_					
	MCMC-Metho	* *			nalysis of			
	approximation		d PCP-S	ystems.				
Prerequisites	Recommended							
	Introductory l			ons of alg	gorithms and			
	complexity the				1	1		
	Teaching forms	at Gro	oup size	h/week	Workload[h]	CP		
Format	Lecture			4	60 T / 105 S	5.5		
	Exercises			2	30  T / 75  S	3.5		
	T = face-to-fa	ce teaching;	S = inde	pendent s	study			
Exam achievements	Oral exam				(gra	ided)		
Study achievements	Successful exe	rcise particip	ation		(not gra	ided)		
Forms of media								
	• S. Arora, C.	Lund: Hard	ness of A	pproxima	ations. In:			
	Approximation							
	Hochbaum, ed	.), PWS, 199	06		`			
		•		approxi	mative Algorith	men		
	für harte Bere	chnungsprob	leme, Leo	cture Not	es (5th edition)	,		
Literature	Universität Bo	onn, 2007						
	• B. Korte, J.	Vygen: Com	binatoria	l Optimi	zation: Theory	and		
	Algorithms (6)	th edition), S	pringer,	2018				
	_ `				s, Springer, 2001	1		
	• D. P. Willian			_				
			-		ersity Press, 20	11		

Module MA-INF 1202	Chip Design	n						
Workload	Credit points	Duration	Freque	ency				
270 h	9 CP	1 semester	every	year				
Module	Prof. Dr. Jens	s Vygen						
coordinator								
Lecturer(s)	All lecturers o	f Discrete M	athemati	cs				
Classification	Programme		Mode	Seme	ster			
Classification	•	M. Sc. Computer Science   Optional   1. or 2.						
Technical skills		Knowledge of the central problems and algorithms in chip						
			-		gorithms for so	_		
	_	eal-world problems, also with respect to technical constraints.						
	_	Techniques to develop and implement efficient algorithms for						
		very large instances.  Mathematical modelling of problems occurring in chip design,						
Soft skills		_	_			gn,		
	development o	-			thinking,			
	_	presentation of solutions to exercises						
Contents		Problem formulation and design flow for chip design, logic synthesis, placement, routing, timing analysis and optimization						
-	, ,	ement, routi	ng, timin	g analysı	s and optimizat	tion		
Prerequisites	none		. 1		***	- CD		
	Teaching forms	at Gro	oup size	h/week	• •	CP		
Format	Lecture			4	60 T / 105 S	5.5		
	Exercises			2	30  T / 75  S	3.5		
	T = face-to-fa	ce teaching;	S = inde	pendent s				
Exam achievements	Oral exam					aded)		
Study achievements	Successful exe	rcise particip	ation		(not gra	aded)		
Forms of media								
			_		The Handbook			
	Algorithms for VLSI Physical Design Automation. CRC Press,							
	New York, 2008.							
	• S. Held, B. Korte, D. Rautenbach, J. Vygen: Combinatorial							
	optimization in VLSI design. In: "Combinatorial Optimization:							
Literature	Methods and Applications" (V. Chvátal, ed.), IOS Press,							
	Amsterdam 2011, pp. 33-96 • S. Held, J. Vygen: Chip Design. Lecture Notes (distributed							
	,		Design. I	∟ecture N	otes (distribute	ea		
	during the cou	,	C M4	in and I	V Colorfor	la .		
					.K. Scheffer, ed			
		_		-	nentation, Circu			
	pesign, and P	rocess techn	orogy. Cl	no Press	, 2nd edition, 2	010		

Module	Discrete an	d Comput	otional C	oomot	+ 10 % 7			
MA-INF 1203	Discrete an	u Comput	ational G	reome	ы <b>1 у</b>			
Workload	Credit points	Duration	Frequenc	cy				
270 h	9 CP	1 semester	every ye	ar				
Module	Prof. Dr. Ann	e Driemel						
coordinator								
Lecturer(s)	Prof. Dr. Ann	Prof. Dr. Anne Driemel, PD Dr. Elmar Langetepe,						
	Dr. Herman H	Dr. Herman Haverkort						
Classification	Programme		Mode	Seme	ster			
	M. Sc. Compu		Optional	1-4.				
Technical skills	0				cepts in the are			
		liscrete and computational geometry; design and analysis of						
	_			-	of the complex	ity		
	of geometric c	_			owledge			
	autonomously							
Soft skills	Social compet	`			_			
		olutions, goal-oriented discussions in teams), methodical						
	competence (a	. ,	, -	, ,				
	· ·	commitment :	and willing	ness to	learn, creativity	у,		
	endurance).	C		1.				
Contents				_	ms, hyperplane			
			_	_	tion, spanners,			
	_				n, VC-dimension	n,		
	epsilon-nets, v		,	_	٠,			
	randomized in			_	tric distance			
Duamaguisitas	problems in di		and mgne	Γ.				
Prerequisites	BA-INF 114 –		der algorit	hmisch	en Ceometrie			
	Teaching forms			/week	Workload[h]	CP		
Format	Lecture	at GIO	oup size 1	4	60 T / 105 S	5.5		
rormat	Exercises			2	30 T / 75 S	3.5		
			C · 1	_	'	3.5		
T	T = face-to-fa	ce teaching;	S = indepe	endent s		1 1\		
Exam achievements	Oral exam	. ,			, -	$\frac{\operatorname{ded}}{\operatorname{1}}$		
Study achievements	Successful exe	rcise particip	ation		(not gra	aea)		
Forms of media	T: : M /	1 T /	D: 1	<u> </u>				
	• Jiri Matouse							
	Graduate Text					- nle		
	• Mark de Bei Overmars. Co	· ·	<u> </u>		Kreveld, and Ma	лК		
Literature	Applications (	-		_				
	978-3-540-779'		n). Springe	51. ISDI	N			
	• Narasimhan		netric Span	ner Not	works			
	·		_					
	• Klein, Concrete and Abstract Voronoi Diagrams							

Module	Graduate S	eminar Di	screte (	Optimiz	ation			
MA-INF 1205								
Workload	Credit points	Duration	Freque	ency				
180 h	6 CP	1 semester	every y	year				
Module	Prof. Dr. Jens	s Vygen						
coordinator								
Lecturer(s)	All lecturers of Discrete Mathematics							
Classification	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	iter Science	Optiona	ıl 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 re	present such results and relations.						
Soft skills	Ability to read	and unders	tand rese	arch pape	ers, abstract			
	thinking, prese	entation of n	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 Opt	imization				
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP		
rormat	Seminar		10	4	60 T / 120 S	6		
	T = face-to-fa	ce teaching;	S = inde	pendent s	study			
Exam achievements	Oral presentat	ion, written	report		(gra	ded)		
Study achievements					(not gra	ded)		
Forms of media					-			
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		Freque	ncy		
120 h	4 CP						
Module	Prof. Dr. Heik	Prof. Dr. Heiko Röglin					
coordinator							
Lecturer(s)	Prof. Dr. Ann	Prof. Dr. Anne Driemel, Prof. Dr. Thomas Kesselheim,					
	Prof. Dr. Heik	o Röglin,	PD	Dr. Elm	ar Lange	tepe,	
	Dr. Herman H	laverkort,	Seni	ior Prof.	Dr. Mar	ek Karpinski	
CI 10 II	Programme			Mode	Semest	ter	
Classification	M. Sc. Computer Science   Optional   2.						
Technical skills	Ability to perform individual literature search, critical reading,						
	understanding	, and clear	r pre	esentatio	n.		
Soft skills	Presentation o	f solutions	an	d metho	ds, critica	l discussion of	
	applied method	ds and tec	hnic	ques			
Contents	Current topics	in design	and	l analysi	s of rando	omized and	
	approximation	algorithm	ns ba	ased on l	astest res	search literatur	e
Prerequisites	none						
TD 4	Teaching forms	at	Gro	up size	h/week	Workload[h]	CP
Format	Seminar			10	2	30 T / 90 S	4
	T = face-to-face	ce teachin	g; S	= indep	endent st	udy	
Exam achievements	Oral presentat	ion, writte	en re	eport		(gra	ded
Study achievements		(not graded)					
Forms of media							
Literature	The relevant li	terature v	vill l	oe annou	inced in t	ime.	

Module	Lab Combin	natorial Al	gorithn	ns				
MA-INF 1207								
Workload	Credit points	Duration	Frequency					
270 h	9 CP							
Module	Prof. Dr. Jens	s Vygen						
coordinator								
Lecturer(s)	All lecturers of Discrete Mathematics							
Classification	Programme		Mode	Semes	ster			
Classification	M. Sc. Compu	iter Science	Optiona	d 2.				
Technical skills	Competence to	Competence to implement advanced combinatorial algorithms,						
	handling nonti	handling nontrivial data structures, testing, documentation.						
	Advanced soft	Advanced software techniques.						
Soft skills	Efficient imple	ementation of	complex	algorith	ms, abstract			
	thinking, docu	mentation of	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	n a meeti	ng in the previo	ous		
	semester.							
Prerequisites	Recommended	:						
	MA-INF 1102	- Combinato	orial Opti	imization				
TD 4	Teaching forms	at Gro	oup size	h/week	Workload[h]	CP		
Format	Lab		8	4	60 T / 210 S	9		
	T = face-to-fa	ce teaching;	S = inde	pendent s	study			
Exam achievements	Oral presentat	ion, written	report		(gra	ded)		
Study achievements					(not gra	ded)		
Forms of media								
T:44	The topics and the relevant literature will be announced towards							
Literature	the end of the previous semester							

Module	Seminar Ad	Seminar Advanced Topics in Cryptography						
MA-INF 1209								
Workload	Credit points	Duration	ı	Frequer	ıcy			
120 h	4 CP 1 semester every semester							
Module	Dr. Michael N	Dr. Michael Nüsken						
coordinator								
Lecturer(s)	Dr. Michael N	Dr. Michael Nüsken						
Classification	Programme			Mode	Semest	ter		
Classification	M. Sc. Compu	iter Scienc	ce	Optional	2. or 3	3.		
Technical skills	Understanding	Understanding research publications, often written tersely.						
	Distilling this	Distilling this into a presentation. Determination of relevant vs.						
	irrelevant mat	relevant material. Developing a presentation that fascinates						
	fellow students	fellow students.						
Soft skills	_	_		_		orally and in v	isual	
	media. Motiva	_			participa	te. Critical		
	assessment of							
Contents			-	0 2 0,		g from year to	year,	
	is studied in d	epth, base	ed or	current	research	literature		
Prerequisites	Required:							
	MA-INF 1103	- Cryptos	grap	hy				
	and one further	er course i	n cry	yptograp	hy like T	he Art of		
	Cryptography	or eSecur	ity.					
Format	Teaching forms	at	$\operatorname{Gro}$	up size	h/week	Workload[h]	CP	
rormat	Seminar			10	2	30 T / 90 S	4	
	T = face-to-fa	ce teachin	ıg; S	= indep	endent st	cudy		
Exam achievements	Oral presentat		<u> </u>				ded)	
Study achievements	_	· · · · · · · · · · · · · · · · · · ·				(not gra	ded)	
Forms of media						<u> </u>		
Literature	Current confer	rence publ	licati	ons, to b	e annour	nced in time		

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

Module MA-INF 1217	Seminar Theoretical Foundations of Data Science						
Workload	Credit points	Duration	Frequen	ıcv			
120 h	4 CP 1 semester every year						
Module	Prof. Dr. Heiko Röglin						
coordinator		O					
Lecturer(s)	Prof. Dr. Ann	e Driemel, F	rof. Dr. T	Thomas K	Kesselheim,		
. ,	Prof. Dr. Heil	Prof. Dr. Heiko Röglin, PD Dr. Elmar Langetepe,					
	Dr. Herman Haverkort						
CI 'C '	Programme	ramme Mode		Semest	Semester		
Classification	M. Sc. Computer Science		Optional	2. or 3	2. or 3.		
Technical skills	Ability to understand new research results presented in original					inal	
	scientific papers.						
Soft skills	Ability to pres	sent and to c	ritically di	scuss the	ese results in th	ıe	
	framework of	the correspon	nding area				
Contents	Current confer	rence and jou	ırnal pape	rs			
Prerequisites	none						
Format	Teaching form	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 = indep	endent st	udy		
Exam achievements	Oral presentat	tion, 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 semester	ester at least every 2 years				
Module	Prof. Dr. Tho	mas Kesselh	eim				
coordinator							
Lecturer(s)	Prof. Dr. Thomas Kesselheim						
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	M. Sc. Computer Science Optiona			3.		
Technical skills	Understanding	Understanding approaches for modeling uncertainty in					
	algorithmic th	algorithmic theory. Designing and analyzing algorithms with					
	performance guarantees in the context of uncertainty.						
Soft skills	Oral and writt	Oral and written presentation of solutions and methods					
Contents	• Advanced O	nline Algorit	$_{ m hms}$				
	• Markov Dec	isions Proces	ses				
	• Stochastic and	nd Robust O	ptimizat	ion			
	• Online Learn	ning Algorith	ms and	Online Co	onvex Optimizat	tion	
	• Sample Com	plexity					
Prerequisites	none						
	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							
Literature	lecture notes, research articles						

Module MA-INF 1219	Seminar Algorithmic Game Theory						
Workload	Credit points	Duration	Frequer	ncy			
120 h	4 CP	1 semeste	r   every y	ear			
Module	Prof. Dr. Thomas Kesselheim						
coordinator							
Lecturer(s)	Prof. Dr. Tho	mas Kessell	neim				
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	Optional	2. or 3	3.			
Technical skills	Ability to und	Ability to understand new research results presented in original					
	scientific pape	scientific papers.					
Soft skills	Ability to perf	Ability to perform individual literature search, critical reading,					
	and clear dida	ctic present	ation				
Contents	Advanced topi	_			_	mic	
	Mechanism De	esign based	on current	conference	e and journal		
	papers						
Prerequisites	none						
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
Tormat	Seminar		10	2	30 T / 90 S	4	
	T = face-to-fa	ce teaching;	S = indep	endent st	udy		
Exam achievements	Oral presentat	ion, written	report		(gra	ided)	
Study achievements					(not gra	ided)	
Forms of media							
Literature							

Module MA-INF 1220	Seminar Al	gorithms	for Comp	outation	al Analytic	S
Workload	Credit points	Duration	Frequen	ıcy		
120 h	4 CP	1 semeste				
Module	Prof. Dr. Petra Mutzel					
coordinator						
Lecturer(s)	Prof. Dr. Peti	a Mutzel				
Classification	Programme		Mode	Semest	ter	
Classification	M. Sc. Compu	Optional	2. or 3	3.		
Technical skills	Ability to perf	Ability to perform individual literature search, critical reading,				
	understanding	understanding, and clear didactic presentation.				
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 topics	in algorithi	ns for com	putationa	al analytics bas	sed
	on recent research	arch literatu	re.			
Prerequisites	Recommended	:				
	Interest in Alg	gorithms				
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	ided)
Study achievements					(not gra	ided)
Forms of media						
Literature	The relevant l	iterature wi	l be annou	nced in t	ime.	

Module MA-INF 1221	Lab Compu	tational	Analytic	S			
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semeste	r every year				
Module	Prof. Dr. Petr	a Mutzel					
coordinator							
Lecturer(s)	Prof. Dr. Petr	a Mutzel					
Classification	Programme		Mode	Seme	ster		
	M. Sc. Compu	iter Science	Option	al 2. or	3.		
Technical skills	computational	Ability to design, analyze and implement efficient algorithms for computational analytics problems. The LAB also includes experimental evaluation and documentation of the implemented software					
Soft skills		ble document collaboration time; abi	ntation of ng with ot ity to clas	software; thers in si			
Contents	Design of efficient structures for			_	gorithms and da ems.	ıta	
Prerequisites	Recommended	:					
	Interests in alg	$_{ m gorithms}$					
Format	Teaching forms	at G	oup size	h/week	Workload[h]	CP	
rormat	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching	S = inde	pendent s	study		
Exam achievements	Oral presentat	ion, writter	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature	The relevant l	iterature wi	ll be anno	ounced in	time.		

Module	Lab High P	erformand	e Optin	nization	<u> </u>		
MA-INF 1222							
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semester	er every year				
Module	Prof. Dr. Petr	a Mutzel					
coordinator							
Lecturer(s)	Prof. Dr. Petr	a Mutzel, D	r. Sven N	Iallach			
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Optiona	al 2. or	2. or 3.		
Technical skills	Ability to desi	Ability to design, analyze and implement efficient algorithms for					
	computational	computational analytics problems. The lab also includes					
	experimental e	evaluation a	nd docum	entation	of the implemen	$_{ m ted}$	
	software.						
Soft skills	Ability to prop	perly presen	and defe	nd design	decisions, to		
	prepare readal	ole documen	tation of	software;	skills in		
	constructively	collaboratin	g with ot	hers in sr	nall teams over	a	
	longer period	of time; abil	ty to clas	sify 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	
Format	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching;	S = inde	pendent s	study		
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra	$\overline{\operatorname{ded}}$	
Forms of media							
Literature	The relevant l	iterature wil	l be anno	unced in	time.		

Module	Algorithmic	Game Tl	neory					
MA-INF 1301								
Workload	Credit points	Duration	Freque	-				
270 h	9 CP	1 semester		2 years				
Module	Prof. Dr. Tho	mas Kessein	eım					
coordinator	Df D Tl	T/ 11-	_•					
Lecturer(s)	Prof. Dr. Tho		,					
	Senior Prof. D	r. Maiek K	Mode	Seme	at on			
Classification	Programme Mode M. Sc. Computer Science Options			I				
Technical skills			_		methods related to	<u> </u>		
remilear skins		-		-		0		
	the Game Theory for analyzing modern Internet-based communication networks and for designing algorithms for the							
		underlying problems of transmission control, resource allocation,						
					natorial auctions,	- ,		
	and the netwo		_	,	,			
Soft skills	Presentation of	f solutions a	nd metho	ods, critic	cal discussion of			
	applied metho							
Contents	The most defin	ning charact	eristic of	the Inter	net is that it was			
	not designed by a single central entity, but emerged from the							
	complex interactions of many individual entities or economic							
	agents, such as network operators, service providers, designers,							
	users, etc. We aim at providing basic framework and basic							
	techniques for analyzing and designing algorithms for the							
	following Internet-related problems and contexts: game theoretic							
	problems connected to the Internet and other decentralized							
	networks, resource allocation, mechanism design, Nash and							
	market equilibria, network economics, combinatorial auctions, cost allocations and network design.							
					le and unifying techniques			
					unifying technique			
	that have emerged recently in the above areas and discuss new fundamental paradigms in design of the relevant algorithms.							
D 114			design of	tne reiev	vant algorithms.			
Prerequisites	Recommended Introductory k		foundati	ong of ale	rorithms and			
	complexity the	_		ons or are	gorrinns and			
	Teaching forms		oup size	h/week	Workload[h]	CP		
Format	Lecture	at GI	Jup size	4		$\frac{5.5}{5.5}$		
Tormat	Exercises			2	1 '	3.5		
		oo too ohimm	C inde			0.0		
Even eshiowers	T = face-to-fa Written exam	ce teaching;	s = mae	репаент		047		
Exam achievements	Successful exe	rcisa particir	ation		(grade (not grade			
Study achievements Forms of media	Successiui exe.	icise particij	auton		(not grade	eu)		
rorms or media	• D P Rortso	kas A Nadi	с А Е	Ozdadari	Convex Analysis	1		
		,	,	ozuagiai.	Convex Analysis	,		
	and Optimization, Athena, 2003  • M. Karpinski, W. Rytter: Fast Parallel Algorithms for Graph							
	Matching Problems, Oxford Univ. Press, 1998							
	• D. M. Kreps: A Course in Microeconomic Theory, Princeton							
Literature	Univ. Press, 1							
			en, E. Ta	rdos, V.V	V. Vazirani (ed.):			
	• N. Nisan, T. Roughgarden, E. Tardos, V.V. Vazirani (ed.): Algorithmic Game Theory, Cambridge Univ. Press, 2007							
	• M. J. Osborne, A. Rubinstein: A Course in Game Theory,							

Module	Seminar Co	mputati	ona	d Geon	netry		
MA-INF 1304							
Workload	Credit points	Duration		Frequen	ıcy		
120 h	4 CP   1 semester   every year						
Module	Prof. Dr. Ann	Prof. Dr. Anne Driemel					
coordinator							
Lecturer(s)	Prof. Dr. Ann	Prof. Dr. Anne Driemel, PD Dr. Elmar Langetepe,					
	Dr. Herman H	Dr. Herman Haverkort					
Classification	Programme			Mode	Semest	ter	
	M. Sc. Compu	iter Scienc	e	Optional	2-4.		
Technical skills	To independen	To independently study problems at research level, based on					
	research public	research publications, to prepare a concise summary, to present					
	the summary i	in a scienti	ific t	talk, to le	ead a crit	ical discussion	
	with other sen	ninar parti	cipa	ints.			
Soft skills							
Contents	Current topics	in compu	tati	onal geor	netry.		
Prerequisites	Recommended	:					
	BA-INF 114 –	Grundlag	en c	ler algori	thmische	n Geometrie	
	MA-INF 1203	– Discrete	and	d Compu	itational	Geometry	
TD 4	Teaching forms	at	Gro	up size	h/week	Workload[h]	CP
Format	Seminar			10	2	30 T / 90 S	4
	T = face-to-fa	ce teaching	g; S	= indep	endent st	sudy	
Exam achievements	Oral presentat	ion, writte	en re	eport		(gra	ded)
Study achievements						(not gra	$\overline{\operatorname{ded}}$
Forms of media	Multimedia pr	ojector, bl	ack	board.			
Literature	The relevant li	iterature w	vill ł	oe annou	nced.		

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

Module MA-INF 1307	Seminar Ad	Seminar Advanced Algorithms					
Workload	Credit points	Duration	Freque	ncy			
120 h	4 CP	1 semeste	_	•			
Module	Prof. Dr. Tho	mas Kessel	neim				
coordinator							
Lecturer(s)	Prof. Dr. Ann	Prof. Dr. Anne Driemel, Prof. Dr. Thomas Kesselheim,					
	Prof. Dr. Heil	ko Röglin, F	D Dr. Eln	nar Lange	etepe,		
	Dr. Herman Haverkort						
Classification	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optiona	1 3.	3.		
Technical skills	Presentation of selected advanced topics in algorithm design and					and	
	various applica	ations					
Soft skills	Ability to perf	orm individ	ual literat	ure search	ı, critical readi	ng,	
	understanding	, and clear	didactic pr	esentation	n		
Contents	Advanced topi	cs in algori	hm design	based on	newest research	$\operatorname{ch}$	
	literature						
Prerequisites	none						
Format	Teaching forma	at C	roup size	h/week	Workload[h]	CP	
rormat	Seminar		10	2	30 T / 90 S	4	
	T = face-to-fa	ce teaching	S = indep	oendent st	tudy		
Exam achievements	Oral presentat	ion, writter	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature	The relevant li	iterature wi	ll be anno	ınced in t	ime.		

Module	Lab Algorit	Lab Algorithms for Chip Design					
MA-INF 1308							
Workload	Credit points	Duration	Freque	-			
270 h	9 CP	1 semester	every	year			
Module	Prof. Dr. Jens	s Vygen					
coordinator							
Lecturer(s)		All lecturers of Discrete Mathematics					
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Computer Science		Optiona	al 3.			
Technical skills	_		_		SI design, efficient	$\operatorname{ent}$	
	handling of ve	handling of very large instances, testing, documentation.					
	Advanced soft	Advanced software techniques.					
Soft skills	Efficient imple	Efficient implementation of complex algorithms, abstract					
	thinking, mode	thinking, modelling of optimization problem in VLSI design,					
	documentation	of source c	ode				
Contents	A currently ch	allenging pr	oblem wi	ll be chos	en each semeste	er.	
	The precise ta	sk will be ex	plained i	n a meeti	ng in the previo	ous	
	semester.		-				
Prerequisites	Recommended	:					
	At least 3 of the	he following:					
	MA-INF 1102	- Combinat	orial Opt	imization			
	MA-INF 1202	– Chip Desi	$\operatorname{gn}$				
	MA-INF 1205	- Graduate	Seminar	Discrete	Optimization		
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP	
rormat	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching;	S = inde	pendent s	study	'	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media					· -		
T	The topics and the relevant literature will be announced towards						
Literature	the end of the	previous ser	nester				

Module	Lab Efficien	Lab Efficient Algorithms: Design, Analysis and						
MA-INF 1309	Implementa	Implementation						
Workload	Credit points	Credit points   Duration   Frequency						
270 h	9 CP	1 semeste	r at leas	st every y	ear			
Module	Prof. Dr. Heil	ko Röglin	·					
coordinator								
Lecturer(s)	Prof. Dr. Ann	e Driemel,	Prof. Dr.	Thomas 1	Kesselheim,			
	Prof. Dr. Heil	ko Röglin, F	D Dr. El	mar Lang	etepe,			
	Dr. Herman H	[averkort						
Classification	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	ter Science	Options	al   3.				
Technical skills	Ability to design, analyze and implement efficient algorithms for							
	selected comp	selected computational problems.						
Soft skills	ability to work on advanced algorithmic implementation							
	projects, to we	ork in small	teams, cl	ear didact	tic presentation	and		
	critical discuss	ion of resul	ts					
Contents	Design of efficient	ient exact a	nd approx	imate alg	gorithms and da	ıta		
	structures for	selected cor	nputation	al probler	ns.			
Prerequisites	none							
Format	Teaching forms	at G	oup size	h/week	Workload[h]	CP		
Format	Lab		8	4	60 T / 210 S	9		
	T = face-to-fa	ce teaching	S = inde	pendent s	study			
Exam achievements	Oral presentat	ion, writter	report		(gra	ided)		
Study achievements					(not gra	$\overline{\mathrm{ded}}$		
Forms of media	, -							
Literature	The relevant li	terature wi	ll be anno	unced in	time.			

Module	The Art of Cryptography							
MA-INF 1312								
Workload	Credit points	Duration	Freque	ency				
270 h	9 CP	1 semester	r every year					
Module	Dr. Michael Nüsken							
coordinator								
Lecturer(s)	Dr. Michael N	Dr. Michael Nüsken						
Classification	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	Optiona	al 2.					
Technical skills	Insights into t	he theoretica	l founda	tions behi	ind security			
	concerns and i	concerns and measures, and of the interplay between computing						
	power, and sec	ower, and security requirements. Mastery of advanced						
		echniques for cryptosystems and cryptanalysis.						
Soft skills	Oral presentat	Oral presentation (in tutorial groups), written presentation (of						
	exercise solution	ons), team co	ollaborat	ion in solv	ving homework			
	problems, criti	ical assessme	$\operatorname{nt}$					
Contents	Possible topics	s are						
	• pseudorando	mness and z	ero-know	ledge,				
	• security redu			<i>G</i> ,				
	• lattices.	,						
Prerequisites	Recommended	:						
	MA-INF 1103	- Cryptogra	phy					
	Teaching forms	at Gre	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	$\overline{ded}$		
Forms of media								
Literature	Varying							

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

Module MA-INF 1315	Lab Computational Geometry						
Workload	Credit points Duration Frequency						
270 h	9 CP 1 semester every year						
Module	Prof. Dr. Ann	e Driemel					
coordinator							
Lecturer(s)	Prof. Dr. Ann	e Driemel, F	D Dr. Eli	nar Lan	getepe,		
	Dr. Herman H	Iaverkort					
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Optional	$oxed{2}$ .	2.		
Technical skills	Ability to design, analyze, implement and document efficient						
	algorithms for	algorithms for selected problems in computational geometry.					
Soft skills	Ability to properly present, defend and discuss design and						
	implementatio	n decisions,	to docume	ent softw	are according t	О	
	given rules and	d to collabor	ate with c	ther stu	dents in small		
	groups.						
Contents	Various proble	ems in comp	ıtational g	geometry	·.		
Prerequisites	none						
Format	Teaching forms	at Gre	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	tion, written	report		(gra	ided)	
Study achievements					(not gra	ided)	
Forms of media							
Literature	The relevant l	iterature will	be annou	inced in	time.		

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

# 2 Graphics, Vision, Audio

MA-INF 2111	L2E2	6 CP	Foundations of Graphics	31
MA-INF 2113	L2E2	6 CP	Foundations of Audio Signal Processing	32
MA-INF 2201	L4E2	9 CP	Computer Vision	33
MA-INF 2202	L4E2	9 CP	Computer Animation	34
MA-INF 2203	L4E2	9 CP	Selected Topics in Signal Processing	35
MA-INF 2204	L2E2	6 CP	Rendering Techniques I	36
MA-INF 2205	L2E2	6 CP	Geometry Processing I	37
MA-INF 2206	Sem2	4  CP	Seminar Vision	38
MA-INF 2207	Sem2	4  CP	Seminar Graphics	39
MA-INF 2208	Sem2	4 CP	Seminar Audio	40
MA-INF 2209	L4E2	9 CP	Advanced Topics in Computer Graphics I	41
MA-INF 2210	Sem2	4 CP	Seminar Computer Animation	42
MA-INF 2212	L2E2	6 CP	Pattern Matching and Machine Learning for Audio Signa	ıl
			Processing	43
MA-INF 2213	L3E1	6 CP	Computer Vision II	44
MA-INF 2214	L2E2	6 CP	Computational Photography	45
MA-INF 2215	Sem2	4 CP	Seminar Digital Material Appearance	46
MA-INF 2216	Lab4	9 CP	Lab Visual Computing	47
MA-INF 2217	L2E2	6 CP	Advanced Deep Learning for Graphics	48
MA-INF 2218	L2E2	6 CP	Video Analytics	49
MA-INF 2219	Sem2	4  CP	Seminar Visualization and Medical Image Analysis	50
MA-INF 2220	Lab4	9 CP	Lab Visualization and Medical Image Analysis	51
MA-INF 2221	Sem2	4  CP	Seminar Visual Computing	52
MA-INF 2222	L4E2	9 CP	Visual Data Analysis	53
MA-INF 2302	L2E2	6 CP	Physics-based Modelling	54
MA-INF 2304	L2E2	6 CP	Rendering Techniques II	55
MA-INF 2305	L2E2	6 CP	Geometry Processing II	56
MA-INF 2306	L2E2	6 CP	Virtual Reality	57
MA-INF 2307	Lab4	9 CP	Lab Vision	58
MA-INF 2308	Lab4	9 CP	Lab Graphics	59
MA-INF 2309	Lab4	9 CP	Lab Audio	60
MA-INF 2310	L4E2	9 CP	Advanced Topics in Computer Graphics II	61
MA-INF 2311	Lab4	9 CP	Lab Computer Animation	62
MA-INF 2312	L3E1	6 CP	Image Acquisition and Analysis in Neuroscience	63
MA-INF 2313	L2E2	6 CP	Deep Learning for Visual Recognition	
MA-INF 2314	L4E2	9 CP	Image Processing, Search and Analysis I	65
MA-INF 2315	L4E2	9 CP	Seminar Computational Photography	
MA-INF 2316	L4E2	9 CP	Lab Digital Material Appearance	

Module MA-INF 2111	Foundations of Graphics						
Workload	Credit points	Duration	Freque	ncy			
180 h	6 CP	1 semeste	r   every y	ear			
Module	Prof. Dr. Reinhard Klein						
coordinator							
Lecturer(s)	Prof. Dr. Reinhard Klein, Prof. Dr. Andreas Weber,						
	Prof. Dr. Mat	thias Hullin					
Classification	Programme		Mode	Semest	ter		
	M. Sc. Compu	iter Science	Optiona	$l \mid 1. \text{ or } 2$	2.		
Technical skills	Knowledge of	basic mathe	matical te	chniques of	commonly used	l in	
	Graphics with	a strong en	nphasis on	their app	lication to real		
	world problem						
Soft skills	Research abilit	Research abilities, information retrieval abilities, collaboration					
	abilities, self n						
Contents	_	•		_	plications to in	_	
	formation (rig	·	,		, ,		
					nodelling; Ordi	nary	
	differential equ	ations with	application	ns to phy	sical based		
	modelling						
Prerequisites	Required:	D 1	6.0	1. 77.	1 4 1	,	
	MA-INF 2101		ns of Grap	ohics, Visi	on and Audio	has	
	not been passe						
<b>.</b>	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				,,,	ded)	
Study achievements	Successful exe	rcise partici	pation		(not gra	ded)	
Forms of media							
Literature							

Module	Foundations of Audio Signal Processing							
MA-INF 2113								
Workload	Credit points	Duration	Freque	ncy				
180 h	6 CP	1 semest	ter every	every year				
Module	apl. Prof. Dr. Frank Kurth							
coordinator								
Lecturer(s)	apl. Prof. Dr.	Frank Ku	rth, Prof. I	Or. Michae	el Clausen			
Classification	Programme		Mode	Semes	ter			
Classification	M. Sc. Compu	iter Scienc	e Optiona	l   1.				
Technical skills	Introduction	• Introduction to basic concepts of analog and digital signal						
	processing;	processing;						
	Applications	• Applications in the field of Audio Signal Processing;						
	• Signal Proce	• Signal Processing Algorithms;						
	Implementing	• Implementing basic Signal Processing Algorithms						
Soft skills	Solving basic S	Solving basic Signal Processing Problems; Implementing Signal						
	Processing Alg	gorithms u	sing state-o	f-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							
Contents			_	_	l Signal Proces	sing;		
	Fourier Transf	,	0 0		, 0			
	Filters; Audio	_		-				
	Windowed For	ırier Trans	sform; 2D-S	ignal Proc	essing			
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 exe	rcise partic	cipation		(not gra	ded)		
Forms of media	Slides, Blackb	Slides, Blackboard, Whiteboard						
Literature								

Module	Computer	Vision					
MA-INF 2201	G 111	ъ	ъ				
Workload	Credit points	Duration	Frequency				
270 h	9 CP 1 semester every year						
Module	Prof. Dr. Jürgen Gall						
coordinator	D ( D I !!	G 11					
Lecturer(s)	Prof. Dr. Jürg	gen Gall					
Classification	Programme	~ .	Mode	Seme			
	M. Sc. Computer Science   Optional   1. or 2.						
Technical skills					cal methods and	d	
	their applicati						
Soft skills		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					
	their applicati	ons in compu	iter visio	n. For ex	ample, linear fil	lters,	
	edges, derivati	ves, Hough t	ransform	, segment	tation, graph cu	ıts,	
	mean shift, ac	tive contours	, level se	ts, MRFs	, expectation		
	maximization,	background	subtract	ion, temp	oral filtering, a	ctive	
	appearance me	odels, shapes	, optical	flow, 2d t	racking, camera	as,	
	2d/3d features	s, stereo, 3d r	econstru	ction, 3d	pose estimation	1,	
	articulated po	se estimation	, deform	able mesh	nes, RGBD visio	on.	
Prerequisites	Recommended	:	·		,		
-	Basic knowled	ge of linear a	lgebra, a	nalysis, p	orobability theor	ry,	
	C++ program	_	,	<i>0</i> / <b>1</b>	v	0 /	
	Teaching forms		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	,	1	
Exam achievements	Written exam					ded)	
Study achievements	Successful exe	rcise particip	ation		(not gra		
Forms of media		1 1			( 0		
	• R. Hartley,	A. Zisserman	: Multip	le View G	Seometry in		
	Computer Vis		P				
Literature			sion: Ale	gorithms :	and Application	$_{ m ns}$	
	<ul> <li>R. Szeliski: Computer Vision: Algorithms and Applications</li> <li>S. Prince: Computer Vision: Models, Learning, and Inference</li> </ul>						
	5.1111100.0	5111P4001 <b>V</b> 15	.011, 1,100	, 10011		1100	

Module	Computer Animation						
MA-INF 2202							
Workload	Credit points	Duration	Frequency				
270 h	9 CP	1 semester	every year				
Module	Prof. Dr. Andreas Weber						
coordinator							
Lecturer(s)	Prof. Dr. And	lreas Weber					
CI :C ::	Programme Mode Semes			ster			
Classification	M. Sc. Compu	iter Science	Optiona	d 2.			
Technical skills	Students will	learn fundam	ental par	adigms u	sed in compute	r	
	animation. Th	animation. They will learn to use mathematical models of					
	motions to come up with algorithmic solutions of problems of						
	the synthesis of	the synthesis of motions of virtual characters.					
Soft skills	Social competences (work in groups), communicative skills						
	(written and oral presentation)						
Contents	Fundamentals	Fundamentals of computer animation; kinematics;					
	representation	s of motions;	motion o	capturing	; motion editing	g;	
	motion synthe	motion synthesis; facial animations					
Prerequisites	Recommended	:					
	MA-INF 2111	- Foundatio	ns of Gra	phics			
	Teaching form	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	Written exam				(gra	ded)	
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)	
Forms of media							
	• Dietmar Jac	kel, Stephan	Neunreit	her, Fried	drich Wagner:		
	Methoden der Computeranimation, Springer 2006						
T:tonotuno	• Rick Parent:	Computer A	Animation	n: Algori	thms and		
Literature	Techniques, M	lorgan Kaufn	nan Publi	ishers 200	)2		
	• Frederic I. P	Parke , Keith	Waters:	Compute	er Facial Animat	tion.	
	A K Peters, L	td. 1996					

Module	Selected Topics in Signal Processing						
MA-INF 2203			1				
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. Dr. Michael Clausen					
Classification	Programme		Mode	Semes	ster		
	M. Sc. Compu		Optiona				
Technical skills	Learning adva				=		
	_		-		examples from		
	_	_	-	_	focus on music		
	_	•		_	nals and designi	_	
					ios. Mathemati		
	_	modelling of signal processing problems in practical applications.  Design and implementation of corresponding algorithms and					
		-			_	1	
	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,						
		_	_	,		nms,	
	general concep			-			
	_		_		ns, for example		
		•	is, signa	compres	sion, denoising,		
Duonoguisitos	source separat	1011.					
Prerequisites	none	C. C.	:	la /www.alv	Worldood [b]	CP	
D	Teaching forms Lecture	at Gro	up size	h/week	Workload[h] 60 T / 105 S	5.5	
Format	Exercises			$\frac{4}{2}$	30 T / 75 S	3.5	
			~			0.0	
	T = face-to-fa	ce teaching;	S = inde	pendent s		>	
Exam achievements	Written exam				,-	aded)	
Study achievements	Successful exe	rcise particip	ation		(not gra	aded)	
Forms of media	<b>T</b> .		1	1 11.			
	• Lecture script and selected research publications						
	• Hayes: Statistical Digital Signal Processing and Modelling,						
	John Wiley, 19		1.01	1.15			
Literature	· ·	nolakıs: Digi	tal Signa	I Processi	ing, Prentice Ha	all,	
	1996						
	• Klapuri, Davy: Signal Processing, Methods for Music						
	Transcription, Springer, 2006						

Module MA-INF 2204	Rendering T	echniqu	ies .	Ī			
Workload	Credit points	Duration		Freque	ncy		
180 h	6 CP	1 semest	ter	every y	ear		
Module	Prof. Dr. Reinl	hard Klei	n				
coordinator							
Lecturer(s)	Prof. Dr. Reinhard Klein						
Classification	Programme		]	Mode	Semest	ter	
Classification	M. Sc. Computer Science   Optional   2.						
Technical skills	Analytical form						
	and knowledge		-	_	•	_	
	of photorealistic	_			_		thms
	for the simulati	_					
	volume data set	ts. Self-de	epen	dent im	piementai	tion of the bas	ic .
Soft skills	algorithms.  Analytical prob	lom dose	rinti	on gron	tivity solt	f dopondont	
Soft Skills			_			_	
	solution of practical problems in the area of rendering, presentation of solution strategies and implementations, self-dependent literature research, collaboration abilities,						
	self-management						
Contents		Topics among others will be: models for the description of					
	optical materia					-	ıme
	visualization and rendering equation; algorithms and techniques						
	for the solution		_	_	-		
	equation; advar	nced meth	$\operatorname{nods}$	for pho	torealistic	image genera	tion
	in real-time app	olications	like	3D gan	nes. In ad	dition, results	from
	state of the art	research	will	be pres	ented.		
Prerequisites	Recommended:					_	
	Algorithms and					_	
	multidimension						ge in
	stochastics and		s, nu	merical	analysis a	and numerical	
	linear algebra,			•	1 / 1	337 11 1/11	CD
T	Teaching format Lecture	t	Gro	up size	h/week	Workload[h]	2.5
Format	Exercises				$\frac{2}{2}$	30 T / 45 S 30 T / 75 S	$\begin{vmatrix} 2.5 \\ 3.5 \end{vmatrix}$
		, 1:	a	. 1			0.0
D 11	T = face-to-fac	e teaching	g; S	= indep	endent st		1 1\
Exam achievements	Oral exam	_:	_:				$\frac{\operatorname{ded}}{\operatorname{ded}}$
Study achievements	Successful exerc	cise partic	стра	1011		(not gra	idea)
Forms of media	• L. Szirmay-K	alog: Mor	nto (	arla M	othods in	Clobal	
							reitz
	Illumination, Institute of Computer Graphics, Vienna University of Technology, Vienna.						
	URL: citeseer.ist.psu.edu/szirmay-kalos00montecarlo.html,						
Literature	1999/	D 1 =					
пиетаците	• P. Dutre, K. Bala, P. Bekaert: Advanced Global Illumination,						
	2nd ed., B&T,			Dl ·	11 D 1	Danda	
	• M. Pharr, G. Humphreys: Physically Based Rendering,						
	Elsevier, 2004						
	• J. Kautz, J. Lehtinen, PP. Sloan: Precomputed Radiance Transfer: Theory and Practice, Siggraph Course Notes, 2005						
	11ansier, 1 neo	ry and FI	acu	ce, bigg.	apii Coul	Lac INDICES, ZUU	,

Module	Geometry I	Processing	Ι						
MA-INF 2205									
Workload	Credit points	Duration	Freque	ncy					
180 h	6 CP	1 semeste	r every year						
Module	Prof. Dr. Rein	nhard Klein							
coordinator									
Lecturer(s)	Prof. Dr. Rein	Prof. Dr. Reinhard Klein							
Classification	Programme		Mode	Semes	ter				
Classification	M. Sc. Compu		Optiona						
Technical skills	Analytical form	mulation of	problems i	elated to	geometry				
		rocessing and knowledge of techniques and algorithms to							
		optimize, process and store geometry data. Especially, learning							
	of techniques t	_							
	digital models	_		impleme	nt current				
	geometry proc				0.1				
Soft skills		Analytical problem description, creativity, self-dependent							
	_	solution of practical problems in the area of mesh processing, presentation of solution strategies and implementations, self-dependent literature research, collaboration abilities,							
	_								
<u> </u>		self-management							
Contents		Topics among other will be: Methods for the generation of polygonal meshes (Laser scanning, registration and integration							
	1	`	<u> </u>	Point based representations,					
	_	_ ,		_		a d			
	Reconstruction mesh compress	_				IG			
	Mesh decimati			_	0,	ne.			
	coarse-to-fine								
	addition result		,						
Prerequisites	Recommended		01 0110 011	7 1 00 001 011	Will be present				
1 ToToquistos	Algorithms an		tures, bas	ic knowle	dge on				
	multidimension				_	ge in			
	stochastics and								
	linear algebra,			Ü					
	Teaching forms	at G	roup size	h/week	Workload[h]	CP			
Format	Lecture			2	30 T / 45 S	2.5			
	Exercises			2	30 T / 75 S	3.5			
	T = face-to-fa	ce teaching:	S = inder	endent st	udv	1			
Exam achievements	Oral exam	0,	1			ded)			
Study achievements	Successful exe	rcise partici	oation		(not gra				
Forms of media					, ,				
	• R. Scopigno	, C. Anduja	, M. Goes	ele, H. Le	ensch: 3D Data	ì			
	Acquistion, Eurographics Tutorial, 2002								
	• E. Grinspun	, M. Desbru	n (organiz	ers): Disc	rete Differenti	al			
Literature	_	Applied In	roduction	, Siggrapl	n Course Notes	5,			
	2006								
	· ·			_	Based on Triai	ngle			
	Meshes, Siggra	aph Course i	Notes, 200	6					

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

Module MA-INF 2207	Seminar Gr	aphics					
Workload	Credit points	Duration	1	Freque	ncy		
120 h	4 CP	1 semes	ter	every s	emester		
Module	Prof. Dr. Rein	hard Klei	in				
coordinator							
Lecturer(s)	Prof. Dr. Rein	nhard Klei	n				
Classification	Programme			Mode	Semest	ter	
Classification	M. Sc. Compu	iter Scienc	ce	Optiona	$1 \mid 2$ . or $3$	3.	
Technical skills	Ability to und	Ability to understand new research results presented in original					
	scientific pape	scientific papers.					
Soft skills	Ability to present and to critically discuss these results in the						
		framework of the corresponding area.					
Contents	Current confer	rence and	jour	nal pape	ers.		
Prerequisites	Recommended	:					
	Mathematical	backgroun	$\operatorname{ad}$ (:	multidim	nensional	analysis and li	near
	algebra, basic	numerical	me	thods)			
	Basic knowled	ge in Com	put	er Grapl	nics		
To 4	Teaching forms	at	Gro	oup size	h/week	Workload[h]	CP
Format	Seminar			10	2	30 T / 90 S	4
	T = face-to-fa	ce teachin	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							
Literature							

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

Module MA-INF 2209	Advanced T	opics i	n (	Comp	ıter Graphics I				
Workload	Credit points	Duratio		Frequ					
270 h Module	9 CP Prof. Dr. Reinha	1 semes	ster	every	year				
coordinator	Tron Br. Remma	1110111							
Lecturer(s)	Prof. Dr. Reinha	rd Klein							
Classification	Programme M. Sc. Computer	Programme Mode Semester  M. Sc. Computer Science Optional 2. or 3.							
Technical skills		Analytical formulation of problems related to geometry processing and							
Soft skills	analyze and store major algorithms volume data sets	rendering. Knowledge of techniques and algorithms to optimize, process, analyze and store geometry and reflectance data as well as knowledge of the major algorithms for the simulation of light distributions in 3D-scences and volume data sets. Self-dependent implementation of the basic algorithms. Based on the knowledge and skills acquired students should be able to							
	processing and re identify the maprocessing or ren discuss problem researchers from processing or ren and should have results, flexibility to communicate	read and judge current scientific literature in the area of geometry rocessing and rendering identify the major literature concerning a given problem in geometry rocessing or rendering and gain an overview of the current state of the art discuss problems concerning geometry processing or rendering with esearchers from different application fields present and propose different solutions and work in a team to solve a mesh rocessing or rendering problem and should have acquired key-competences like motivation to deliver esults, flexibility, scientific integrity, ability to adapt to changes and ability							
Contents	Topics among otl	Topics among other will be:							
	refinement  • mesh editing to  • optical materia  • light transport  • algorithms and  • advanced meth  In addition, resul	chniques l properti and rende technique ods for pl	es ar ering es for	s: denoised and light equations the soluents of the soluents o	sing, smoothing, decimation, sources	on			
Prerequisites					data structures, multidimens analysis and numerical linear				
	Teaching forma	at_	G	roup si	ze h/week Workload[l	n] CP			
Format	Lecture Exercises				4 60 T / 105 S 2 30 T / 75 S				
	T = face-to-face	teaching;	S =	indepen	dent study				
Exam achievements	Oral presentation					(graded)			
Study achievements Forms of media	Successful exercis	se particip	oatio	n	(not	graded)			
Literature	Processing, A K  M. Gross, HP.  2007)  R. Scopigno, C Eurographics Tut  E. Grinspun, M Applied Introduce  L. Szirmay-Kal of Computer Graciteseer.ist.psu.ec  P. Dutre, K. Ba B&T, 2006	Peters (7. Pfister, P. . Andujar torial, 200 I. Desbruttion, Sigg os: Monte phics, Vie lu/szirma ala, P. Be	Oktoint- c, M. 2 n (or graph e-Carenna y-kal	Goesele Goesele ganizers Course rlo Meth Univers os00mon t: Advan	raphics, Morgan Kaufmann ( , H. Lensch: 3D Data Acquist ): Discrete Differential Geome Notes, 2006 nods in Global Illumination, In ity of Technology, Vienna. Ul ntecarlo.html, 1999/ nced Global Illumination, 2nd	21. Juni sion, etry: An estitute RL: ed.,			
	• M. Pharr, G. H revised edition. (				Based Rendering, Elsevier, 2	nd			

Module MA-INF 2210	Seminar Co	mputer	Ar	nimatio	1		
Workload	Credit points	Duration	ı	Freque	ncy		
120 h	4 CP	1 semes	ter	every s	emester		
Module	Prof. Dr. And	reas Web	er				
coordinator							
Lecturer(s)	Prof. Dr. And	lreas Web	er				
Classification	Programme			Mode	Semest	ter	
Classification	M. Sc. Compu	M. Sc. Computer Science			1 2.		
Technical skills	Ability to und	Ability to understand new research results presented in original					
	scientific pape	scientific papers.					
Soft skills	Ability to pres	Ability to present and to critically discuss these results in the					
	framework of	framework of the corresponding area.					
Contents	Current confer	rence and	jou	rnal pape	ers.		
Prerequisites	Recommended	:					
	At least 1 of t	he followi	ng:				
	MA-INF 2202	– Compu	ter	Animatic	n		
	MA-INF 2311	– Lab Co	mp	uter Anir	nation		
To 4	Teaching forms	at	$\mathbf{Gr}$	oup size	h/week	Workload[h]	CP
Format	Seminar			10	2	30 T / 90 S	4
	T = face-to-fa	ce teachin	ıg; S	S = indep	endent st	udy	
Exam achievements	Oral presentat	ion, writt	en 1	report		(gra	ded)
Study achievements						(not gra	ded)
Forms of media							
Literature							

Module	Pattern Matching	and N	Machin	e Learr	ning for Aud	lio	
MA-INF 2212	Signal Processing						
Workload	Credit points Duration	Duration Frequency					
180 h	6 CP 1 seme	1 semester   every year					
Module	apl. Prof. Dr. Frank Kurth						
coordinator							
Lecturer(s)	apl. Prof. Dr. Frank &	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen					
Classification	Programme						
Classification	M. Sc. Computer Scien	nce O	ptional	2.			
Technical skills	• Introduction into sele	ected to	opics of	digital si	ignal processing	g;	
	• Applications in the f	• Applications in the field of Audio Signal Processing;					
	• Methods of Automat	Methods of Automatic Pattern Recognition					
Soft skills	Audio Signal Processing Applications; Extended programming						
	skills for signal processing applications; Capability to analyze;						
	Time management; Pro			,	_	ions	
		and solutions of others, and working in groups.					
Contents	The lecture is presente			,			
	motivated from the ap				•	re:	
	Windowed Fourier tran		,		,		
	Matching; Signal Class		n; Hidde	en Marko	ov Models;		
	Support Vector Machin	nes					
Prerequisites	none			. , .			
<b>-</b>	Teaching format	Grou	p size	h/week	Workload[h]	CP	
Format	Lecture			2	30 T / 45 S	2.5	
	Exercises			2	30 T / 75 S	3.5	
	T = face-to-face teaching	ing; S =	= indepe	endent st			
Exam achievements	Written exam				,,,	ded)	
Study achievements	Successful exercise par				(not gra	ded)	
Forms of media	Slides, Blackboard, Whiteboard						
Literature							

Module	Computer V	Vision II						
MA-INF 2213								
Workload	Credit points	Duration	Free	quenc	y			
180 h	6 CP	1 semest	ester every year					
Module	Prof. Dr. Jürgen Gall							
coordinator								
Lecturer(s)	Prof. Dr. Jürg	gen Gall						
Classification	Programme	Programme Mode Semester						
Classification	M. Sc. Compu	iter Scienc	e Optio	onal	2. or 3	3.		
Technical skills					0	thods and their	r	
	applications to							
Soft skills		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	applications in computer vision. For example, linear methods for						
	classification a	and regress	ion, boos	sting,	, randon	n forests, neura	al	
	networks, SVN	As, prototy	pe meth	ods,	nearest	neighbors,		
	_	,		<u> </u>		ed learning, ima	age	
	classification,	object dete	ection, ac	ction	recognit	tion, pose		
	estimation, fac	ce analysis	, tracking	g.				
Prerequisites	Required:							
	MA-INF 2201	- Comput	er Vision	1				
	Teaching forms	at	Group si	ze l	h/week	Workload[h]	CP	
Format	Lecture				3	45 T / 45 S	3	
	Exercises				1	15 T / 75 S	3	
	T = face-to-fa	ce teaching	g; S = in	depe	ndent st	udy		
Exam achievements	Oral exam					(gra	ded)	
Study achievements	Successful exe	rcise partic	ipation			(not gra	ded)	
Forms of media								
Literature								

Module MA-INF 2214	Computation	nal Phot	ography						
Workload	Credit points	Duration	Freque	ncy					
180 h	6 CP	1 semeste	r   every y	ear					
Module	Prof. Dr. Mat	thias Hullir							
coordinator									
Lecturer(s)	Prof. Dr. Mat	thias Hullir							
Cl:6+:	Programme		Mode	Semest	ter				
Classification	M. Sc. Compu	3.							
Technical skills	Foundations in	Foundations in optics and image sensors. Signal processing and							
	inverse proble	ns in imagi	ng. Color s	spaces and	d perception.				
	Image alignme	Image alignment and blending. High-dimensional representations of light transport (light fields, reflectance fields)							
	representation								
	reflectance dis	reflectance distributions). Computational illumination.							
Soft skills	• to read and	• to read and understand current literature in the field							
	• to implemen	$\bullet$ to implement standard computational photography techniques							
	• to propose and implement solutions to a given problem								
	• to follow goo	• to follow good scientific practice by planning, documenting							
	and communic	eating their	work						
Contents	• Image sensor	rs							
	• Optics								
	• Panoramas								
	• Light fields								
	• Signal proce	ssing and in	verse prob	lems					
	• Color, perce	ption and H	DR						
	• Reflectance :	fields and li	ght transpo	ort matric	ces				
Prerequisites	Required:								
	Basic knowled	ge in comp	ıter graphi	cs, data s	tructures,				
	multidimension	nal analysis	und linear	algebra,	numerical ana	lysis			
	and numerical	linear algel	cora, C++cora	or MATL	AB				
	Teaching forms	at C	roup size	h/week	Workload[h]	CP			
Format	Lecture			2	30 T / 45 S	2.5			
	Exercises			2	30  T / 75  S	3.5			
	T = face-to-fa	ce teaching	S = inder	endent st	udy				
Exam achievements	Oral exam	0.				ded)			
Study achievements	Successful exe	rcise partici	pation		(not gra				
Forms of media			•		, 9				
Literature									

Module MA-INF 2215	Seminar Dig	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	thias Hullin					
coordinator							
Lecturer(s)	Prof. Dr. Mat	thias Hullin					
Classification	Programme	Programme Mode Semester					
Classification	M. Sc. Computer Science   Optional   2.						
Technical skills	Ability to und	Ability to understand new research results presented in original					
	scientific papers.						
Soft skills	Ability to pres	ent and to c	ritically di	scuss the	se results in th	ie	
	framework of t	he correspon	nding area				
Contents	Current confer	ence and jou	rnal pape	rs			
Prerequisites	none						
Format	Teaching forma	at G	oup size	h/week	Workload[h]	CP	
rormat	Seminar		10	2	30 T / 90 S	4	
	T = face-to-face	ce teaching;	S = indep	endent st	udy		
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature							

Module	Lab Visual	Computin	$\mathbf{g}$					
MA-INF 2216								
Workload	Credit points	Duration	Freque	ency				
270 h	9 CP	1 semester	every	every year				
Module	Jun-Prof. Dr. Angela Yao							
coordinator								
Lecturer(s)	Jun-Prof. Dr.	Jun-Prof. Dr. Angela Yao						
Classification	Programme	Programme Mode Semester						
Classification	M. Sc. Compu	iter Science	Option	al 1-4.				
Technical skills	The students v	will carry ou	t a pract	ical task	(project) in the			
	context of computer vision, including test and documentation of							
	the implemented software/system.							
Soft skills	Ability to prop							
	prepare readable documentation of software; skills in							
	constructively	constructively collaborating with others in small teams over a						
		,		ssify ones	own results inte	o the		
	state-of-the-ar							
Contents					s and application	ns.		
	You will get a							
			_	_	s. At the end of	the		
	semester, you	-		, .				
			a repor	t describi	ng the method	and		
	experimental of	outcomes.						
Prerequisites	none				1			
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP		
2 02 2220	Lab		8	4	60 T / 210 S	9		
	T = face-to-fa	ce teaching;	S = inde	pendent s	study			
Exam achievements	Oral presentat	ion, written	report		(gra	ided)		
Study achievements					(not gra	ided)		
Forms of media								
Literature								

Workload Credit points Duration Frequency 180 h 6 CP 1 semester every year  Module Prof. Dr. Reinhard Klein coordinator						
Module Prof. Dr. Reinhard Klein coordinator						
coordinator						
Lecturer(s) Dr. Michael Weinmann						
Classification Programme Mode Semester						
Classification M. Sc. Computer Science Optional 1-4.						
Technical skills Students will be introduced to adapt and apply deep learning	g					
techniques to various applications in computer graphics.						
Soft skills Productive work in small teams, development and realization	n of					
individual approaches and solutions, critical reflection of						
competing methods, discussion in groups.						
Contents This course focuses on cutting-edge Deep Learning technique						
for computer graphics. After a brief review of CNNs the foc	us					
will be laid on autoencoders, generative models and the						
extension of these methods to graph- and manifold-structure	$_{\mathrm{ed}}$					
data. Applications discussed will include inverse problems in	1					
computer graphics and the synthesis of models including dat	ta					
completion and super-resolution.						
Prerequisites Recommended:						
The course will build upon the basics of machine learning as	well					
as fundamentals and basic architectures of neural networks.						
Therefore, it is highly recommended to have taken Deep						
Learning for Visual Recognition or a similar course as a						
prerequisite. Exercises will be a mix of theory and practical						
(Python).						
Teaching format Group size h/week Workload[h]	CP					
Format Lecture 2 30 T / 45 S	2.5					
Exercises 2 30 T / 75 S	3.5					
T = face-to-face teaching; $S = independent study$						
	ded)					
Study achievements Successful exercise participation (not gra						
Forms of media	(not graded)					
Literature No required text, supplemental readings will be given in class	ss.					

Module MA-INF 2218	Video Anal	ytics					
Workload	Credit points	Duration	Freque	ncy			
180 h	6 CP   1 semester   at least every 2 years						
Module	Prof. Dr. Jürg	gen Gall	-				
coordinator							
Lecturer(s)	Prof. Dr. Jürg	Prof. Dr. Jürgen Gall					
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	iter Science	Optional	l 2-4.			
Technical skills	Students will l	earn advance	ed techniq	ues for an	alyzing video o	lata.	
Soft skills	Productive wo	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, spatio	-temporal	action de	etection, video		
	context, spatio	o-temporal n	nodeling of	f humans	and objects,		
	anticipation, a segmentation.	affordance, vi	deo summ	narization	, semantic vide	eo	
Prerequisites	Required:						
Trerequisites	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	n and Me	edical In	mage Analys	sis		
MA-INF 2219		Г						
Workload	Credit points	Duration	Frequer	•				
120 h	4 CP	1 semeste						
Module	Prof. Dr. Tho	mas Schultz						
coordinator								
Lecturer(s)	Prof. Dr. Tho	mas Schultz						
Classification	Programme		Mode	Semest	ter			
Classification	M. Sc. Computer Science   Optional			$1 \mid 2$ .				
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	earch for rel	evant scien	tific litera	ature.			
Contents	Current confer	ence and jo	urnal pape	ers				
Prerequisites	Recommended	:						
	At least one of	f the followi	ng:					
	• MA-INF 222	22 – Visual I	Data Analy	vsis				
	• MA-INF 231		·		lysis in			
	Neuroscience	O	1					
TD 4	Teaching forms	at G	roup size	h/week	Workload[h]	CP		
Format	Seminar		10	2	30 T / 90 S	4		
	T = face-to-fa	ce teaching;	S = indep	endent st	udy			
Exam achievements	Oral presentat	ion, written	report		(gra	ded)		
Study achievements					(not gra	$\overline{\operatorname{ded}}$		
Forms of media								
Literature								

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

Module MA-INF 2221	Seminar Visual Computing						
Workload	Credit points	Duration	Freque	ıcy			
120 h	4 CP	1 semeste	er every s	emester			
Module	Jun-Prof. Dr.	Angela Yao	)				
coordinator							
Lecturer(s)	Jun-Prof. Dr. Angela Yao						
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	iter Science	Optional	$\lfloor 2 \rfloor$ 2. or 3	3.		
Technical skills	Ability to und	Ability to understand new research results presented in original					
	scientific papers.						
Soft skills		Ability to present and to critically discuss these results in the					
	framework of	framework of the corresponding area.					
Contents	Current confe	ence and jo	urnal pape	ers			
Prerequisites	Required:						
	At least 1 of t	he following	; <b>:</b>				
	MA-INF 2201	- Compute	r Vision				
	MA-INF 2217	- Advance	l Deep Lea	rning for	Graphics		
	MA-INF 2313	– Deep Lea	rning for V	isual Rec	cognition		
	MA-INF 4315	- Probabili	stic Graph	ical Mode	els		
Format	Teaching forms	at (	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, writter	report		(grad	$\overline{\text{ded}}$	
Study achievements					(not grad	$\overline{\mathrm{ded}}$	
Forms of media							
Literature							

Module MA-INF 2222	Visual Data	a Analysis						
Workload	Credit points	Duration	Freque	ency				
270 h	9 CP	1 semester	every	year				
Module	Prof. Dr. Tho	mas Schultz	1					
coordinator								
Lecturer(s)	Prof. Dr. Tho	omas Schultz,	Prof. D	r. Reinha	rd Klein			
Classification	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	iter Science	Option	al   1-4.				
Technical skills	Ability to desi	Ability to design, implement, and make proper use of systems						
	for visual data	analysis. Kn	owledge.	of algori	thms and			
	techniques for	the visualizat	tion of r	nulti-dime	ensional data,			
	graphs, as wel	l as scalar, ve	ctor, an	d tensor f	ields.			
Soft skills			,	-	ent solution of			
					analysis, critica	ıl		
	reflection on v							
	_	strategies and implementations, self management						
Contents	This class pro			-	-			
	algorithms for	data analysis	via inte	eractive v	isualization.			
	Specific topics	include perce	eptual p	rinciples,	luminance and			
	· ·	-			gration of visual			
					arning, as well a	as		
	specific algorit		_					
				-	tion, graphs, dir	rect		
	and indirect v							
	visualization,		sor field	visualiza	tion.			
Prerequisites	Recommended							
					nowledge in line			
	_				programming.			
	Teaching form	at Gro	up 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-fa	ce teaching; S	S = inde	pendent s	study			
Exam achievements	Written exam				(gra	ded)		
Study achievements	Successful exe	rcise participa	ation		(not gra	ded)		
Forms of media					•	-		
	A.C. Telea, Data Visualization: Principles and Practice. CRC Press, Second Edition, 2015							
Literature	M. Ward et al., Interactive Data Visualization: Foundations, Techniques, and Applications. CRC Press, 2010							
	T. Munzner, V 2015	Visualization A	Analysis	and Desi	gn, A K Peters	,		

Module MA-INF 2302	Physics-based Modelling								
Workload	Credit points	Duration	Freque	псу					
180 h	6 CP	1 semester							
Module	Prof. Dr. Andreas Weber								
coordinator									
Lecturer(s)	Prof. Dr. Andreas Weber								
Cl:64:	Programme		Mode	Semest	ter				
Classification	M. Sc. Compu	iter Science	Optiona	l 3.					
Technical skills	Students learn	Students learn the fundamental techniques of physics-based							
	modelling for o	computer gra	aphics and	l compute	er animation.	$\Gamma \mathrm{he}$			
	students shall	be able to c	noose appr	ropriate n	nathematical				
	models. Know	ing the algo-	rithmic tee	chniques a	and algorithmi	$\mathbf{c}$			
	issues, they sh	all be able t	o come up	with soft	tware solutions	for			
	specific proble	ms.							
Soft skills	Social compete	ences (work	in groups)	, commun	nicative skills				
	(written and o	(written and oral presentation)							
Contents	Initial value pr	roblems; par	ticle simul	ation; rigi	id body simula	tion;			
	multi-body-sys	,		,	- '	cloth			
	modelling; hai	r modelling;	physics-ba	ased moti	on synthesis				
Prerequisites	Recommended	:							
	MA-INF 2111		ns of Graj	phics					
	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				,,,	ded)			
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)			
Forms of media									
	• Dietmar Jackel, Stephan Neunreither, Friedrich Wagner:								
Literature	Methoden der	-	,						
nioci au ai c	• David M. Bo			_	,				
	Advanced co	ourse notes o	n physics-	based mo	delling				

Module	Rendering 7	Гесhniqu	ies	II					
MA-INF 2304									
Workload	Credit points	Duration		Freque	ncy				
180 h	6 CP	1 semes		every y	ear				
Module	Prof. Dr. Rein	nhard Klei	n						
coordinator									
Lecturer(s)	Prof. Dr. Rein	nhard Klei	n						
Classification	Programme			Mode	Semes	ter			
Classification	M. Sc. Compu	M. Sc. Computer Science   Optional   3.							
Technical skills	Analytical form	nulation of	of pr	oblems i	elated to	image based			
	rendering and	rendering and knowledge of advanced techniques in the field of							
	rendering. Kno	rendering. Knowledge of methods and models for the acquisition							
	and description	and description of light sources and optical material properties							
	_	for Computer Graphics applications. Knowledge of methods and							
	models for the	•			•	0			
	_	rendering techniques and digital photography. Self-dependent							
	implementation of the basic algorithms.								
Soft skills		Analytical problem description, creativity, self-dependent							
	solution of pra	-				_			
	rendering and								
	strategies and	_			_				
	research, colla								
Contents		Topics among others will be: advanced material acquisition and							
	modelling tech	- /	_		_	_			
	rendering; digi	- '			_	d scene model	ling		
	and rendering;		tiona	al photo	graphy				
Prerequisites	Recommended			1	. 1 1	1			
	Algorithms an					_			
	multidimension	· ·			,		ge m		
	stochastics and		s, nu	ımericai	anaiysis a	and numerical			
	linear algebra,			•	1 / 1	XX7 11 1[11]	CD		
D	Teaching forma	at	Gro	up size	h/week	Workload[h]   30 T / 45 S	2.5		
Format	Lecture Exercises				$\frac{2}{2}$	30 T / 45 S 30 T / 75 S	$\begin{vmatrix} 2.5 \\ 3.5 \end{vmatrix}$		
			~			'	3.5		
	T = face-to-face	ce teachin	g; S	= indep	endent st		1 1\		
Exam achievements	Oral exam					· -	$\frac{\mathrm{ded}}{\mathrm{ded}}$		
Study achievements	Successful exer	rcise parti	сіра	tion		(not gra	ided)		
Forms of media	- II D / T	olo M. O	05.1	. (		aliatic M	1a :		
	• H.P.A. Lenso	,		, ,	,		ıs ın		
	Computer Graphics, Siggraph Course Notes, 2005								
	• P. Debevec, E. Reinhard (organizers): High-Dynamic-Range								
Literature	<ul> <li>Imaging: Theory and Applications, Siggraph Course Notes, 2006</li> <li>N. Hoffman (organizer): Physically Based Reflectance for</li> </ul>								
		` -	,			tenectance for			
	Games, Siggra	-		,		tational			
	• R. Raskar, J		,		_	uaulonal			
	Photography, Siggraph Course Notes, 2006								

Module	Geometry Proces	sing II							
MA-INF 2305									
Workload	Credit points   Durat	1	ncy						
180 h	6 CP   1 sem	0 0	rear						
Module	Prof. Dr. Reinhard K	lein							
coordinator									
Lecturer(s)	Prof. Dr. Reinhard K	lein							
Classification	Programme	Mode	Semest	ter					
Classification	M. Sc. Computer Science	ence   Optiona	1 3.						
Technical skills	Analytical formulatio	n of problems	related to	geometry					
	processing, shape ana	lysis and shap	e retrieval	as well as					
	knowledge of advance	d algorithms a	nd technic	ques from these	e				
	fields. Self-dependent	fields. Self-dependent implementation of the algorithms.							
Soft skills	Analytical problem description, creativity, self-dependent								
	solution of practical p	roblems in the	area of in	mage based					
	rendering and digital	photography, p	presentatio	on of solution					
	strategies and implementations, self-dependent literature								
	research, collaboration	a abilities, self-	-managem	ent					
Contents	This class is focussed	This class is focussed on advanced topics in the field of geometry							
	processing. Students	will get familia	r with rec	cent developme	$_{ m ents}$				
	in the area of shape a	nalysis and sh	ape retrie	val. Topics am	ong				
	others will be		-	-					
	Parameterization of	surfaces							
	• Shape segmentation		oilarity						
	• Shape classification	_	-	leve					
	• Shape spaces and st			S V CO I					
Prerequisites	Recommended:	austicai shape	anarysis						
Trerequisites	Algorithms and data	structures has	ic knowle	dge on					
	multidimensional ana			_	re in				
	stochastics and statis	=			50 111				
	linear algebra, C++	ics, ildilicitear	anarysis						
	Teaching format	Group size	h/wook	Workload[h]	СР				
Format	Lecture	Group size	2	30 T / 45 S	2.5				
Tormat	Exercises		$\frac{2}{2}$	30 T / 75 S	$\begin{vmatrix} 2.5 \\ 3.5 \end{vmatrix}$				
			1	,	0.0				
	T = face-to-face teach	sing; S = indeptorus	pendent st		1 1				
Exam achievements	Oral exam			,,,	ded)				
Study achievements	Successful exercise pa	rticipation		(not gra	ded)				
Forms of media									
	• T. Funkhouser, M. Kazhdan, Shape-Based Retrieval and								
	Analysis of 3D-Models, Siggraph Course Notes, 2004								
	• L. Dryden, K.V. Mardia, Statistical Shape Analysis, John								
Literature	Wiley & Sons, 1998		_						
	• H. Krim, Jr, A. Yez	` ′							
	Shapes (Modeling an			Engineering and	l				
	Technology), Birkhäu	ser Boston, 20	06						

Module	Virtual Rea	lity						
MA-INF 2306								
Workload	Credit points	Duration	Frequer	ncy				
180 h	6 CP	1 semester	every y	ear				
Module	Prof. Dr. Rein	nhard Klein	'					
coordinator								
Lecturer(s)	Prof. Dr. Rein	nhard Klein						
C1 10 11	Programme		Mode	Semes	ter			
Classification	M. Sc. Compu	iter Science	Optional	l 3.				
Technical skills	Basic knowled	ge of hard- a	nd softwa	re compo	nents of currer	nt		
	VR-Systems, I	Broad knowle	edge of tra	acking-, c	ollision detecti	on-		
	and real-time	and real-time rendering algorithms, knowledge of methods to						
	integrate hapt	integrate haptic and sound, knowledge of GPU programming						
	with emphasis	with emphasis on special effect generation, ability to implement						
	components of	a VR-Syste	m					
Soft skills	Analytical pro	Analytical problem description, creativity, self-dependent						
	solution of pra	ctical proble	ms in the	area of V	irtual Reality,			
	presentation o	f solution str	ategies an	nd implem	nentations,			
	self-dependent	literature re	esearch, co	llaboratio	on abilities,			
	self-manageme	ent						
Contents	Scene Graphs, Stereo Seeing (HW, SW), Tracking (HW, SW),							
	Acceleration T	Cechniques (I	OD; Cull	ing), Coll	ision detection	.,		
	Haptics, Sound	d, Special eff	ects (GPU	J-Progran	nming)			
Prerequisites	Recommended	:						
	Mathematical	_	,		-			
	algebra, found	ations of nur	nerical me	ethods), g	good knowledge	e of		
	the foundation	s of comput	er graphic	S				
	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	ided)		
Study achievements	Successful exe	rcise particip	ation		(not gra			
Forms of media								
	• K. Stanney	(ed.): Handb	ook of Vi	rtual Env	ironments.			
	Lawrence Erlb	aum Associa	ites, 2002					
	• W. Sherman, A. Craig: Understanding Virtual Reality.							
T*4	Morgan Kaufman, 2002							
Literature	• D. Pape: Co	mmodity-Ba	sed Proje	ction VR.	, Siggraph Cou	ırse		
	Notes, 2006							
	• N. Tatarchuk (organizer): Advanced Real-Time Rendering							

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

Module MA-INF 2308	Lab Graphi	cs					
Workload	Credit points	Duration	]	Frequen	cy		
270 h	9 CP	1 semest	er	every se	mester		
Module	Prof. Dr. Reir	hard Klei	n				
coordinator							
Lecturer(s)	Prof. Dr. Reir	Prof. Dr. Reinhard Klein					
CI 10 II	Programme		N	Iode	Semes	ster	
Classification	M. Sc. Computer Science		еО	ptional	3.		
Technical skills	The students v	will carry o	out a	practica	al task (	(project) in the	
	context of geor	context of geometry processing, rendering, scientific visualization					ation
	or human com	or human computer interaction, including test and					
	documentation	documentation of the implemented software/system.					
Soft skills	Ability to prop	Ability to properly present and defend design decisions, to					
	prepare readal	ole docume	entati	ion of so	oftware;	skills in	
	constructively	collaborat	ing w	vith other	ers in sr	nall teams over	a
	longer period	of time; ab	ility 1	to classi	fy ones	own results into	the the
	state-of-the-ar	t of the re	sp. aı	rea			
Contents	Varying selected	ed topics of	elose t	to curre	nt resea	rch in the area	of
	0 0 2	0,	derin	ng, scien	tific visi	ualization or hu	man
	computer inter	raction.					
Prerequisites	none						
Format	Teaching forms	at (	Froup	size l	n/week	Workload[h]	CP
Tormat	Lab		8		4	60 T / 210 S	9
	T = face-to-fa	ce teaching	g; S =	= indepe	endent s	study	
Exam achievements	Oral presentat	ion, writte	en rep	port		(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	Semester			
Classification	M. Sc. Compu	iter Scienc	e Option	al 3.				
Technical skills	The students v	The students will carry out a practical task (project) in the						
	context of aud	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	entation of	software;	skills in			
	constructively	collaborat	ing with o	thers in si	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	sp. area.					
Contents								
Prerequisites	none							
Format	Teaching forms	at C	roup size	h/week	Workload[h]	CP		
rormat	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			<u> </u>		(not gra	$\overline{\operatorname{ded}}$		
Forms of media								
Literature								

Module	Advanced Topics	in Comput	er Granl	nics II			
MA-INF 2310			<b>-</b>				
Workload	Credit points   Durat	ion Freque	ncy				
270 h	9 CP 1 semester   every year						
Module	Prof. Dr. Reinhard Klein						
coordinator							
Lecturer(s)	Prof. Dr. Reinhard Kle	in					
C1 10 11	Programme	Mode	Semester				
Classification	M. Sc. Computer Scien	ce Optional	3.				
Technical skills	• apply methods of geo	metry and digi	tal appearai	nce processing to	real		
	world problems and des	sign and impler	nent novel a	application softwa	are		
	in these areas	in these areas					
	• apply methods of sha	pe segmentatio	n and shape	e similarity to no	vel		
	problems						
	• design novel shape re	trieval applicat	ions				
	• apply basic concepts	of statistical sh	ape analysis	s and shape space	es to		
	real world applications						
	• apply geometric and	radiometric cal	ibration alg	orithms to camer	a		
	based acquisition system	ns					
	• select and apply light	source and op	tical materia	al models for			
	computer graphics appl	ications					
	• incorporate basic ima	ge based algori	thms into re	endering applicat	ions		
Soft skills	Analytical problem des	cription, creative	vity, self-dep	pendent solution	of		
	practical problems, pres	sentation of sol	ution strate	gies and			
	implementations, self-d	ependent litera	ture researc	h, collaboration			
	abilities, self-manageme						
Contents	This class is focused on			-			
	digital appearance proc	~	_				
	developments in the are	-			al		
	acquisition and modeling	ng techniques. '	Topics amor	ng others will be			
	• Parameterization of s	urfaces					
	• Shape segmentation a	and shape simil	arity				
	• Shape classification a	nd content base	ed retrieval				
	• Shape spaces and sta						
	Optical material acqu	isition and mo	delling tech	niques			
	Algorithms and techn	iques of image	based rende	ering			
	• Digital photography	or image based	l scene mod	elling and render	ing		
	Basic computational	photography					
Prerequisites	none						
	Teaching format	Group size	h/week	Workload[h]	CP		
Format	Lecture		4	60 T / 105 S	5.5		
	Exercises		2	30 T / 75 S	3.5		
	T = face-to-face teaching	g: S = independent S = independent S	ndent study	•			
Exam achievements	Oral exam			(grae	$\overline{\text{ded}}$		
Study achievements	Successful exercise part	icipation		(not grad			
Forms of media	oror oror	- F		(2100 8100			
Literature							

Module	Lab Compu	ter Anima	ation				
MA-INF 2311							
Workload	Credit points	Duration	Freque	Frequency			
270 h	9 CP	1 semester	at leas	at least every year			
Module	Prof. Dr. And	reas Weber	'				
coordinator							
Lecturer(s)	Prof. Dr. And	Prof. Dr. Andreas Weber					
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	Optiona	al 3.				
Technical skills	The students v	will carry ou	t a pract	ical task (	(project) in the		
	context of com	nputer anima	ation, inc	luding tes	st and		
	documentation	locumentation of the implemented software/system.					
Soft skills	Ability to prop	Ability to properly present and defend design decisions, to					
		repare readable documentation of software; skills in					
			_		nall teams over		
	O 1	,	·	ssify ones	own results into	o the	
	state-of-the-ar						
Contents		-	se to cur	rent resea	rch in the area	of	
	computer anin	nation.					
Prerequisites	Recommended						
	At least 1 of the	he following					
	MA-INF 2202	- Computer	Animati	on			
	MA-INF 2302	- Physics-b	ased Mod	lelling			
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP	
rormat	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching;	S = inde	pendent s	study		
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature							

Module	Image Acqu	uisition and	l Analys	sis in N	euroscience				
MA-INF 2312									
Workload	Credit points	Duration	Frequer	ıcy					
180 h	6 CP	1 semester	at least	every 2	years				
Module	Prof. Dr. Thomas Schultz								
coordinator									
Lecturer(s)	Prof. Dr. Tho	omas Schultz							
Cl:64:	Programme		Mode	Semes	ter				
Classification	M. Sc. Compu	iter Science	Optional	l 1-4.					
Technical skills	Students will	learn about i	mage acqu	uisition a	nd analysis				
	pipelines whic	h are used in	neuroscie	ence. The	y will understa	and			
	algorithms for	image recon	struction,	artifact ı	removal, image				
	registration ar	nd segmentat	ion, as we	ll as relev	vant statistical	and			
	machine learn	ing technique	s. A part	icular foc	us will be on d	lata			
	from Magnetic	from Magnetic Resonance Imaging and on mathematical models for functional and diffusion MRI data.							
	for functional								
Soft skills	Productive wo	Productive work in small teams, self-dependent solution of							
					mage processin	<b>O</b> /			
	presentation o	f solution str	ategies an	ıd implen	nentations, self				
	management,	critical reflec	tion of co	nclusions	drawn from				
	complex exper	complex experimental data.							
Contents	This course co	overs the full	image for	mation ar	nd analysis pip	eline			
	that is typical	ly used in bio	medical s	studies, fr	om image				
	acquisition to	image proces	sing and	statistical	l analysis.				
Prerequisites	Recommended	l <b>:</b>							
	Mathematical	background	(calculus,	linear alg	gebra, statistic	s);			
	imperative pro	ogramming.							
	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	cudy				
Exam achievements	Oral exam	9,				ded)			
Study achievements	Successful exe	rcise particip	ation		(not gra				
Forms of media					, ,				
	• B. Preim, C	. Botha: Visi	ıal Compi	uting for	Medicine: The	ory,			
	• 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		-	J	Ü				
	• D.K. Jones: Diffusion MRI: Theory, Method, and								
	Applications,		•		•				

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

Module MA-INF 2314	Image Proc	essing, Sea	arch an	d Analy	sis I			
Workload	Credit points	Duration	Freque	ency				
270 h	9 CP 1 semester   every year							
Module	Prof. Dr. Chr.	istian Bauck						
coordinator			Ü					
Lecturer(s)	Prof. Dr. Chr.	istian Bauck	hage					
	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	ter Science	Options	al 2. or	3.			
Technical skills	Upon complet		_					
	processing         • implement a	<ul> <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> <li>design and implement their own algorithms for image</li> </ul>						
Soft skills	Students will I foundations of editing. They	Students will learn about the mathematical and algorithmic foundations of digital image processing and raster graphics editing. They will learn about the basic concepts and procedures in this area and to implement them on their own.						
Contents	<ul> <li>technical four photography</li> <li>mathematical coordinate single four frames of the four filters of the filters of</li></ul>	al representa ystems and of sforms and of and high past Gaussian filter ring and more lementations a methods be effects and ning	tions of coordinat convolutions filtering ring phologica of various	ligital ima e transfor ons g al operati us kinds o	ages emations ons of filters			
Prerequisites	none							
Format			$\begin{array}{l} \mathbf{oup\ size} \\ \mathbf{S} = \mathbf{inde} \end{array}$	h/week  4 2 pendent s	Workload[h] 60 T / 105 S 30 T / 75 S	5.5 3.5		
Exam achievements	Written exam	0,1	-1140	1		aded)		
Study achievements	Successful exe	rcise particir	ation		(not gra			
Forms of media	• lecture slides			nline	(110) 818	iaca)		
rorms of media					are made availa	ble		
Literature	<ul><li>Gonzales and</li><li>Jähne, "Digi</li></ul>		_	_	essing"			

Module MA-INF 2315	Seminar Co	mputatio	nal Pho	tograph	У		
Workload	Credit points	Credit points   Duration   Frequency					
270 h	9 CP	9 CP 1 semester every year					
Module	Prof. Dr. Mat	thias Hullin	'				
coordinator							
Lecturer(s)	Prof. Dr. Mat	Prof. Dr. Matthias Hullin					
Classification	Programme	Programme Mode Semester			ster		
Classification	M. Sc. Compu	iter Science	Option	al   2. or	3.		
Technical skills							
Soft skills							
Contents							
Prerequisites	none						
	Teaching forms	at Gı	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	Schriftliche Pr	üfung			(gra	ded)	
Study achievements	Erfolgreiche Ü	bungsteilna	hme		(not gra	ded)	
Forms of media							
Literature							

Module MA-INF 2316	Lab Digital	Materi	ial A	Appear	ance		
Workload	Credit points						
270 h Module		9 CP   1 semester   every year Prof. Dr. Matthias Hullin					
coordinator	Prof Dr Mat						
Lecturer(s)		Prof. Dr. Matthias Hullin					
Classification	Programme Mode M. Sc. Computer Science Options				Semester 2. or 3.		
Technical skills							
Soft skills							
Contents							
Prerequisites	none						
	Teaching forms	at	$\mathbf{Gro}$	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 teachi	ing; S	S = inde	pendent s	study	
Exam achievements	Schriftliche Pr	üfung				(gra	ded)
Study achievements	Erfolgreiche Ü	bungstei	lnah	me		(not gra	ded)
Forms of media							
Literature							

## 3 Information and Communication Management

MA-INF 3106	L2E2	6 CP	Privacy in Ubiquitous Computing	69
MA-INF 3201	L2E2	6 CP	Network Security	70
MA-INF 3202	L2E2	6 CP	Mobile Communication	71
MA-INF 3207	L2E2	6 CP	Advanced Logic Programming	72
MA-INF 3209	Sem2	4  CP	Seminar Selected Topics in Communication	
			Management	73
MA-INF 3215	Sem2	4  CP	Seminar Selected Topics in Malware Analysis and	
			Computer/Network Security	74
MA-INF 3216	Sem2	4  CP	Seminar Sensor Data Fusion	75
MA-INF 3218	Sem2	4  CP	Seminar Model-Driven Software Engineering	76
MA-INF 3219	Lab4	9 CP	Lab Model-Driven Software Engineering	77
MA-INF 3222	L4E2	9 CP	eSecurity	78
MA-INF 3227			Seminar Anonymity and Privacy on the Internet	<b>7</b> 9
MA-INF 3229			· ·	
MA-INF 3233	L2E2	6 CP	Advanced Sensor Data Fusion in Distributed Systems	81
MA-INF 3234	Lab4	9 CP	Lab Mobile Sensing Systems	82
MA-INF 3235	L2E2	6 CP	Usable Security and Privacy	83
MA-INF 3236	L2E2	6 CP	IT Security	84
MA-INF 3237	L2E2	6 CP	Array Signal and Multi-channel Processing	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	•	88
MA-INF 3310	L2E2	6 CP	Introduction to Sensor Data Fusion - Methods and	
			Applications	89
MA-INF 3311	L4E2	9 CP	Topics in Applied Cryptography	90
MA-INF 3312	Lab4	9 CP	Lab Sensor Data Fusion	91
MA-INF 3317			1	92
MA-INF 3318	Sem2	4 CP	Seminar Verification of Complex Systems	93
MA-INF 3319	Lab4	9 CP	Lab Usable Security and Privacy	94
MA-INF 3320	Lab4	9 CP	Lab Security in Distributed Systems	95
MA-INF 3321	Sem2	4 CP	Seminar Usable Security and Privacy	96
MA-INF 3322	L2E2	6 CP	Program Analysis and Binary Exploitation	
MA-INF 3323	Lab4	9 CP	Lab Fuzzing Bootcamp	
<b>MA-INF 3324</b>	Lab4	9 CP	Lab Design of Usable Security Mechanisms	99

Module MA-INF 3106	Privacy in U	Ubiquito	us (	Compu	ting		
Workload	Credit points	Duration		Frequer	ıcy		
180 h	6 CP	1 semest	er	every y	ear		
Module	JunProf. Dr.	Delphine	Chr	ristin			
coordinator							
Lecturer(s)	JunProf. Dr.	Delphine	Chr	ristin			
CI 10 II	Programme		I	Mode	Semes	ter	
Classification	M. Sc. Compu	iter Science	e (	Optional	1-3.		
Technical skills	Students gain	knowledge	abo	out key o	concepts	of privacy	
	(including lega	al and econ	omi	ical aspe	cts) and	field of ubiquit	ous
	computing. The	hey are abl	e to	identify	threats	to privacy in g	iven
	application sce	enarios. Th	iey l	learn fur	ndamenta	l techniques to	)
	protect users'	protect users' privacy. Relying on this background, they are able to understand and analyze cutting-edge solutions.					
	to understand						
Soft skills	Written and or	ritten and oral communicative skills, critical thinking and					
	problem solvin	roblem solving skills, teamwork, and time management					
Contents		atroduction to privacy and ubiquitous computing, privacy					
	threats, privac	hreats, privacy-enhancing systems in selected scenarios, usable					
	privacy						
Prerequisites	Recommended						
	MA-INF 3202	T			ion		
	Teaching forma	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-fa	ce teaching	g; S	= indep	endent st	cudy	
Exam achievements	Oral exam					(gra	ided)
Study achievements	Successful exer	rcise partic	ipat	tion		(not gra	ded)
Forms of media							
	John Krumm, 2009	Ubiquitou	s Co	omputing	g Fundan	nentals, Crc Pr	Inc,
	Alessandro Ac Digital Privacy Pubn, 2007	-			,		,
Literature	Mireille Hildel Madelin, Digit Personal Data	al Enlighte	enm	ent Year			
	Jan Camenisch Privacy and Id					<del>-</del> ·	
	Additional resolution	earch litera	tur	e will be	announc	ced during the	

Module	Network Se	curity						
MA-INF 3201								
Workload	Credit points	Duration	Freque	-				
180 h	6 CP	1 semester	every y	rear				
Module	Prof. Dr. Pete	er Martini						
coordinator								
Lecturer(s)	Prof. Dr. Pete	er Martini, D		bil. Robe	rt Koch			
Classification	Programme		Mode	Semes				
	M. Sc. Compu		Optiona					
Technical skills				-	etwork security	y.		
	This includes i							
	· · · · · · · · · · · · · · · · · · ·	-			evel of security			
					on to encryptic	n		
	techniques, the				nesses and a			
		scussion of upcoming new technologies.  heoretical exercises to support in-depth understanding of						
Soft skills		-	-	-	_			
	_	ecture topics and to stimulate discussions, practical exercises in						
			_		eted organisation			
	•	practical work and critical discussion of own and others' results.						
Contents		Threats and attack scenarios, cyber kill chain, organizational aspects, technical aspects: securing networks using different						
	_ ′	•	0		0			
	_		,		ection systems)	,		
	security protoc		_	-	· <del>-</del>			
		-	orks, secu	rity aspec	ts of IPv6, pri	vacy		
<b>.</b>	protection, end							
Prerequisites	Recommended		° 1     •	c				
		_			ication system	S		
	(e.g. BA-INF				-	lidaa		
	available)	leior Frogran	ime imor	шанк, ы	nglish lecture sl	naes		
	/	-		1- /1-	XX71-11[1-1	CD		
Format	Teaching forma Lecture	ii Gi	oup size	h/week	Workload[h]	2.5		
rormat	Exercises			$\begin{vmatrix} 2 \\ 2 \end{vmatrix}$	30 T / 75 S			
				I	•	0.0		
	T = face-to-fa	ce teaching;	S = indep	pendent st				
Exam achievements	Written exam					ded)		
Study achievements	Successful exer	rcise particip	ation		(not gra	ded)		
Forms of media	**************************************	1. T :	D	<u> </u>	Q •:			
	• William Stal							
	Principles and	`		, ·		•,		
Literature	_			thusen: N	etzwerksicherh	eit,		
	Spektrum Aka		_	, ,	·, A 1 1·			
	_	: Introduction	n to Con	iputer Se	curity, Addison	1		
	Wesley							

Module	Mobile Con	nmunicati	on				
MA-INF 3202	1,10,0110 0011						
Workload	Credit points	Duration	Frequer	ncy			
180 h	6 CP	1 semeste	r   every y	ear			
Module	Prof. Dr. Pete	er Martini					
coordinator							
Lecturer(s)	Prof. Dr. Pete	er Martini, l	Or. Matthi	as Frank			
Classification	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu		Optional				
Technical skills	Knowledge ab	out key con	cepts of mo	obile com	munication		
	including mob	ility manag	ement (bot	h technol	ogy independe	$\operatorname{nt}$	
	and technology	y dependent	), knowled	ge about	wireless		
	technologies ar			-			
	'	nd/or other network technologies, ability to evaluate and assess					
		cenarios with communication of mobile devices. In-depth					
	understanding		_	_	,		
	systems and no		· -		_		
	strengthening	-	esentation a	and discu	ssion of solution	ons	
	to current chal						
Soft skills	Theoretical ex			-	_		
	lecture topics			, -			
	teamwork to s		_		_		
	practical work						
Contents		Mobility Management in the Internet, Wireless Communication Basics, Wireless Networking Technologies, Cellular/Mobile					
	· · · · · · · · · · · · · · · · · · ·		_	· ,	,		
	Communicatio		•	data cor	nmunication),		
	Ad-hoc and Se		rks.				
Prerequisites	Recommended		of bosies of		ication and one	-	
	Bachelor level (e.g. BA-INF	_				.S	
	(German Bach					lidos	
	available) and					nues	
	Systems	/ OI WIM-IIVI	0100 11	incipies c	n Distributed		
	Teaching forms	at C	roup size	h/week	Workload[h]	CP	
Format	Lecture	10	Toup Size	2	30 T / 45 S	2.5	
Tormat	Exercises			2	30 T / 75 S	3.5	
	T = face-to-fa	co tonchina	S = indep		•	0.0	
Exam achievements	Oral exam	ce teaching,	5 — maep	endent st		ded)	
Study achievements	Successful exer	rcise nartici	nation		(not gra		
Forms of media	Buccessiui exci	reise partier	pation		(not gra	acaj	
Torms or media	• Jochen Schil	ler: Mobile	Communic	ations A	ddison-Wesley		
	2003	ici: Mobile	Communic	a010115, 11	dalson wesley,	,	
	• William Stal	llings: Wire	less Comm	unication	s and Network	ing.	
Literature	Prentice Hall,	_				01	
	• Further up-t		ature will b	e annour	nced in due cou	ırse	
	before the beg						
	before the beg	mning of th	e lecture				

Module MA-INF 3207	Advanced L	ogic Prog	ramming	3				
Workload	Credit points	Duration	Frequen	cy				
180 h	6 CP	1 semester	every year					
Module	Dr. Günter Kı	niesel						
coordinator								
Lecturer(s)	Dr. Günter Kı	niesel						
Cl:64:	Programme		Mode	Semes	ter			
Classification	M. Sc. Compu	iter Science	Optional	2. or 3	3.			
Technical skills	Ability to mas	ter advance	d logic pro	graming	techniques and	to		
	write clean bu	t highly effic	eient Prolog	g prograr	ns using these			
	techniques; con	mpetence in	problem s	olving us	ing the declara	tive		
	paradigm; con	paradigm; competence in using the non-logical features of						
	Prolog;							
Soft skills	Skills in writte	Skills in written and oral presentation of the solutions to						
	programming	programming assignments, collaboration with other students in						
	small teams	small teams						
Contents	Quick refresh	of logic prog	ramming b	asics and	d a Prolog			
	development e	nvironment,	searching,	understa	anding			
	backtracking a	and the cut,	context ar	guments,	difference lists	3,		
	data structure	s, constraint	programn	ning, met	a-programming	g,		
	meta-interpret	ers, partial	evaluation,	partial $\epsilon$	evaluation of			
	meta-interpret	ers, efficient	Prolog pro	ogrammiı	ng, logic progra	am		
	analysis.							
Prerequisites	Recommended	:						
	Good knowled	ge of the for	indations of	of Logic I	Programming			
	Teaching forms	at G	roup size	h/week	Workload[h]	CP		
Format	Lecture			2	30 T / 45 S	2.5		
	Exercises			2	30  T / 75  S	3.5		
	T = face-to-fa	ce teaching;	S = indep	endent st	udy			
Exam achievements	Written exam				(gra	ded)		
Study achievements	Successful exe	rcise particij	oation		(not gra	ded)		
Forms of media					·			
Literature	• L. Sterling, l Press.	E. Shapiro (	ed.): The A	Art of Pro	Prolog, Springer olog (2nd ed.)			
	• Richard O'K	Teefe: The C	raft of Pro	log, MIT	Press.			

Module	Seminar Se	Seminar Selected Topics in Communication							
MA-INF 3209	Managemer	$\mathbf{nt}$							
Workload	Credit points	Duration	Freque	ncy					
120 h	4 CP	1 semeste	er at least every year						
Module	Prof. Dr. Pete	er Martini							
coordinator									
Lecturer(s)	Prof. Dr. Pete	er Martini,	Prof. Dr. 1	Michael M	leier –				
Classification	Programme		Mode	Semes	ter				
Classification	M. Sc. Compu	iter Science	Optiona	$1 \mid 2$ . or $3$	3.				
Technical skills	Ability to und	Ability to understand new research results presented in original							
	scientific pape	rs.							
Soft skills	Ability to pres	Ability to present and to critically discuss these results in the							
	framework of								
Contents		rence and jo	ournal pape	ers, currer	nt standardizat	ion			
	drafts								
Prerequisites	Required:								
		•			ollowing lecture	s:			
	Principles of I		- ,		, .	>			
				nmunicati	ion (MA-INF3:	202),			
	IT Security (N	-		ı	T				
Format	Teaching forms	at (	Group size	h/week	Workload[h]	CP			
	Seminar		10	2	30 T / 90 S	$\mid 4$			
	T = face-to-fa	ce teaching	S = indep	oendent st	tudy				
Exam achievements	Oral presentat	tion, writter	report		(gra	ded)			
Study achievements					(not gra	ded)			
Forms of media									
Literature	The relevant la	iterature w	ll be annou	inced tow	rards the end o	f the			
Discrature	previous semes	$\operatorname{ster}$	previous semester						

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

Module MA-INF 3216	Seminar Sensor Data Fusion						
Workload	Credit points	Duration	Frequer	ncy			
120 h	4 CP	1 semester	semester every year				
Module	P.D. Dr. Wolf	gang Koch					
coordinator							
Lecturer(s)	P.D. Dr. Wolf	P.D. Dr. Wolfgang Koch					
CI :C .:	Programme		Mode	Semest	ter		
Classification	M. Sc. Compu	ter Science	Optional	$\lfloor 2.$			
Technical skills	Ability to und	erstand new	research i	esults pre	esented in origi	inal	
	scientific pape	rs.					
Soft skills	Ability to pres	sent and to c	ritically d	iscuss the	ese results in th	ne	
	framework of	the correspon	nding area	•			
Contents	Current confer	ence and jou	ırnal pape	ers			
Prerequisites	none						
TD 4	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
Format	Seminar		10	2	30 T / 90 S	4	
	T = face-to-fa	ce teaching;	S = indep	endent st	udy		
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
Literature	The relevant li seminar.	terature wil	be annou	nced at t	he beginning o	f the	

Module	Seminar Model-Dr	iven Softv	vare Engi	ineering		
MA-INF 3218						
Workload	Credit points Duratio		-			
120 h	4 CP 1 semes	ter   every y	ear			
Module	Dr. Günter Kniesel					
coordinator						
Lecturer(s)	Dr. Günter Kniesel		I			
Classification	Programme	Mode	Semester			
	M. Sc. Computer Science		2.	1 , 1,,, 1		
Technical skills	• Understand the differen	ices between	model drive	n and traditional		
	software development	, 1	1	C 1:00 4 1 1		
	• Describe the common f		eculiarities	of different model		
	driven development appro		,	1.0.		
	• Assess the suitability of					
	• Select appropriate tools			pment tasks		
Soft skills	• Explain the individual			_1_:11_		
Soft skills	• Refinement of scientific	_	-			
	• Mine for profound knowledge about a given subject					
	• Distill and communicate the summary of a computer science topic orally					
	• Evaluate the scientific integrity of a written summary					
	Use modern presentation software					
<u> </u>	Model driven software development concepts, tools and methods. In					
Contents	particular:					
	• Models, meta-models and meta-meta-models (General, MOF,					
	EMOF, ECORE)					
	• Text to model, model to model, model to text transformation					
	• Imperative versus declarative model transformation					
	Model-driven versus otl		-			
	Best practice and resea	rch issues in	model based	development		
Prerequisites	Recommended:					
	MA-INF 3207 – Advance					
Format	Teaching format	Group size	-	Workload[h] CP		
	Seminar	10	2	30 T / 90 S   4		
	T = face-to-face teaching	S = Independent	ndent study			
Exam achievements	Oral presentation, writter	1 report		(graded)		
Study achievements				(not graded)		
Forms of media	• Web page: https://sew	ki.iai.uni-bor	n.de/teachi	ng/seminars/start		
	• Slides (Powerpoint/PD	F)				
	• Mailing list for student	8				
	• "Model-Driven Software	-				
	Management". Thomas S					
Literature	• "Model-Driven Software					
Diverature	Book, Volker Gruhn (Eds	, .				
	• David S. Frankel: Mode		hitecture: A	applying MDA to		
	Enterprise Computing, Jo	ohn Wiley				

Module MA-INF 3219	Lab Model-	Driven S	oftware 1	Engineer	ring		
Workload	Credit points	Duration	Frequer	ıcv			
270 h	9 CP	1 semester	_	-			
Module	Dr. Günter Kni	iesel					
coordinator							
Lecturer(s)	Dr. Günter Kni	iesel					
Classification	Programme		Mode	Semester			
Classification	M. Sc. Comput		Optional	2.			
Technical skills	On successful co	ompletion of	this modul	e, students	should be able	to:	
	<ul> <li>Describe the process of model driven software development and support this description with personal experiences</li> <li>Connect model driven software development guidelines to copractical examples</li> <li>Be able to use one or several concrete MDSD tools and tech and explain their use to others</li> </ul>						
Soft skills	Students should	l be able to:					
	<ul> <li>Run a software project based on MDSD tools, techniques and methods</li> <li>Establish and iteratively evolve a project plan</li> <li>Collaborate in a team</li> </ul>						
	<ul> <li>Estimate the required time and other resources for given tasks</li> <li>Manage a software development project with time constraints</li> </ul>						
Contents						1 1	
Contents	Model driven software development methods are the key to a new lev of automation and tool integration in software development. Students will learn how MDSE concepts, tools an methods boost the development of general purpose and domain specific languages, leverage software						
D 11	quality analysis tools and foster automated software improvement.						
Prerequisites	Required:						
	MA-INF 3218 – Seminar Model-Driven Software Engineering The seminar lays the conceptual foundations for the work in the lab.						
Format	Teaching forms Lab	at (	Froup size 8	h/week	Workload[h] 60 T / 210 S	<b>CP</b>   9	
				_	'	9	
	T = face-to-face			dent study		1 1	
Exam achievements	Oral presentation	on, written r	eport		, , ,	aded)	
Study achievements Forms of media	• Web page bt	tna / /aavrilri	iai uni han	n do/tooghi	(not gr	aded)	
rorms of media	• Web page: https://sewiki.iai.uni-bonn.de/teaching/labs/start						
	<ul><li>Slides (Powerpoint/PDF)</li><li>Wiki as a shared knowledge base</li></ul>						
	Task Tracking System (Electronical or Physical)						
	• Shared repository for source code and development documents						
	Mailing list						
Literature	<ul> <li>Maning list</li> <li>"Model-Driven Software Development: Technology, Engineering, Management". Thomas Stahl, Markus Voelter, Wiley 2006.</li> <li>"Model-Driven Software Development". Sami Beydeda, Matthias Book, Volker Gruhn (Eds), ISBN 978-3-540-25613-7, Springer 2005</li> <li>David S. Frankel: Model Driven Architecture: Applying MDA to Enterprise Computing, John Wiley</li> </ul>					as 05 to	
	• Modellgetrieb Management. d			g, Technike	en, Engineering,		

Module	eSecurity						
MA-INF 3222							
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semeste	r   every	year			
Module	Prof. Dr. Joac	chim von zu	r Gathen				
coordinator							
Lecturer(s)	Prof. Dr. Joac	chim von zu	r Gathen	Dr. Micl	nael Nüsken		
Classification	Programme		Mode	Seme	ster		
Classification	_	M. Sc. Computer Science   Optional   2.					
Technical skills	Understanding	Understanding of security concerns and measures, and of the					
	interplay betw	interplay between computing power and security requirements in					
	the realm of re	the realm of real-world applications, in particular internet-based					
	ones. Mastery	ones. Mastery of advanced techniques for the design of					
	cryptosystems	cryptosystems and practical cryptanalysis.					
Soft skills	Oral presentation (in tutorial groups), written presentation (or					(of	
	exercise solution	ons), team	collaborat	ion in sol	ving homework		
	problems, criti	ical assessm	ent.				
Contents	First focus: se	curity on th	e interne	t and secu	re protocols.		
	Furthermore:	at least one	real worl	d applicat	tion, for exampl	e	
	• electronic he	ealth cards,					
	• electronic ele	,					
	• electronic pa	ssports.					
Prerequisites	Required:						
	MA-INF 1103	- Cryptogr	aphy				
	Teaching forms	at G	oup size	h/week	Workload[h]	CP	
Format	Lecture			4	60 T / 105 S	5.5	
	Exercises			2	30  T / 75  S	3.5	
	T = face-to-fa	ce teaching	S = inde	ependent s	study		
Exam achievements	Written exam				(gra	ded)	
Study achievements	Successful exe	rcise partici	pation		(not gra	ded)	
Forms of media							
Literature	Varying accord	ding to the	selected t	opic			

Module MA-INF 3227	Seminar An	onymity a	nd Priva	acy on t	the Internet			
Workload	Credit points	Duration	Frequer	ıcy				
120 h	4 CP	1 semester	every ye	ear				
Module	Prof. Dr. Björ	n Scheuerma	nn					
coordinator								
Lecturer(s)	Prof. Dr. Björ	Prof. Dr. Björn Scheuermann						
Classification	Programme		Mode	Semest	ter			
	M. Sc. Compu	ter Science	Optional	2.	2.			
Technical skills	Ability to unde	Ability to understand new research results presented in original						
	scientific paper	·s.						
Soft skills	Ability to prese	ent and to c	ritically di	scuss the	se results in th	ne		
	framework of t	he correspor	nding area					
Contents	Current conference	ence and jou	ırnal pape	rs.				
Prerequisites	none							
Format	Teaching forma	ıt Gı	oup size	h/week	Workload[h]	CP		
rormat	Seminar		10	2	30 T / 90 S	4		
	T = face-to-face	ce teaching;	S = indep	endent st	udy			
Exam achievements	Oral presentati	ion, written	report		(gra	ded)		
Study achievements					(not gra	$\overline{\operatorname{ded}}$		
Forms of media								
Literature								

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

Module	Advanced S	ensor Dat	a Fusion	in Dist	ributed	
MA-INF 3233	Systems					
Workload	Credit points	Duration	Freque	ıcy		
180 h	6 CP	1 semester	every y	ear		
Module	PD Dr. Wolfg	ang Koch				
coordinator						
Lecturer(s)	Dr. Felix Govaers					
Classification	Programme		Mode	Semes	ter	
Classification	M. Sc. Compu	iter Science	Optional	1 2.		
Technical skills	For challenging	g state estim	ation task	s, algorit	hms which enh	ance
	the situational	awareness b	y fusing s	ensor info	ormation are	
		•			ular to improve	
	_	-	_	_	nsors. This im	_
	_				hodologies such	
					d correlations of	
		_			nication links l	
	limited bandwidth, data reduction techniques have to be applied					
	at the sensor sites, that is local tracks have to be computed.					
	Once recieved at a fusion center (FC), the tracks then are fused					
	to reconstruct a global estimate. In this lecture, methodologies					
	to a achieve a distributed state estimation are considered.  Among these are tracklet fusion, the Bar-Shalom-Campo					
	Among these are tracklet fusion, the Bar-Shalom-Campo formula, the Federated Kalman Filter, naive fusion, the					
	distributed Kalman filter and the least squares estimate.					
Soft skills	Mathematical					
Soft Shifts	mathematical		_		actor of	
Contents					la, the Federat	ed
	tracklet fusion, the Bar-Shalom-Campo formula, the Federated Kalman Filter, naive fusion, the distributed Kalman filter and					
	the least squares estimate, Accumulated State Densities,					
	Decorrlated fu	sion, produc	t represen	tation		
Prerequisites	Recommended	:				
	At least 1 of the	he following:				
	BA-INF 137 –	Einführung	in die Ser	sordaten	fusion	
	MA-INF 3310	– Introducti	on to Sen	sor Data	Fusion - Metho	ods
	MA-INF 3310 – Introduction to Sensor Data Fusion - Methods and Applications					
	Teaching forms		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	udv	•
Exam achievements	Oral exam	<u> </u>	<b>r</b>			ded)
Study achievements	Successful exer	rcise particip	ation		(not gra	
Forms of media	Power Point				, 9	
	W. Koch: "Tra	acking and S	ensor Dat	a Fusion:	Methodologica	al
		_			_	
Literature	Framework and Selected Applications", Springer, 2014.  D. Hall, CY. Chong, J. Llinas, and M. L. II: "Distributed Data					
	Д. пан. ∪ ۲.	Chong. J. L	linas, and	M. L. II:	"Distributed I	Jata

Module	Lab Mobile	Sensing S	ystems				
MA-INF 3234							
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semester	every	year			
Module	JunProf. Dr.	Delphine Cl	nristin				
coordinator							
Lecturer(s)	JunProf. Dr.	Delphine Ch	nristin				
. ,	Programme	1	Mode	Seme	ster		
Classification	M. Sc. Compu	ter Science	Optiona	al 2. or	3.		
Technical skills	The students v				ctical solutions		
		_	_	_	ile sensing syste	ms,	
	including programming mobile devices and the corresponding infrastructure.						
Soft skills		Organized in small teams, the students will interact and					
	_				l analyze the des	sign	
	_		-	-	is analysis. The	0	
	_	_			ill be documente	ed in	
	a written repo		_				
Contents	Mobile sensing						
	_	, ,	0	•	sensors, such as		
	_						
	cameras, microphone, GPS, and accelerometers, are used to capture contextual information about the users and their						
	_				of this lab, the		
	_			_	challenging resea	rch	
	field by addres	-					
		_					
	• New mobile	_				_	
	_			-	ous contributions	8	
	• Incentive sch		ourage u	sers cont	ributions		
D	• Usable priva						
Prerequisites	Recommended MA-INF 3202		mmunica	ation			
	Teaching forma	at Gro	up size	h/week	Workload[h]	CP	
Format	Lab		8	h/week	Workload[h] 60 T / 210 S	9	
		1	'				
	T = face-to-fa			pendent s			
Evam achievements	Oral presentation, written report (graded)					1 1\	
Exam achievements	Orar presentat	ion, written	report				
Study achievements	Orar presentat	ion, written	report		(grad (not grad		
	_				(not grad	ded)	
Study achievements	Burke, J., Esta	rin, D., Hanse	en, M., I	,	(not grad	ded)	
Study achievements	Burke, J., Esta Reddy, S., Sriv	rin, D., Hanse	en, M., I	rticipator	(not grade, Ramanathan, ry sensing. In:	ded)	
Study achievements	Burke, J., Esta Reddy, S., Sriv Proceedings of	rin, D., Hanse vastava, M., 2 5 the 1st Wor	en, M., I	rticipator	(not grade, Ramanathan, ry sensing. In:	ded)	
Study achievements	Burke, J., Esta Reddy, S., Sriv	rin, D., Hanse vastava, M., 2 5 the 1st Wor	en, M., I	rticipator	(not grade, Ramanathan, ry sensing. In:	ded)	
Study achievements	Burke, J., Esti Reddy, S., Sriv Proceedings of (WSW), pp. 1	rin, D., Hanse vastava, M., 2 the 1st Wor -5.	en, M., I 2006. Pa kshop oi	rticipator n World-	(not grade, Ramanathan, ry sensing. In:	ded) N.,	
Study achievements	Burke, J., Esta Reddy, S., Sriv Proceedings of (WSW), pp. 1 Campbell, A.,	rin, D., Hanse vastava, M., 2 5 the 1st Wor -5. Eisenman, S	en, M., I 2006. Pa kshop or ., Lane,	rticipator n World- : N., Miluz	(not grade), Ramanathan, by sensing. In: Sensor-Web	N.,	
Study achievements	Burke, J., Esta Reddy, S., Sriv Proceedings of (WSW), pp. 1 Campbell, A., 2006. People-o	rin, D., Hanse vastava, M., 2 5 the 1st Wor -5. Eisenman, S centric urban	en, M., I 2006. Pa kshop or ., Lane, sensing.	rticipator n World- N., Miluz In: Proc	(not grade, Ramanathan, Ty sensing. In: Sensor-Web zo, E., Peterson,	N., R., and	
Study achievements	Burke, J., Esta Reddy, S., Sriv Proceedings of (WSW), pp. 1 Campbell, A., 2006. People-o	rin, D., Hanse vastava, M., 2 5 the 1st Wor -5. Eisenman, S centric urban	en, M., I 2006. Pa kshop or ., Lane, sensing.	rticipator n World- N., Miluz In: Proc	(not grader, Ramanathan, Pry sensing. In: Sensor-Web 220, E., Peterson, Reedings of the 21	N., R., and	
Study achievements Forms of media	Burke, J., Esta Reddy, S., Sriv Proceedings of (WSW), pp. 1 Campbell, A., 2006. People-o Annual Interna pp. 18–31.	rin, D., Hanse vastava, M., 2 5 the 1st Wor -5. Eisenman, S centric urban ational Wirel	en, M., I 2006. Pa kshop on ., Lane, sensing. ess Inter	rticipator n World- N., Miluz In: Proc enet Confe	(not grade), Ramanathan, by sensing. In: Sensor-Web zo, E., Peterson, eeedings of the 2derence (WICON)	, R., and ),	
Study achievements Forms of media	Burke, J., Estr Reddy, S., Sriv Proceedings of (WSW), pp. 1 Campbell, A., 2006. People-of Annual Internation pp. 18–31. Campbell, A.,	rin, D., Hanse vastava, M., 2 7 the 1st Wor -5. Eisenman, S centric urban ational Wirel Eisenman, S	en, M., I 2006. Pa kshop or ., Lane, sensing. ess Inter	rticipator n World- N., Miluz In: Proc enet Confe N., Miluz	(not grades), Ramanathan, by sensing. In: Sensor-Web  zo, E., Peterson, seedings of the 2derence (WICON)  zo, E., Peterson,	N., , R., and ), , R.,	
Study achievements Forms of media	Burke, J., Esta Reddy, S., Sriv Proceedings of (WSW), pp. 1 Campbell, A., 2006. People-of Annual Internation pp. 18–31. Campbell, A., Lu, H., Zheng,	cin, D., Hanse vastava, M., 2 the 1st Wor -5. Eisenman, S centric urban ational Wirel Eisenman, S X., Musoles	en, M., I 2006. Pa kshop or ., Lane, sensing. ess Inter ., Lane, i, M., Fo	rticipator n World- N., Miluz In: Proc enet Confe N., Miluz dor, K., 1	(not grade), Ramanathan, by sensing. In: Sensor-Web  zo, E., Peterson, eedings of the 2derence (WICON)  zo, E., Peterson, Eisenman, S., Al	N., , R., and ), , R.,	
Study achievements Forms of media	Burke, J., Esta Reddy, S., Sriv Proceedings of (WSW), pp. 1 Campbell, A., 2006. People-o Annual Interna pp. 18–31. Campbell, A., Lu, H., Zheng, G., 2008. The	rin, D., Hanse vastava, M., 2 the 1st Wor -5. Eisenman, S centric urban ational Wirel Eisenman, S X., Musoles rise of people	en, M., I 2006. Pa kshop or ., Lane, sensing. ess Inter ., Lane, i, M., Fo	rticipator n World- N., Miluz In: Proc enet Confe N., Miluz dor, K., 1	(not grades), Ramanathan, by sensing. In: Sensor-Web  zo, E., Peterson, seedings of the 2derence (WICON)  zo, E., Peterson,	N., , R., and ), , R.,	
Study achievements Forms of media	Burke, J., Esta Reddy, S., Sriv Proceedings of (WSW), pp. 1 Campbell, A., 2006. People-of Annual Internation pp. 18–31. Campbell, A., Lu, H., Zheng, G., 2008. The Computing 12	rin, D., Hanse vastava, M., 2 the 1st Wor -5. Eisenman, S centric urban ational Wirel Eisenman, S X., Musoles rise of people, 12-21.	en, M., I 2006. Pa kshop or ., Lane, sensing. ess Inter ., Lane, i, M., Fo	n World- N., Miluz In: Proc enet Confe N., Miluz dor, K., I sensing.	(not grade), Ramanathan, by sensing. In: Sensor-Web  zo, E., Peterson, seedings of the 2derence (WICON)  zo, E., Peterson, Eisenman, S., All IEEE Internet	N., , R., nd ), , R.,	
Study achievements Forms of media	Burke, J., Esta Reddy, S., Sriv Proceedings of (WSW), pp. 1 Campbell, A., 2006. People-of Annual Internation pp. 18–31. Campbell, A., Lu, H., Zheng, G., 2008. The Computing 12 Christin, D., F	rin, D., Hanse vastava, M., 2 the 1st Wor -5. Eisenman, S centric urban ational Wirel Eisenman, S X., Musoles rise of people , 12–21. Reinhardt, A.	en, M., I 2006. Pa kshop or ., Lane, sensing. ess Inter ., Lane, i, M., Fo e-centric	rticipator n World- N., Miluz In: Proc enet Confe N., Miluz dor, K., I sensing.	(not grade), Ramanathan, by sensing. In: Sensor-Web  zo, E., Peterson, seedings of the 2derence (WICON)  zo, E., Peterson, Eisenman, S., Alderence Internet  llick, M., A surv	N., R., nd ), R., hn,	
Study achievements Forms of media	Burke, J., Estr Reddy, S., Sriv Proceedings of (WSW), pp. 1 Campbell, A., 2006. People-of Annual Internation pp. 18–31. Campbell, A., Lu, H., Zheng, G., 2008. The Computing 12 Christin, D., Fon privacy in the	rin, D., Hanse vastava, M., 2 the 1st Wor -5. Eisenman, S centric urban ational Wirel Eisenman, S X., Musoles rise of people , 12–21. Reinhardt, A. mobile partic	en, M., I 2006. Pa kshop or ., Lane, sensing. ess Inter ., Lane, i, M., Fo e-centric , Kanher ipatory s	N., Miluz In: Proceed Confe N., Miluz dor, K., I sensing.	(not grade), Ramanathan, by sensing. In: Sensor-Web  zo, E., Peterson, seedings of the 2derence (WICON)  zo, E., Peterson, Eisenman, S., All IEEE Internet	N., , R., nd ), , R., hn,	

Module MA-INF 3235	Usable Security	and P	rivacy			
Workload	Credit points Du	ation	Freque	ncy		
180 h		emester	every y	rear		
Module	Prof. Dr. Matthew	Smith				
coordinator						
Lecturer(s)	Prof. Dr. Matthew	Smith				
Classification	Programme	١	Mode	Semest	ter	
Technical skills	M. Sc. Computer S		Optiona the use bil		oma of IT goalin	
Technical Skills	and privacy mecha usability of IT secu	Students will be familiar with usability problems of IT security and privacy mechanisms, understand methods for exploring usability of IT security and privacy mechanisms as well being able to design and execute usability studies.				
Soft skills	Working with sci	entific lit	erature			
	• Communication s	skills				
	• Team working skills					
Contents	The lecture on Usa aspects of human f and privacy. The lessecurity and privace international research	actors ar ecture in y as well	nd usabili cludes bo as a sele	ty in the oth the forection of o	context of secundations of us autting edge	ırity
	<ul> <li>Evaluation of usability issues of existing security &amp; privacy models or technology</li> <li>Design and evaluation of new usable security &amp; privacy technology</li> <li>Impact of organizational policy on security and privacy interaction</li> <li>Lessons learned from designing, deploying, managing or evaluating security &amp; privacy technologies</li> <li>Foundations of usable security &amp; privacy</li> <li>Methodology for usable security &amp; privacy research</li> <li>Ethical, psychological, sociological and economic aspects of</li> </ul>					
Prerequisites	security & privacy Required:	tecimolo	gies			
1 Terequisites	Knowledge about IT Security is advantageous but not mandatory.					
	Recommended:					
	At least 1 of the following:					
	BA-INF 138 – IT-Sicherheit					
	BA-INF 136 – Rea	ktive Sic	herheit			
	MA-INF 1103 – Cr	vptogran	ohv			
	MA-INF 3229 – La					
	Teaching format		oup size	h/week	Workload[h]	СР
Format	Lecture			2	30 T / 45 S	2.5
	Exercises			2	30 T / 75 S	3.5
	T = face-to-face te	aching S	S — inder		,	1
Exam achievements	Written exam	acming, s	, — muep	ondent St		ded)
Study achievements	Successful exercise	particips	ation		(not gra	
Forms of media	Successful exercise	Participe	~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~		(HOU SIA	<u>aca)</u>
Literature						

Module MA-INF 3236	IT Security					
Workload	Credit points	Duration	Frequer	ıcy		
180 h	6 CP	1 semester	every year			
Module	Prof. Dr. Mic	hael Meier				
coordinator						
Lecturer(s)	Prof. Dr. Mic	hael Meier				
CI :C ::	Programme		Mode	Semest	ter	
Classification	M. Sc. Compu	iter Science	Optional	1. or 2	2.	
Technical skills	Students are introduced to selected active research fields of IT security and gain deep knowledge of the research literature.  Students learn selected aspects of IT security. This includes risks and vulnerabilities of today's information technology as well as concepts to increase the level of IT security, their applications and their weaknesses.					
Soft skills	Theoretical exercises to support in-depth understanding of lecture topics and to stimulate discussions, practical exercises in teamwork to support time management, targeted organization of practical work and critical discussion of own and others' results.					
Contents	<ul><li>advanced ne attack detection</li><li>cryptograph</li><li>building aut</li><li>advanced ho</li></ul>	<ul> <li>security threats</li> <li>advanced network security: internet routing security, network attack detection, network information hiding</li> <li>cryptographic key management</li> <li>building automation security</li> <li>advanced host security</li> <li>security patterns</li> </ul>				
Prerequisites	Required: Fundamental l systems, netwo	_	the follow	ving areas	s: operating	
	Teaching forms		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 = inden	endent st	udv	-
Exam achievements	Written exam		P			ded)
Study achievements	Successful exe	rcise particip	ation		(not gra	
Forms of media					(1100 810	
2011ID OI IIICUIU						

Module	Array Signal and Multi-channel Processing					
MA-INF 3237						
Workload	Credit points	Duration	Frequen	cy		
180 h	6 CP	1 semester	every year			
Module	Prof. Dr. Wol	fgang Koch				
coordinator						
Lecturer(s)	Dr. Marc Oisp	Dr. Marc Oispuu				
Classification	Programme		Mode	Semes	ter	
Classification	M. Sc. Compu	iter Science	Optional	2. or 3	3.	
Technical skills	Localization of	Localization of multiple sources using passive sensors is a				
	fundamental t	fundamental task encountered in various fields like wireless				
	communication	n, radar, son	ar, and sei	smology.	In this lecture, a	
	unified framew	vork for elect	romagneti	c and acc	oustic signals and	
	signal processi	ng technique	es are prese	ented. Fu	irthermore, the	
	sensor calibrat	ion, directio	n finding,	and bear	ings-only	
	localization pr	oblem are co	nsidered.	Special a	pplications are	
	emphasized, li	ke small airb	orne array	s for unr	nanned aerial	
	vehicles (UAV	s).				
Soft skills	Mathematical	Mathematical derivation of algorithms, applications of				
	mathematical					
Contents	Estimation the	. ,	,		,	
	conventional b	eamforming	Multiple	Signal Cl	lassification	
	, , , , , , , , , , , , , , , , , , , ,			-	calization, Direct	
	Position Deter	mination (D	PD), $Appl$	ications		
Prerequisites	Recommended					
	Recommended			ons of Au	ıdio Signal	
	Processing" (N					
	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	cudy	
Exam achievements	Oral Exam				(graded)	
Study achievements	Successful exe	rcise particip	ation		(not graded)	
Forms of media	Power Point					
	H. L. van Tree	, -	·	_		
Literature	Detection, Est	imation, and	l Modulati	on Theor	ry. New York:	
	Wiley-Interscie	ence, 2002.				

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

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

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

Module	Introduction to Sensor Data Fusion - Methods and					$\overline{\mathbf{d}}$	
MA-INF 3310	Application	.S					
Workload	Credit points	Duration	ı	Frequen	cy		
180 h	6 CP	1 semes	ter	every ye	ear		
Module	P.D. Dr. Wolf	gang Kocl	1				
coordinator							
Lecturer(s)	P.D. Dr. Wolf	gang Kocl	1				
Classification	Programme			Mode	Semest	ter	
Classification	M. Sc. Compu			Optional	3.		
Technical skills		_				sheory of sensor	r
				-		ries on how to	
				_		analytical calcu	
	,					an filter is deri	
		_				ches to a wide	
		pectrum of applications will be shown. All algorithms will be notivated by examples from ongoing research projects,					
	_	_					
	industrial coop			impressi	ons of cu	rrent	
	demonstration	demonstration hardware.					
	Because of inh	Because of inherent practical issues, every sensor measures					
	certain proper	ties up to	an ei	rror. Th	is lecture	shows how to	
	model and ove	ercome thi	s erro	or by an	applicati	ion of theoretic	cal
	tools such as I	-					
	_					ons, maneuver	ing
	phases, and m						
Soft skills	Mathematical					ation of	
	mathematical						
Contents	Gaussian prob				,	,	
	0 2		,			ole Model Filter	r,
	Retrodiction,	Smoothing	g, Ma	neuver	Modeling		
Prerequisites	none		~		. , .		- CP
	Teaching forms	at	Grou	ıp 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	ıg; S	= indep	endent st		
Exam achievements	Oral exam						ded)
Study achievements	Successful exe	rcise parti	cipat	ion		(not gra	ded)
Forms of media							
						Methodologica	al
Literature	Framework an	d Selected	l App	olications	s", Spring	ger, 2014.	
Diveracule	Y. Bar-Shalon	n: "Estima	ation	with Ap	plication	s to Tracking a	and
	Navigation", V	Viley-Inter	rscien	ice, 2001			

Module	Topics in A	pplied Cry	ptogra	phy		
MA-INF 3311						
Workload	Credit points	Duration	Freque	ency		
270 h	9 CP	1 semester	every	year		
Module	Prof. Dr. Joac	chim von zur	Gathen			
coordinator						
Lecturer(s)	Prof. Dr. Joac	chim von zur	Gathen,	Dr. Mich	nael Nüsken	
Classification	Programme	Mode	Semes	ster		
Classification	M. Sc. Computer Science   Optional   3.			al 3.		
Technical skills	Gain deeper u	nderstanding	in a spe	cial area	of cryptography	7
	close to curren	t research.				
Soft skills	Oral presentat	Oral presentation (in tutorial groups), written presentation (of				
	exercise solution	exercise solutions), team collaboration in solving homework				
	problems, critical assessment.					
Contents	One varying, a	One varying, advanced topic related to current research in				
	applied crypto	graphy, e.g.				
	• mobile secur	ity, or				
	• design and a	nalysis of ha	sh functi	ons.		
Prerequisites	Required:					
	MA-INF 1103	- Cryptogra	phy			
	and one further	er course in o	rvptogra	phy like T	Γhe Art of	
	Cryptography			r J		
	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	Written exam				(gra	ded)
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)
Forms of media						
Literature						

Module MA-INF 3312	Lab Sensor Data Fusion					
Workload	Credit points	Duration	Freque	encv		
270 h	9 CP	1 semeste				
Module	P.D. Dr. Wolf	gang Koch	-	J = ===		
coordinator						
Lecturer(s)	P.D. Dr. Wolfgang Koch					
. ,	Programme Mode Semester					
Classification	M. Sc. Compu	iter Science	Option	al $3$ .		
Technical skills	The students will work together on a data fusion project using					
	various sensor hardware. Latest algorithms for fusing					
	information from several nodes will be implemented.					
Soft skills	The students shall work together in a team. Everyone is					
	responsible for	a specific p	art in the	e context	of a main goal.	
	Results will be	e exchanged	and integ	grated via	software interfa	aces.
Contents	Varying select	ed topics or	sensor d	ata fusion	l.	
Prerequisites	none					
TD 4	Teaching forms	at G	oup size	h/week	Workload[h]	CP
Format	Lab		8	4	60 T / 210 S	9
	T = face-to-fa	ce teaching	S = inde	ependent :	study	
Exam achievements	Oral presentat	ion, writter	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
T*4	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	4 CP   1 semester   every year				
Module	Prof. Dr. Michael Meier					
coordinator						
Lecturer(s)	Prof. Dr. Michael Meier, Prof. Dr. Peter Martini					
Classification	Programme		Mode	Semest	ter	
Classification	M. Sc. Compu	ter Science	Optional	2.	$\mid 2.$	
Technical skills	Ability to understand new research results presented in original					
	scientific paper	S.				
Soft skills	Ability to prese	ent and to c	ritically di	scuss the	se results in th	ne
	framework of t	he correspond	nding area	•		
Contents	Current confer	ence and jou	rnal pape	rs		
Prerequisites	none					
Format	Teaching forma	ıt G	oup size	h/week	Workload[h]	CP
rormat	Seminar		10	2	30 T / 90 S	4
	T = face-to-face	ce teaching;	S = indep	endent st	udy	
Exam achievements	Oral presentati	ion, written	report		(gra	ded)
Study achievements					(not gra	ded
Forms of media						
Literature						

Module MA-INF 3318	Seminar Ve	rification o	of Comp	lex Syst	tems		
Workload	Credit points	Duration	Frequer	ncv			
120 h	4 CP	1 semester	_	every 2	vears		
Module	JunProf. Dr.				) 56.25		
coordinator		9					
Lecturer(s)	JunProf. Dr.	Janis Voigt	länder				
	Programme	<u> </u>	Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optional				
Technical skills	Knowledge in	topics in the	_		and verifying		
	behaviour of c	omplex syste	ms such a	as softwar	e. Competenc	e to	
	mine for profo	und knowled	ge about a	a given su	ıbject, in parti	cular	
	acquiring and	studying original	ginal litera	ature. Un	derstanding		
	scientific publi	,			_		
	suitable preser						
	material. Pres	_			-	nd in	
	oral presentati	*	_				
	Ability to disc		_			nts,	
Soft skills		and to constructively deal with critical feedback by others.  Communication skills (preparing and presenting talks, using					
Soft Skills		(-		-			
	visual media, preparing a structured written document), social skills (motivating other students, ability to accept and formulate						
	,	_		-	=	diacc	
	criticism), self competences (time management with long-ranging deadlines, self-study, ability to analyse, creativity).						
Contents	Techniques for analyzing the correctness of complex systems						
	such as softwa						
	well as conside	eration of pra	actical too	ls. Specti	rum ranging fr	om	
	formal to semi	i-formal; posi	tioning of	techniqu	es within this		
	spectrum. Spe	ecific themes	of interest	t include:			
	Specification	formalisms	and langu	ages			
	• Decision pro			J			
	• Modelling de	esired proper	ties of a s	ystem			
	Model check	_					
	• Theorem pro	_					
	• Static (flow)			erpretatio	n		
	• Code analys	_					
	• Testing (app	*	,	_	/		
	• Runtime ver	*			itoring)		
	Applications	and pragma	tics of vei	rification			
	A selection of	topics will b	e made in	each sem	nester.		
Prerequisites	none	Т			T		
Format	Teaching forms	at G1	oup size	h/week	Workload[h]	CP	
	Seminar		10	2	30 T / 90 S	4	
	T = face-to-fa			endent st			
Exam achievements	Oral presentat	tion, written	report			aded)	
Study achievements					(not gra	aded)	
Forms of media							
Literature	The relevant l	iterature will	be annou	inced in t	ime.		

Module	Lab Usable Security and Privacy					
MA-INF 3319						
Workload	Credit points	Duration	Freque	ncy		
270 h	9 CP	1 semester	ester   every year			
Module	Prof. Dr. Mat	thew Smith				
coordinator						
Lecturer(s)	Prof. Dr. Mat	Prof. Dr. Matthew Smith				
Classification	Programme		Mode	Semes	ster	
Classification	M. Sc. Compu	iter Science	Optiona	d 2.		
Technical skills	The students will carry out a practical task (project) in the					
	context of usa	context of usable security and privacy, including user studies.				
Soft skills	Ability to create and defend a scientific user study					
Contents	Students have	a great degr	ee of free	dom to c	hose their own	
	topics within t	the context of	f human	aspects o	of security and	
	privacy.					
Prerequisites	Required:					
	MA-INF 3235	– Usable Se	curity and	d Privacy		
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP
rormat	Lab		8	4	60 T / 210 S	9
	T = face-to-fa	ce teaching;	S = indep	pendent s	study	
Exam achievements	Oral presentat	tion, written	report		(gra	ided)
Study achievements					(not gra	ded)
Forms of media						
Literature						

Module MA-INF 3320	Lab Security in Distributed Systems						
Workload	Credit points	Duration	Freque	ency			
270 h	9 CP	1 semeste	_	-			
Module	Prof. Dr. Mat	thew Smith		<u>-</u>			
coordinator							
Lecturer(s)	Prof. Dr. Mat	thew Smith					
CI 'C '	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	Option	al 2.				
Technical skills	The students	will carry ou	t a pract	ical task (	(project) in the		
		context of distributed security, including documentation of the implemented software/system.					
	Strong program	Strong programming skills required.					
Soft skills	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	tributed sys	tems, inc	luding 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 De</li> <li>Anomaly De</li> <li>Security Vis</li> </ul>	y S y arning for Se etection Systetection					
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					ided)	
Study achievements		,			(not gra		
Forms of media					( . 8 -		
Literature							

Module MA-INF 3321	Seminar Usable Security and Privacy					
Workload	Credit points	Duration	Frequen	ıcy		
120 h	4 CP	CP 1 semester   every year				
Module coordinator	Prof. Dr. Matthew Smith					
Lecturer(s)	Prof. Dr. Mat	Prof. Dr. Matthew Smith				
G1 10 11	Programme	Programme Mode Semester				
Classification	M. Sc. Compu	ter Science	Optional	2.		
Technical skills	· ·	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 t	the correspon	nding area			
Contents	Current confer	ence and jou	ırnal pape	rs		
Prerequisites	none					
Format	Teaching forms	at G	oup size	h/week	Workload[h]	CP
rormat	Seminar		10	2	30 T / 90 S	4
	T = face-to-fa	ce teaching;	S = indep	endent st	udy	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)
Study achievements					(not gra	ded)
Forms of media						
Literature						

Module MA-INF 3322	Program A	nalysis an	d Binary	Exploi	tation				
Workload	Credit points	Duration	Frequen	.cy					
180 h	6 CP	1 semester	every year	ar					
Module	Prof. Dr. Peter	Martini							
coordinator									
Lecturer(s)	Prof. Dr. Peter			dilla					
Classification	Programme		Mode	Semester					
	*	M. Sc. Computer Science   Optional   2. or 3.							
Technical skills	Static and dynamic program analysis, Exploitation (Stack-based Buffer Overflows, Format String Exploits, Heap Exploitation, Use-After-Free Exploits) and Countermeasures (Stack Cookies, NX, ASLR, RELRO)								
Soft skills	Vulnerability D	Vulnerability Discovery in Computer Programs, Application of taught Techniques, Working with Binary Representations, Assembly							
Contents	Our computers that the source those programs during the deve circumstances) arbitrary code of find well known	run a lot of code of those contain bugs lopment. The been exploited execution. In exploitable	elosed source e programs , mistakes ose bugs co by attacker this lecture ougs and he	that the probability of the control	rograms meanir lable. Naturally rogrammer mad certain may lead to be teach you how bit them.	e to			
	You will first learn about basic binary program analysis such as static and dynamic analysis. After this introduction we will talk about vulnerability discovery in general meaning that you will learn how to find exploitable bugs by yourself. Next we move on to basic stack-based buffer overflows and add mitigation techniques (stack cookies, NX, ASLR, RELRO,) as we progress and exploit them as well. After we finished the topic of stack-based buffer overflows we move on to more advanced topics such as format string exploits, heap exploitation, use-after-free exploits and others. The lecture ends with a practical fuzzing example and a vulnerability analysis of an open-source mail server.								
Prerequisites	Required:								
	Recommended: You should have an equivalent knowledge as presented in the lectures "Kommunikation in verteilten Systemen", "Systemnahe Programmierung" (bonus: "Malware Boot Camp" and "Reaktive Sicherheit") You should also have basic knowledge of the Linux operating system								
	(including Bash					CIII			
	Teaching forma	<u>′                                    </u>	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 or written (graded)				nalified students	)			
Study achievements	Successful exerc	ise participa	ion		(not gr	aded)			
Forms of media	Successiui exerc	no participa	.1011		(Hot gi	aucu)			
Literature	The relevant litelecture	erature will b	e announce	ed at the b	eginning of the				

Module	Lab Fuzzing Bootcamp						
MA-INF 3323							
Workload	Credit points	Duration	Freque	ncy			
270 h	9 CP	1 semester	every y	ear			
Module	Prof. Dr. Mat	Prof. Dr. Matthew Smith					
coordinator							
Lecturer(s)	Prof. Dr. Matthew Smith						
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Optiona	1 2. or	3.		
Technical skills	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 present	and defe	nd design	n decisions, to		
	prepare readal	ole document	ation of s	software;	skills in		
	constructively	collaboratin	g with oth	ners in sr	nall teams over	a	
	longer period	of time; abili	ty to class	sify ones	own results into	o the	
	state-of-the-ar	t of the resp	area				
Contents							
Prerequisites	none						
Format	Teaching forms	at Gro	oup size	h/week	Workload[h]	CP	
Format	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching;	S = indep	endent s	study		
Exam achievements	Oral presentat	ion, written	report		(gra	ided)	
Study achievements					(not gra	ded	
Forms of media							
Literature							

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

## 4 Intelligent Systems

MA-INF	4111	L2E2	6 CP	Intelligent Learning and Analysis Systems: Machine	101
				Learning	
MA-INF	4112	L2E2	6 CP	Intelligent Learning and Analysis Systems: Data Mining	
3.6.4. TXTD	4440	T 0F0	a CD	and Knowledge Discovery	
MA-INF	_			Cognitive Robotics	
MA-INF				Robot Learning	
MA-INF				Artificial Life	
MA-INF			6 CP	Autonomous Mobile Systems	
MA-INF				Technical Neural Nets	
MA-INF				Dynamically Reconfigurable Systems	
MA-INF				Seminar Vision Systems	109
MA-INF	4209	Sem2	4 CP	Seminar Principles of Data Mining and Learning	
				Algorithms	
MA-INF				*	
MA-INF				Seminar Cognitive Robotics	
MA-INF	4212	L2E2	6 CP	Data Science and Big Data	
MA-INF				Seminar Humanoid Robots	
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	Data Mining and Machine Learning Methods in	
				Bioinformatics	117
MA-INF	4217	Sem2	4 CP	Seminar Machine Learning Methods in the Life	
				Sciences	
MA-INF	4218	Lab4	9 CP	Lab Modeling and Simulation	119
MA-INF	4226	Lab4	9 CP	Lab Parallel Computing for Mobile Robotics	120
MA-INF	4228	L4E2	9 CP	Foundations of Data Science	121
MA-INF	4229	L4E2	9 CP	Pattern Recognition (1)	122
MA-INF	4302	L2E2	6 CP	Advanced Learning Systems	123
MA-INF	4303	L2E2	6 CP	Learning from Non-Standard Data	124
MA-INF	4304	Lab4	9 CP	Lab Cognitive Robotics	125
MA-INF	4306	Lab4	9 CP	Lab Development and Application of Data Mining and	
				Learning Systems	126
MA-INF	4307	Lab4	9 CP	Lab Field Programmable Gate Arrays	127
MA-INF	4308	Lab4	9 CP	Lab Vision Systems	128
MA-INF	4309	Lab4	9 CP	Lab Sensor Data Interpretation	129
MA-INF	4310	Lab4	9 CP	Lab Mobile Robots	130
MA-INF	4312	L2E2	6 CP	Semantic Data Web Technologies	131
MA-INF	4313	Sem2	4  CP	Seminar Semantic Data Web Technologies	132
MA-INF	4314	Lab4	9 CP	Lab Semantic Data Web Technologies	133
MA-INF	4318	Sem2	4 CP	Seminar Representation Learning for Big Data	
				Analytics	134
MA-INF	4319	L4E2	9 CP	Game AI	135
MA-INF	4320	Lab4	9 CP	Lab Representation Learning on Graphs	136
MA-INF	4321	Sem2	4 CP	Seminar Learning from Time Series	137
MA-INF	4323	L4E2	9 CP	Pattern Recognition (2)	

Module MA-INF 4111	Intelligent I Learning	Learning	g an	d Anal	ysis Sys	stems: Mach	ine		
Workload	Credit points	Duratio		Freque	ncy				
180 h	6 CP	1 seme		every y	rear				
Module	Prof. Dr. Stef	an Wrobe	el						
coordinator	D 0 D 0: 0	***	,						
Lecturer(s)	Prof. Dr. Stef	an Wrobe			T ~				
Classification	Programme			Mode	Semest				
ml:1 -l-:11-		M. Sc. Computer Science   Optional   1. or 2.  This module is one of two complementary modules in which							
Technical skills		students gain an understanding of the most important							
	_	paradigms and methods of intelligent learning systems as they							
	are used in da			_	_		$\circ_{j}$		
	behaviour (ma	-		•	_		erv		
	in databases).		_			_	-		
	predictive lear	ning fron	ı exa	mples ar	nd on age	nt learning, an	d		
	teaches the ma	ain classe	s of a	algorithn	ns for the	se tasks. At th	e		
	end of the mo				_	_			
	appropriate m		·		•	*			
	learning applic								
	results, and wi					-	r		
	further develop This module c	-	_		-	_			
	before or after				4112 and	can be taken			
Soft skills					en presen	ntation of solut	ions		
	discussions in	,			_				
	and formulate				_	•	1		
Contents	Types of learn	ing and a	naly	sis tasks	, most im	portant			
	non-parametri	c and par	rame	tric metl	nods for s	upervised learn	ning		
	(e.g., decision		,		*	•			
	neighbourhood								
	approaches), r	eintorcem	nent l	learning,	evaluatio	on and learning			
D ::4	theory.								
Prerequisites	Required: MA-INF 4102	- Intellig	ont I	Aarning	and Anal	veie Svetame h	26		
	not been passe	_		zcarining	and mai	ysis bystems ii	.as		
	Recommended								
	Prior knowled		habil	ity theor	v linear a	algebra artifici	al		
	intelligence, in					9	CO.		
	Teaching forms			oup size	h/week	Workload[h]	СР		
Format	Lecture				2	30 T / 45 S	2.5		
	Exercises				2	30 T / 75 S	3.5		
	T = face-to-fa	ce teachi	ng; S	= inder	endent st	udy			
Exam achievements	Written exam		J, -	T			ded)		
Study achievements	Successful exer	rcise part	icipa	tion		(not gra			
Forms of media	Lectures, exerc				es	· · · · · · · · · · · · · · · · · · ·			
	- Tom Mitchel	l, Machin	ie Le	arning, I	McGraw-H	Hill, 1997			
Literature	- Ian Witten, I 2000	Eibe Frar	nk, D	ata Min	ing, Morg	an Kauffmann	,		

Module MA-INF 4112	Intelligent I				stems: Data				
	Mining and								
Workload	Credit points	Duration	Freque	-					
180 h	6 CP Prof. Dr. Stefa	1 semester	every y	ear					
Module	Prof. Dr. Stell	an wrobei							
coordinator	Prof. Dr. Wro	11							
Lecturer(s)									
Classification		tor Sajonas	Mode Optiona						
Technical skills	-	M. Sc. Computer Science   Optional   1. or 2.  This module is one of two complementary modules in which							
Technical skins	students gain a		_	-					
	paradigms and		_		_	οv			
	are used in dat		_	_		Cy			
	behaviour (ma	·	,	-		erv			
	in databases).		<u> </u>	<u> </u>					
	pattern discove								
	algorithms for	·							
	module, studer	*		_					
	methods and s		_	_					
	applications ar			-		nd			
	will know where to start whenever adaptation or further								
	development of algorithms and systems is necessary. This								
	module complements MA-INF 4111 and can be taken before or								
	after that mod	lule.							
Soft skills	Communicative skills (oral and written presentation of solutions,								
	discussions in small teams), self competences (ability to accept								
	and formulate								
Contents	Types of learning and analysis tasks, scalability techniques,								
	descriptive data mining methods, association rules, subgroups,								
	clustering, pre- and postprocessing, data storage (data								
	warehouses, OLAP), special data types (spatial, network, text, multimedia data), interactive and visual systems.								
D ::		ta), interacti	ve and vi	suai syste	ams.				
Prerequisites	Required:	Intelligent	Loorning	and Anal	vaia Svatoma b	D.C.			
	MA-INF 4102 - Intelligent Learning and Analysis Systems has								
	not been passed.								
	Recommended: Prior knowleds		ility theor	u linoar s	olgobro ortifici	al.			
	intelligence, in	_	-	- :		.aı			
	Teaching forma		oup size	h/week	Workload[h]	СР			
Format	Lecture	it Gi	oup size	2	30 T / 45 S	2.5			
rormat	Exercises			$\frac{2}{2}$	30 T / 75 S	$\begin{vmatrix} 2.5 \\ 3.5 \end{vmatrix}$			
		1	C · 1		,	0.0			
T. 11	T = face-to-face	ce teacning;	s = indep	endent st		1 1\			
Exam achievements	Written exam	noido martici	ation			$\frac{\operatorname{ded}}{\operatorname{ded}}$			
Study achievements	Successful exer				(not gra	aea)			
Forms of media	Lectures, exerc	<u> </u>			on Kouffraar-				
	- Ian Witten, I 2000	ende Frank, .	Data WIIII	ing, morg	an <b>r</b> aummann	,			
Literature		v. 6. 1 1	, -						
	- Jiawei Han, Micheline Kamber, Data Mining: Concepts and								
	Techniques, Morgan Kaufmann, 2000								

Module MA-INF 4113	Cognitive F	Robotics							
	C	D4:	Th						
Workload	Credit points 6 CP	Duration 1 gamagter	Freque	-					
180 h	0 0								
Module	Prof. Dr. Svei	Prof. Dr. Sven Behnke							
coordinator	D C D C	D 1 1							
Lecturer(s)		Prof. Dr. Sven Behnke							
Classification	Programme	, G:	Mode	Semest					
	M. Sc. Compu		Optiona	I					
Technical skills					es of the intellig	gent			
	systems track.			_	-				
	· · · · · · · · · · · · · · · · · · ·			J, .	perception, and	d			
	action-plannin	g in complex	environn	nents.					
	This module complements MA-INF 4114 and can be taken								
	before or after	before or after that module.							
Soft skills	Communicativ	Communicative skills (oral and written presentation of solutions							
	discussions in	small teams	, self com	petences	(ability to acce	ept			
	and formulate criticism, ability to analyze problems)								
Contents	Probabilistic a	approaches to	state est	imation (	Bayes Filters,				
	Kalman Filter, Particle Filter), motion models, sensor models,								
	self-localization, mapping with known poses, simultaneous								
	mapping and localization (SLAM), iterated closest-point								
	matching, pat	h planning, j	olace- and	person re	ecognition, obje	$\operatorname{ect}$			
	recognition.								
Prerequisites	Required:								
	MA-INF 4101	- Theory of	Sensorimo	otor Syste	ems has not bee	en			
	passed.								
	Teaching forms	at G	roup size	h/week	Workload[h]	CP			
Format	Lecture			2	30 T / 45 S	2.5			
	Exercises			2	30 T / 75 S	3.5			
	T = face-to-face teaching; S = independent study								
Exam achievements	Written exam					ded)			
Study achievements	Successful exe	rcise particip	ation		(not gra	ded)			
Forms of media									
	• S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics.								
	MIT Press, 2005.								
T:4	• B. Siciliano,	O. Khatib (	Eds.): Spi	ringer Hai	ndbook of				
Literature	Robotics, 2008		. –						
	• R. Szeliski:	Computer V	ision: Alg	orithms a	nd Application	ıs,			
	Springer 2010.								

Module	Robot Lear	ning							
MA-INF 4114	G 11.	ъ							
Workload	Credit points	Duration	Freque	-					
180 h	6 CP	1 semester	r   every year						
Module	Prof. Dr. Sver	n Behnke							
coordinator									
Lecturer(s)	Prof. Dr. Sven Behnke, Dr. Nils Goerke								
Classification	Programme	~ .	Mode	Semest					
	M. Sc. Compu		Optiona						
Technical skills				-	es of the intellig	_			
		systems track. Creating autonomous robots that can learn to							
	assist humans in situations of daily life is a fascinating challenge								
		for machine learning. The lecture covers key ingredients for a							
	general robot l		_						
	performance in	,			· · · · · · · · · · · · · · · · · · ·	rning			
		models for control, learning motor primitives, learning from							
	demonstrations and imitation learning, and interactive learning.								
	This module complements MA-INF 4113 and can be taken								
	before or after that module.								
Soft skills	Communicativ	e skills (oral	and writt	ten presen	tation of solut	ions,			
	discussions in	small teams)	, self com	petences	(ability to acce	$\operatorname{ept}$			
	and formulate	criticism, ab	ility to ar	nalyze pro	blems)				
Contents	Reinforcement	learning, M	arkov dec	ision proc	esses, dynamic	;			
	programming,	Monte Carlo	methods	s, tempora	al-difference				
	methods, func	tion approxi	nation, lie	ear quadr	atic regulation	,			
	differential dyn	namic progra	mming, p	artially o	bservable MDI	$P_{\mathbf{S}}$ ,			
	policy gradien	t methods, in	verse rein	nforcemen	t learning,				
	imitation learn	ning, learning	kinemat	ic models	, perceiving an	d			
	handling of ob	jects.							
Prerequisites	none								
	Teaching forms	at G	oup size	h/week	Workload[h]	CP			
Format	Lecture			2	30 T / 45 S	2.5			
	Exercises			2	30 T / 75 S	3.5			
	T = face-to-fa	ce teaching:	S = index	endent st	udv				
Exam achievements	Oral exam	- 01	r			ded)			
Study achievements	Successful exer	rcise particip	ation		(not gra				
Forms of media					, 5				
	• R. Sutton ar	nd A. Barto:	Reinforce	ement Lea	rning, MIT-Pr	ess,			
	1998.				<i>5</i> /	,			
Literature	• O. Sigaud and J. Peters (Eds.): From Motor Learning to								
	Interaction Learning in Robots. Springer, 2010.								

Module	Artificial Li	fe							
MA-INF 4201			1						
Workload	Credit points	Duration	Freque	-					
180 h	6 CP	1 semester	every y	rear					
Module	Prof. Dr. Sver	n Behnke							
coordinator									
Lecturer(s)		Prof. Dr. Sven Behnke, Dr. Nils Goerke							
Classification	Programme	~ .	Mode	Semest	ter				
	M. Sc. Computer Science   Optional   1-3.  Detailed understanding of the most important approaches and								
Technical skills		0		•	* *				
	principles of a		_		_	the			
		current state of research in the field of artificial life							
Soft skills	Capability to i	·			,				
	present and de								
	front of a grou	=	. Critica.	l discussion	on of the result	s of			
	the homework					-			
Contents	Foundations of artificial life, cellular automata, Conway's "Ga of Life"; mechanisms for structural development; foundations								
	· · · · · · · · · · · · · · · · · · ·			-	,	s of			
	nonlinear dyna		,						
	evolutionary m	_							
	learning, artifi		-	_					
	self-organising		_	-	, and swarm				
D 11:	intelligence, pa	article swarm	optimiza	ttion.					
Prerequisites	none			. , .					
	Teaching forma	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 teaching; S	S = indep	endent st					
Exam achievements	Written exam				(gra	ided)			
Study achievements	Successful exer				(not gra				
Forms of media	Pencil and par	· –				ercise			
	group, implem		nall prog	rams, use	e of simple				
	simulation too								
	• Christoph A				*				
	Electronic Library of Science, TELOS, Springer-Verlag								
	• Eric Bonabeau, Marco Dorigo, Guy Theraulaz: Swarm								
	Intelligence: From Natural to Artificial Systems, Oxford								
Literature	University Pre	ss, Santa Fe I	Institute	Studies in	n the Science o	$\mathbf{f}$			
Literature	Complexity.								
	• Andrzej Osy		·	_	_				
	Multicriteria I				-				
	Soft Computin	ng, Physica-Ve	erlag, A	Springer-	Verlag Compar	ıy,			
	Heidelberg								

Module	Autonomous	Mobile	Systems					
MA-INF 4203								
Workload		Duration	Freque	ncy				
180 h	6 CP	1 semeste	every y	ear				
Module	Prof. Dr. Sven	Behnke						
coordinator								
Lecturer(s)		Dr. Dirk Schulz, Prof. Dr. Sven Behnke						
Classification	Programme		Mode	Semest	ter			
Classification	*	M. Sc. Computer Science   Optional   2.						
Technical skills		Profound knowledge of development and test regarding structure						
		and function of learning, autonomous, mobile systems;						
	Knowledge of t	_						
	requirements fo	_		-	_	fic		
	applications and							
Soft skills	The students w	-						
	autonomous mo	-	-	_		-		
	what part of th							
		of the art developments. The student will learn how to plan and implement a software project in small working groups.						
<b>C</b> 1 1	Requirement a so							
Contents	systems, e.g. fo							
	SLAM-methods	-	· ,		· ,			
	methods for act	-	_	_		າຕ		
	paradigms for s	_	_	1115011 01 (		<del>-</del> 8		
Prerequisites	Recommended:	promis app	110000101101					
<b>1</b>	all of the follow	ing:						
	MA-INF 4101 -	_	Sensorim	otor Syste	ems			
	MA-INF 4113 -	-		v				
	Teaching format		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					ded)		
Study achievements	Successful exerc	cise partici	oation		(not gra			
Forms of media					, –			
	• J. Buchli: Mobile Robots: Moving Intelligence, Published by							
	Advanced Robo	otic System	s and Pro	Literatur	Verlag			
Literature	• Sebastian Th		_	d, Dieter	Fox: Probabili	$\operatorname{stic}$		
Diterature	Robotics, MIT							
	Howie Choset	t et al.: Pri	nciples of	Robot Mo	otion, MIT-Pre	ess,		
	2005							

Module MA-INF 4204	Technical N	Technical Neural Nets							
Workload	Credit points	Duration	Freque	ncy					
180 h	6 CP	1 semeste	r every y	ear					
Module	Prof. Dr. Joac	chim K. Anl	auf						
coordinator									
Lecturer(s)	Prof. Dr. Joac	chim K. Anl	auf, Dr. N	ils Goerk	e				
CI 10 II	Programme		Mode	Semes	ter				
Classification	M. Sc. Computer Science   Optional   1-3.								
Technical skills	Detailed know	Detailed knowledge of the most important neural network							
		approaches and learning algorithms and its fields of application.							
	Knowledge and understanding of technical neural networks as								
	Non-Von Neumann computer architectures similar to concepts of								
		brain functions at different stages of development							
Soft skills	The students v	The students will be capable to propose several paradigms from							
	neural network	neural networks that are capable to solve a given task. They can							
	discuss the pro	discuss the pro and cons with respect to efficency and risk. The							
	will be capable	will be capable to plan and implement a small project with state							
	_	of the art neural network solutions.							
Contents	Multi-layer pe	rceptron, ra	dial-basis	function r	nets, Hopfield r	iets,			
	self organizing	maps (Koh	onen), ada	ptive reso	onance theory,	,			
	learning vector	r quantizati	on, recurre	ent networ	·ks,				
	_	_			ning, Q-learning	g,			
	support vector								
			_	_	on approximati	ion,			
	prediction, qua	ality control	, image pr	ocessing,	speech process	ing,			
	action plannin	=				Ο,			
	Implementatio	n of neural	networks i	n hardwa	re and software	e:			
	tools, simulate	ors, analog a	nd digital	neural ha	rdware.				
Prerequisites	none								
	Teaching forms	at G	roup size	h/week	Workload[h]	CP			
Format	Lecture			2	30 T / 45 S	2.5			
	Exercises			2	30 T / 75 S	3.5			
	T = face-to-fa	ce teaching:	S = inder	ı sendent st		ı			
Exam achievements	Written exam	ee waaming,		Jendent Be		ded)			
Study achievements	Successful exer	rcise nartici	nation		(not gra				
Forms of media	Successiai exe	reise partier	Jan 1011		(not gra	acaj			
rorms or media	• Christopher	M Richon:	Noural No	atworks fo	r Pattern				
	_	-			.0: 0198538642				
Literature	ISBN-13: 978-		71310y 1 1 CS	, 10DII-1	.0. 0100000042	,			
Diverature			B Algorit	hs for Pat	ttern Recogniti	ion			
		• Ian T. Nabney: NETLAB. Algoriths for Pattern Recognition, Springer, ISBN-10: 1852334401, ISBN-13: 978-1852334406							
	phimser, 1901	1-10. 10020	)UI, IOD	711-10. 310	J-100200 <del>44</del> 00				

Module MA-INF 4207	Dynamically Reconfigurable Systems								
Workload	Credit points	Duration	Frequ	ency					
180 h	6 CP	1 semest	_	1					
Module	Prof. Dr. Joachim K. Anlauf								
coordinator									
Lecturer(s)	Prof. Dr. Joac	chim K. Aı	nlauf						
CI :C ::	Programme		Mode	Semes	ter				
Classification	M. Sc. Compu	iter Scienc	e Option	al 2.					
Technical skills	Knowledge of	Knowledge of the most important FPGA architectures, ability							
	to select appro	to select appropriate FPGAs for a given application, overview of							
	programming	programming tools							
Soft skills	Communicativ	Communicative skills (oral and written presentation of							
	solutions), soc	ial skills (a	ability to s	olve proble	ems in small tea	ams,			
	discussions of	solution co	oncepts) se	lf compete	nces (ability to	)			
	accept and for	mulate cri	ticism, abi	lity to ana	lyze problems)				
Contents	Architecture o	f FPGAs,	Configura	ole Logic E	Blocks, Wiring				
	Ressources, Sp	pecial Bloc	ks, Hardw	are Descrip	tion Language	s,			
	Synthesis, Tec	hnology M	apping, P	ace and Re	oute, FPGA				
	Computing, P	artial Reco	nfigurabil	ity					
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 = ind	ependent s	tudy				
Exam achievements	Oral exam				(gra	ided)			
Study achievements	Successful exe	rcise partic	eipation		(not gra	ided)			
Forms of media									
Literature	Current resear	ch papers	and techn	ical docum	entation				

Module	Seminar Vi	sion Syste	ms					
MA-INF 4208	G 114 1 4	D 41						
Workload	Credit points 4 CP	Duration 1 semester	Frequency					
120 h	Prof. Dr. Svei		er every semester					
Module	Prof. Dr. Svei	і Беппке						
coordinator	Doof Do Care	Dobreleo De	of Dn Io	a alaissa IV	Aralouf			
Lecturer(s)	Prof. Dr. Sver Dr. Nils Goerl	,	01. D1. JC	aciiiii K	. Amaui,			
Classification	Programme		Mode	Semes	ter			
Classification	M. Sc. Compu	iter Science	Optional	2. or 3	3.			
Technical skills	• Knowledge i	n advanced t	opics in the	ne area o	f technical vision	on		
	systems, such	as image seg	mentation	, feature	extraction, and	d		
	object recogni	tion.						
	• Ability to ur			-				
		original scientific papers and to present them in a research talk						
	as well as in a							
Soft skills	Self-competen	`	_		,			
					and clear dida			
	_		,		sion, structured			
	writing of sem	inar report),	social ski	lls (abilit	y to formulate	and		
	accept criticisi							
Contents					l journals in th	e		
	field of vision	systems cove	ring funda	mental t	echniques and			
	applications.							
Prerequisites	Recommended							
	At least 1 of the	_						
	MA-INF 4111		Learning	and Ana	lysis Systems:			
	Machine Learn	ning						
	MA-INF 4204	- Technical	Neural Ne	ts				
Format	Teaching forms	at G	oup size	h/week	Workload[h]	CP		
rormat	Seminar		10	2	30 T / 90 S	4		
	T = face-to-fa			endent st				
Exam achievements	Oral presentat	ion, written	report		· -	ided)		
Study achievements					(not gra	ided)		
Forms of media	200	~						
	• R. Szeliski: Computer Vision: Algorithms and Applications,							
	Springer 2010.							
Literature	• C. M. Bishop: Pattern Recognition and Machine Learning,							
	Springer 2006.		~	,				
				uter Visi	ion: A Modern			
	Approach, Pre	entice Hall, 2	UU3.					

Algorithms	incipies of	Data M	ining a	nd Learning						
Credit points	Duration	Frequer	ıcv							
4 CP	1 semester	_	-							
		overy y	JG11							
1101. D1. 500R	all Wiosei									
Prof Dr Stefa	an Wrobel									
	<u> </u>	Mode	Semest	ter						
•	ter Science									
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<u> </u>				ng talks, writte	en					
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mining and lea	arning algori	thms. Sear	rch and o	ptimization						
algorithms. Sp	ecialized lea	rning algo	rithms fr	om the frontier	of					
research. Fund	lamental res	ults from 1	neighbour	ring areas.						
Recommended	•									
At least 1 of the	he following:									
MA-INF 4111	- Intelligent	Learning	and Ana	lysis Systems:						
	_	O								
MA-INF 4112	<ul><li>Intelligent</li></ul>	Learning	and Ana	lysis Systems	Machine Learning					
MA-INF 4112 – Intelligent Learning and Analysis Systems:										
		_	erv	<i>J</i> = = = <i>J</i> = = = =						
Data Mining a	nd Knowled	ge Discove			СР					
Data Mining a Teaching forma	nd Knowled	ge Discove	h/week	Workload[h]	<u>CP</u> 4					
Data Mining a  Teaching format  Seminar	and Knowled  Gr	ge Discove	h/week	Workload[h] 30 T / 90 S						
$\begin{aligned} & \text{Data Mining a} \\ & \frac{\text{Teaching forms}}{\text{Seminar}} \\ & T = \text{face-to-face} \end{aligned}$	and Knowled  at Gr  ce teaching;	ge Discove $ \begin{array}{c c} \mathbf{coup \ size} \\ \hline 10 \\ \mathbf{S} = \mathbf{indep} \end{array} $	h/week	Workload[h] 30 T / 90 S	4					
Data Mining a  Teaching format  Seminar	and Knowled  at Gr  ce teaching;	ge Discove $ \begin{array}{c c} \mathbf{coup \ size} \\ \hline 10 \\ \mathbf{S} = \mathbf{indep} \end{array} $	h/week	Workload[h] 30 T / 90 S sudy (gra	ded)					
Data Mining a  Teaching forms Seminar  T = face-to-face Oral presentat	ce teaching; ion, written	ge Discove roup size 10 S = indep report	h/week  2 endent st	Workload[h]   30 T / 90 S   sudy   (gra (not gra	ded)					
$\begin{aligned} & \text{Data Mining a} \\ & \frac{\text{Teaching forms}}{\text{Seminar}} \\ & T = \text{face-to-face} \end{aligned}$	ce teaching; ion, written	ge Discove roup size 10 S = indep report tes, intera	h/week 2 endent st	Workload[h] 30 T / 90 S  udy  (gra  (not gra sentations.	ded)					
	Prof. Dr. Stefa Programme M. Sc. Compute Enhanced and area of machin competence to it to others an auditorium. Le others, in write Communicative presentation of (time manager and formulate Theoretical, stemining and least algorithms. Spresearch. Fundamental Recommended At least 1 of the MA-INF 4111 Machine Learn	Prof. Dr. Stefan Wrobel  Programme M. Sc. Computer Science Enhanced and in-depth known area of machine learning and competence to independent it to others and discuss it was auditorium. Learn how to others, in writing and in proceeding to the presentation of contents in (time management with lost and formulate criticism, and Theoretical, statistical and mining and learning algorithms. Specialized learnesearch. Fundamental resurresearch. Fundamental resurresearch. The following:  MA-INF 4111 – Intelligent Machine Learning	Prof. Dr. Stefan Wrobel  Programme Mode M. Sc. Computer Science Optional Enhanced and in-depth knowledge in area of machine learning and data m competence to independently study s it to others and discuss it with a knowledge in auditorium. Learn how to scientifical others, in writing and in presentation Communicative skills (preparing and presentation of contents in a longer of (time management with long-ranging and formulate criticism, ability to an Theoretical, statistical and algorithms in a longer of the second presentation of contents in a longer of the second presentation of contents in a longer of the second presentation of contents in a longer of the second presentation of contents in a longer of the second presentation of contents in a longer of the second presentation of contents in a longer of the second presentation of contents in a longer of the second presentation of contents in a longer of the second presentation of the second presentati	Prof. Dr. Stefan Wrobel  Programme Mode Semest M. Sc. Computer Science Optional 2. or 3 Enhanced and in-depth knowledge in specializarea of machine learning and data mining, accompetence to independently study scientification it to others and discuss it with a knowledgeal auditorium. Learn how to scientifically present others, in writing and in presentations.  Communicative skills (preparing and presenting presentation of contents in a longer document (time management with long-ranging deadline and formulate criticism, ability to analyse, creating and learning algorithms. Search and of algorithms. Specialized learning algorithms freesearch. Fundamental results from neighbour Recommended:  At least 1 of the following:  MA-INF 4111 – Intelligent Learning and Anal Machine Learning	Prof. Dr. Stefan Wrobel  Programme Mode Semester M. Sc. Computer Science Optional 2. or 3.  Enhanced and in-depth knowledge in specialized topics in the area of machine learning and data mining, acquiring the competence to independently study scientific literature, present to others and discuss it with a knowledgeable scientific auditorium. Learn how to scientifically present prior work by others, in writing and in presentations.  Communicative skills (preparing and presenting talks, written presentation of contents in a longer document), self compete (time management with long-ranging deadlines, ability to and formulate criticism, ability to analyse, creativity).  Theoretical, statistical and algorithmical principles of data mining and learning algorithms. Search and optimization algorithms. Specialized learning algorithms from the frontier research. Fundamental results from neighbouring areas.  Recommended:  At least 1 of the following:  MA-INF 4111 – Intelligent Learning and Analysis Systems:					

Module MA-INF 4210	Seminar Ad	lvanced 7	Гор	ics in '	Technica	al Informati	cs	
Workload	Condit mainta	Duration		Engaria				
120 h	Credit points 4 CP	1 semest		Frequen	•	roorg		
		4 CP   1 semester   at least every 2 years  Prof. Dr. Joachim K. Anlauf						
Module	Prof. Dr. Joac	Prof. Dr. Joachini K. Amaui						
coordinator	D C D I	1 · T/ A	1 (	c				
Lecturer(s)		Prof. Dr. Joachim K. Anlauf						
Classification	Programme			Mode	Semest			
	M. Sc. Compu			_		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	criticism,	disc	ussions	of current	content) self		
	competences (	time mana	gem	ent witl	n long-ran	nging deadlines	3,	
	understanding	of researc	h toj	pics fron	n original	l literature)		
Contents	Current topics	such as: 1	new	architec	tures of c	computers or		
	FPGAs (field						s of	
	dynamically re			_	,			
Prerequisites	none							
-	Teaching forms	at	Groi	up size	h/week	Workload[h]	CP	
Format	Seminar			10	2	30 T / 90 S	4	
	T = face-to-fa	ce teaching	g; S	= indep	endent st	cudy	1	
Exam achievements	Oral presentat	ion, writte	n re	port		(gra	ided)	
Study achievements						(not gra	ided)	
Forms of media								
Literature	Current resear	ch papers						

Module	Seminar Co	gnitive Ro	botics				
MA-INF 4211							
Workload	Credit points	Duration	Frequency				
120 h	4 CP	1 semester	every se	emester			
Module	Prof. Dr. Sver	ı Behnke					
coordinator							
Lecturer(s)	Prof. Dr. Sver	Behnke, D	. Nils Go	erke			
Classification	Programme Mod			Semes	ter		
Classification	M. Sc. Compu	ter Science	Optional	2. or 3	3.		
Technical skills	Knowledge in	advanced to	pics in the	area of o	cognitive robot:	ics,	
	such as robot	perception, a	action plan	ning, and	d robot learnin	g.	
	Ability to und	erstand new	research i	esults pro	esented in origi	inal	
	scientific paper			_	_		
		n a seminar report.					
Soft skills		Self-competences (time management, literature search,					
	self-study), con	`	_			actic	
	presentation of		·-	_			
	writing of sem		*		*		
	accept criticism						
Contents	Current resear	<u> </u>				e	
	field of cogniti				-		
	applications.		O .		•		
Prerequisites	Recommended	<b>:</b>					
	At least 1 of the	he following:					
	MA-INF 4113	<ul> <li>Cognitive</li> </ul>	Robotics				
	MA-INF 4114	Ü					
	Teaching forma		oup size	h/week	Workload[h]	CP	
Format	Seminar		10	2	30 T / 90 S	4	
	T = face-to-fa	ce teaching:	S = indep	endent st	,	ı	
Exam achievements	Oral presentat					ded)	
Study achievements	1	, , , , , , , , , , , , , , , , , , , ,	<u> </u>		(not gra		
Forms of media					· · ·		
	• S. Thrun, W	. Burgard a	nd D. Fox	Probabi	listic Robotics		
i e e e e e e e e e e e e e e e e e e e	l ^	, 6					
MIT Press, 2005.							
Literature	,		Eds.): Spr	inger Ha	ndbook of		
Literature	MIT Press, 20 • B. Siciliano, Robotics, 2008	O. Khatib (	Eds.): Spr	inger Ha	ndbook of		

Module	Data Science	e and Rig	Data				
MA-INF 4212	Data Science	and Dig	Data				
Workload	Credit points	Duration	Frequen	CV			
180 h	6 CP	1 semester	every yes				
Module	Prof. Dr. Stefan		cvery yea				
coordinator	Tion Di. Secian	WIODCI					
Lecturer(s)	Dr. Tamas Horv	ath PD Dr	Michael V	lock			
` ,	Programme		/Iode	Semester			
Classification	M. Sc. Compute		Optional	3. or 4.			
Technical skills	Participants acq		-		nt aspects of big	:	
	data analytics ar	-	_				
	and big data dat		_				
	structured and u		_		- '		
	computer because	se it has enor	mous size	and/or con	tinuously arrive	es	
	with such a high	rate that red	quires imm	nediate pro	cessing.		
Soft skills	Communicative	skills (oral ar	d written	presentation	on of solutions,		
	discussions in tea						
	criticism, ability				-	end"	
	task), social skil				,		
Contents	The module is o		ear, each	time conce	ntrating on one	or	
	more specific iss	ues, such as					
	- architectures a	nd procols for	r big data	systems,			
	- distributed bat	ch and strear	n processi	ng systems	,		
	- non-standard d	latabases for	big data,				
	- databases for s	tructured dat	a,				
	- similarity searc	eh,					
	- synopses for m	assive data,					
	- classical data r	nining tasks f	or massive	e data and,	or data streams	з,	
	- mining massive						
	- applications.						
Prerequisites	Recommended:						
	All of the follow:	_					
	MA-INF 4111 –	Intelligent Le	earning an	d Analysis	Systems: Mach	ine	
	Learning						
	MA-INF 4112 –	9		d Analysis	Systems: Data		
	Mining and Kno						
	Teaching forma	t Gı	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	teaching; S =	= independ	dent study			
Exam achievements	Written exam					aded)	
Study achievements	Successful exerci				(not gra	aded)	
Forms of media	lectures, exercise			1	11		
	- N. Marz and J		-	-	-	of	
	scalable realtime						
	- T. White: Had	oop The Defi	nitive Gui	de. O'REI	LLY, 2012.		
Literature	- A. Rajaraman and J.D. Ullman.: Mining of Massive Datasets.						
	Cambridge Univ	ersity Press,	2011.				
	- G. Cormode, N	I. Garofalaki	s, P.J. Haa	as, and C.	Jermaine: Synor	oses	
	for Massive Data						
	Foundations and	Trends in D	atabases 4	(1-3): 1-29	4 (2012).		

Module MA-INF 4213	Seminar Hu	ımanoid F	Robots					
Workload	Credit points	Duration	Frequer	ıcy				
120 h	4 CP	1 semeste	r every se	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. Compu	M. Sc. Computer Science   Optional   2.						
Technical skills	Knowledge in	advanced to	pics in the	area of h	numanoid robe	tics,		
	such as enviro	nment perce	ption, stat	e estimat	tion, navigation	n, or		
	motion planni	ng. Ability	o understa	and new r	research results	s of		
	scientific pape	rs and to pr	esent them	in a talk	as well as in	a		
	self-written su	mmary.						
Soft skills	Self-competen	ces (time ma	nagement	, literatur	re search,			
	self-study), co	mmunicatio	n skills (pr	eparation	of the talk, cl	lear		
	didactic preser	ntation of te	chniques a	nd experi	imental results	3,		
	scientific discu	ssion, struct	ured writi	ng of sum	nmary), social	skills		
	(ability to form	nulate and a	ccept criti	cism, crit	ical examinati	on of		
	algorithms and		_					
Contents	Current resear	Current research papers from conferences and journals in the						
	field of human	oid robotics	covering f	undamen	tal techniques	and		
	applications.							
Prerequisites	Recommended	:						
	At least 1 of t	he following	:					
	MA-INF 4215	– Humanoi	d Robotics					
	MA-INF 4113	- Cognitive	Robotics					
T .	Teaching forms		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					aded)		
Study achievements	1	,	1		(not gra			
Forms of media					, ,			
	- S. Thrun, W	. Burgard a	nd D. Fox:	Probabil	listic Robotics			
	- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press							
<b>.</b>	- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics							
Literature	- K. Harada, I	E. Yoshida.	K. Yokoi (I	Eds.). Mo	tion Planning	for		
	Humanoid Ro	,	`	,,				
	- Selected pap	ers.						

MA-INF 4214   Vorkload   Credit points   Duration   9 CP   1 semester   very semester   Vorkload   Prof. Dr. Maren Bennewitz   Vorkload   Prof. Dr. Maren Bennewitz   Vorkload   Prof. Dr. Maren Bennewitz   Vorkload   Programme   M. Sc. Computer Science   Optional   2.    Programme   Mode   Optional   Vorkload   Practical experience and in-depth knowledge in the design and implementation of perception, state estimation, environment representation, navigation, and motion planning techniques for humanoid robots. In small groups, the participants analyze a problem, realize a solution, and perform an experimental evaluation.    Soft skills   Self-competences (time management, goal-oriented work, ability to analyze problems theoretically and to find practical solutions), communication skills (collaboration in small teams, oral and written presentation of solutions, critical examination of implementations).    Contents   Robot middleware (ROS), perception, state estimation, environment representations, navigation, and motion planning for humanoid robots.    Prerequisites   Recommended:	Module	Lab Human	oid Robots	8					
Prof. Dr. Maren Bennewitz   Prof. Dr. Maren Bennewitz		G 114 1 4	ъ	Б					
Prof. Dr. Maren Bennewitz		_		_	-				
Color   Colo					emester				
Prof. Dr. Maren Bennewitz		Prof. Dr. Mar	en Bennewitz	i					
Programme   Mode   Optional   2.		D. C.D. M							
Classification  M. Sc. Computer Science   Optional   2.  Technical skills   Practical experience and in-depth knowledge in the design and implementation of perception, state estimation, environment representation, navigation, and motion planning techniques for humanoid robots. In small groups, the participants analyze a problem, realize a solution, and perform an experimental evaluation.  Soft skills   Self-competences (time management, goal-oriented work, ability to analyze problems theoretically and to find practical solutions), communication skills (collaboration in small teams, oral and written presentation of solutions, critical examination of implementations).  Contents   Robot middleware (ROS), perception, state estimation, environment representations, navigation, and motion planning for humanoid robots.  Prerequisites   Recommended:	Lecturer(s)		en Bennewitz						
Practical experience and in-depth knowledge in the design and implementation of perception, state estimation, environment representation, navigation, and motion planning techniques for humanoid robots. In small groups, the participants analyze a problem, realize a solution, and perform an experimental evaluation.    Soft skills	Classification					ster			
implementation of perception, state estimation, environment representation, navigation, and motion planning techniques for humanoid robots. In small groups, the participants analyze a problem, realize a solution, and perform an experimental evaluation.  Self-competences (time management, goal-oriented work, ability to analyze problems theoretically and to find practical solutions), communication skills (collaboration in small teams, oral and written presentation of solutions, critical examination of implementations).  Contents  Robot middleware (ROS), perception, state estimation, environment representations, navigation, and motion planning for humanoid robots.  Prerequisites  Recommended:  At least 1 of the following:  MA-INF 4215 – Humanoid Robotics  MA-INF 4113 – Cognitive Robotics  MA-INF 4113 – Cognitive Robotics  Teaching format  Group size  Nowek  Workload[h]  CP  T = face-to-face teaching; S = independent study  Exam achievements  Oral presentation, written report  (graded)  Study achievements  Forms of media  - S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics.  MIT Press  - B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics  - K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer		-				1 1 .	,		
representation, navigation, and motion planning techniques for humanoid robots. In small groups, the participants analyze a problem, realize a solution, and perform an experimental evaluation.  Self-competences (time management, goal-oriented work, ability to analyze problems theoretically and to find practical solutions), communication skills (collaboration in small teams, oral and written presentation of solutions, critical examination of implementations).  Contents  Robot middleware (ROS), perception, state estimation, environment representations, navigation, and motion planning for humanoid robots.  Prerequisites  Recommended: At least 1 of the following: MA-INF 4215 – Humanoid Robotics MA-INF 4113 – Cognitive Robotics  MA-INF 4113 – Cognitive Robotics  Teaching format Group size h/week Workload[h] CP Lab 8 4 60 T / 210 S 9 T = face-to-face teaching; S = independent study  Exam achievements  Oral presentation, written report (graded)  Study achievements  Oral presentation, written report (graded)  Forms of media  - S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics.  MIT Press  - B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics  - K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer	Technical skills	_		-	_	_			
to analyze problems theoretically and to find practical solutions), communication skills (collaboration in small teams, oral and written presentation of solutions, critical examination of implementations).  Contents  Robot middleware (ROS), perception, state estimation, environment representations, navigation, and motion planning for humanoid robots.  Prerequisites  Recommended: At least 1 of the following: MA-INF 4215 – Humanoid Robotics MA-INF 4113 – Cognitive Robotics  MA-INF 4113 – Cognitive Robotics  Teaching format Group size h/week Workload[h] CP Lab 8 4 60 T / 210 S 9  T = face-to-face teaching; S = independent study  Exam achievements Oral presentation, written report (graded)  Study achievements  Oral presentation, written report Toronto graded  Forms of media  - S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics.  MIT Press  - B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics  - K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer		representation humanoid robe problem, realize	representation, navigation, and motion planning techniques thumanoid robots. In small groups, the participants analyze a problem, realize a solution, and perform an experimental						
Contents       Robot middleware (ROS), perception, state estimation, environment representations, navigation, and motion planning for humanoid robots.         Prerequisites       Recommended:	Soft skills	to analyze pro solutions), con oral and writte	to analyze problems theoretically and to find practical solutions), communication skills (collaboration in small teams, oral and written presentation of solutions, critical examination						
environment representations, navigation, and motion planning for humanoid robots.  Prerequisites  Recommended: At least 1 of the following: MA-INF 4215 – Humanoid Robotics MA-INF 4113 – Cognitive Robotics  MA-INF 4113 – Cognitive Robotics  Teaching format Group size h/week Workload[h] CP Lab 8 4 60 T / 210 S 9  T = face-to-face teaching; S = independent study  Exam achievements Oral presentation, written report (graded)  Study achievements  Oral presentation, written report (not graded)  Forms of media  - S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press - B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics - K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer	Contents			erceptio	n, state	estimation,			
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		environment r	epresentation	s, naviga	tion, and	motion planning	ng		
At least 1 of the following:  MA-INF 4215 – Humanoid Robotics  MA-INF 4113 – Cognitive Robotics  Teaching format Group size h/week Workload[h] CP Lab 8 4 60 T / 210 S 9  T = face-to-face teaching; S = independent study  Exam achievements Oral presentation, written report (graded)  Study achievements (not graded)  Forms of media  - S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics.  MIT Press  - B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics  - K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer		for humanoid	robots.						
$ \begin{tabular}{l lllllllllllllllllllllllllllllllllll$	Prerequisites	Recommended	:						
$ \begin{tabular}{ c c c c c c c c c c c c c c c c c c c$		At least 1 of t	he following:						
		MA-INF 4215	- Humanoid	Robotics	3				
		MA-INF 4113	- Cognitive 1	Robotics					
T = face-to-face teaching; S = independent study  Exam achievements Oral presentation, written report (graded)  Study achievements (not graded)  Forms of media  - S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics.  MIT Press - B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics - K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer					h/week	Workload[h]	CP		
T = face-to-face teaching; S = independent study  Oral presentation, written report (graded)  Study achievements (not graded)  Forms of media  - S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics.  MIT Press - B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics - K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer	Format						9		
Exam achievementsOral presentation, written report(graded)Study achievements(not graded)Forms of media- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics- K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer			ce teaching: 9	l = inder	oendent s	,	ı		
Study achievements(not graded)Forms of media- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT PressLiterature- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics - K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer	Evam achievements		9,		)CIIdelli 8		ded)		
Forms of media  - S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics.  MIT Press  - B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics  - K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer		orar presentat	,	СРОГО		, (0			
- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics.  MIT Press - B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics - K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer						(1100 8100			
MIT Press - B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics - K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer		- S. Thrun. W	. Burgard and	d D. Fox:	Probab	ilistic Robotics.			
- K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer		, ,							
- K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer	Litorature	- B. Siciliano,	O. Khatib (E	ds.): Spr	ringer Ha	ndbook of Robo	otics		
- Selected papers.	Literature	· · · ·							
		- Selected pap	ers.						

Module	Humanoid	Robotics					
MA-INF 4215							
Workload	Credit points	Duration	Freque	Frequency			
180 h	6 CP	1 semester	at least	every 2	years		
Module	Prof. Dr. Mar	en Bennewit	Z				
coordinator							
Lecturer(s)	Prof. Dr. Mar	en Bennewit	Z				
Classification	Programme		Mode	Semes	ter		
Classification	M. Sc. Compu	iter Science	Optiona	l 2-4.			
Technical skills	This lecture co	overs techniq	ues for hu	ımanoid r	obots such as		
	perception, na	vigation, and	l motion p	planning.			
Soft skills	Communicativ	ve skills (oral	and writt	en preser	ntation of solut	ions,	
	discussions in	small teams)	, ability t	o analyze	problems.		
Contents	Self-calibration	Self-calibration with least squares, 3D environment					
	representation	representations, self-localization with particle filters, footstep					
	planning, inve	rse kinemati	cs, whole-	body mot	ion planning w	$\gamma$ ith	
	rapidly explor	ing random t	rees, stati	istical tes	ting.		
Prerequisites	Recommended	:					
	MA-INF 4113	$- \ Cognitive$	Robotics				
	Teaching forms	at G	oup size	h/week	Workload[h]	CP	
Format	Lecture			2	30 T / 45 S	2.5	
	Exercises			2	30 T / 75 S	3.5	
	T = face-to-fa	ce teaching;	S = indep	endent st	cudy		
Exam achievements	Oral exam				(gra	ded)	
Study achievements	Successful exe	rcise particip	ation		(not gra	$\overline{\operatorname{ded}}$	
Forms of media					· -	,	
	• S. Thrun, W	7. Burgard a	nd D. Fox	: Probabi	listic Robotics	•	
	MIT Press, 2005.						
T.*/	• B. Siciliano,	O. Khatib (	Eds.): Spi	ringer Hai	ndbook of Rob	otics	
Literature					otion Planning		
	Humanoid Ro	bots, Springe	er	•			
	• Selected rese	earch papers.					

Module MA-INF 4216	Data Mining Bioinformat		chine Le	earning ]	Methods in				
Workload	Credit points	Duration Frequency							
180 h	6 CP 1 semester   every year								
Module	Dr. Holger Frö	bhlich							
coordinator	D II I D "	11.1							
Lecturer(s)	Dr. Holger Frö Programme	hlich	Mode	Semest	<b>.</b>				
Classification	M. Sc. Compu	ter Science	Optiona	1	ter				
Technical skills	- understandin		_		al data mining	and			
	machine learni	_	_		Q				
	- understandin	g of their a	pplication	in bioinfo	ormatics				
Soft skills	- communication					to			
	exercises		_						
	- self-competer	nces: ability	to analyz	e applicat	ion problems a	nd			
	to formulate pe			11	•				
	- practical skill	ls: ability to	practical	ly implem	ent solutions				
	_	- social skills: working in a small team with other students							
Contents	This lecture gi								
	statistical tech	niques as w	ell as data	mining a	and machine				
	learning algorit	thms. The	use of the	respective	e methods to so	olve			
	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 topic bioinformatics:		ea in the co	ontext of	тнен аррисати	)11 111			
	- Short introdu		oinformati	cs and Bi	omedicine				
	- Statistical Ba								
	inference, stati				·	ic			
	regression, Prin				, G				
	- Clustering								
	- Hidden Mark	ov Models							
	- Principles of	Supervised	Machine I	Learning					
	- Elastic Net								
	- Basics of deep learning								
Prerequisites	none	r							
•	Teaching forma	ıt 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	ce teaching;	S = indep	endent st	tudy				
Exam achievements	Written exam					ded)			
Study achievements	Successful exer	cise partici	pation		(not gra	ded)			
Forms of media	T II1: D 2	D:11-: ·	I II.: 1	(T) Tri	C				
	T. Hastie, R. 7 Statistical Lear	,		n, The El	ements of				
T :44-				o M4-1.	all (A'D a:11 00	.ne			
Literature	S.Boslaugh, P.				-	Uð			
	N. Jones, P. Pevzner, An Introduction to Bioinformatics Algorithms, MIT Press, 2004								

Module	Seminar Ma	achine L	ear	ning M	$\overline{ m ethods}$	in the Life		
MA-INF 4217	Sciences							
Workload	Credit points	Duration		Frequen	-			
120 h	4 CP	1 semes	ter	every ye	ear			
Module	Dr. Holger Fré	ohlich						
coordinator	Dn. Holgon En	Shliah						
Lecturer(s)	Dr. Holger From Programme	DIIIICII		Mode	Semest	ton		
Classification	M. Sc. Compu	ıter Scienc		Optional		Lei		
Technical skills	*					arning methods		
		_		_		e.g. biomedicine		
Soft skills						of a defined topic		
	- self-competer	nces: abili	tv to	identify	relevant	literature for a		
	_		-	_		nalyze scientific		
	publications							
	- social skills:	- social skills: ability to discuss a scientific topic with other						
		students and the staff						
Contents	Machine learn	ing techni	ques	play a c	rucial rol	e in modern life		
	sciences, inclu	ding biom	edici	ne. The	goal of the	his seminar is to		
		·		_	-	es in the context of		
	their application	on to solve	e rea	ıl-world j	problems	in biomedicine.		
	Topics will be	selected fi	rom	the follo	wing area	as:		
	- Ensemble lea	rning						
	- Survival and	disease pr	rogre	ession mo	odels			
	- Bayesian Net	works						
			.g. (	Gaussian	Proceses	, Dirichlet Process		
	Mixture Mode							
	- MCMC meth				~			
	- Deep learnin Networks	g methods	s, e.g	g. DNNs,	CNNs, I	Deep Belief		
	- feature select	ion and n	on-li	near em	bedding r	methods		
	- multi-modal	data fusio	n te	chniques				
	Attendees will	be asked	to p	erform r	esearch a	bout their topic in		
	a self-responsi	ble manne	er.					
Prerequisites	Recommended							
			linin	g and Ma	achine Le	earning Methods in		
	Bioinformatics			.	1 / 1	777 1.1 1/1.1 CD		
Format	Teaching forms Seminar	at	Gro	up size	h/week	Workload[h]   CP     30 T / 90 S   4		
		  -:-:ao tao ab	т. C	I		, ,		
Exam achievements	T = face-to-fa Oral presentat				endent st	(graded)		
Study achievements	Orar presentat	1011, WIIII	U11 16	չ Իսւ		(not graded)		
Forms of media	powerpoint					(mor graded)		
Literature	selected journa	al and con	fere	ice pape	 rs			
	Julia Journe			Pape				

Module	Lab Modeli	ng and Si	mulatior	1			
MA-INF 4218		J					
Workload	Credit points	Duration	Freque	ncy			
270 h	9 CP	1 semeste	r every y	ear			
Module	Prof. Dr. And	reas Weber					
coordinator							
Lecturer(s)	Prof. Dr. And	reas Weber	Prof. Dr.	Holger	Fröhlich		
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	ter Science	Optiona	$1 \mid 2.$			
Technical skills	- ability to des	scribe a syst	em via a r	nodel			
	- ability to cor its results	nduct a simu	ılation stu	dy, visua	lize and interpr	et	
		- ability to implement self-written program modules in MATLAB, R or via usage of some other software					
Soft skills		- ability to communicate effectively in order to implement learned methods together with a team of other students					
	- ability to predecisions	esent and ex	plain resu	lts and to	o defend design		
Contents	Simulation and example, in sy		-		that arise, for ing approaches	are:	
	- Boolean Netv	works					
	- ODEs						
Prerequisites	Recommended		Machine L	earning I	Methods in the	Life	
Format	Teaching forma	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 = indep	endent s	study		
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra		
Forms of media	powerpoint				·	<u> </u>	
	- U. Alon, An	Introduction	n to System	ms Biolog	gy, CRC Press,	2007	
Literature	- E.S. Allman Cambr.Univ.P		des "Math	ıematical	Models in Biol	ogy"	

Module	Lab Parallel Computing for Mobile Robotics							
MA-INF 4226								
Workload	Credit points	Duration	Freque	Frequency				
270 h	9 CP	1 semester	every	year				
Module	Prof. Dr. Mar	en Bennewi	Z					
coordinator								
Lecturer(s)	Prof. Dr. Mar	Prof. Dr. Maren Bennewitz						
Classification	Programme		Mode	Seme	ster			
Classification	M. Sc. Compu	iter Science	Optiona	al 2.				
Technical skills	Students will 1	Students will make practical experience with the design and						
	implementatio	implementation of parallelized algorithms in the context of						
	motion planni	motion planning and navigation.						
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	hers in sr	nall teams over	a		
	longer period	of time; abil	ty to clas	sify 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		
Format	Lab		8	4	60 T / 210 S	9		
	T = face-to-fa	ce teaching;	S = inde	pendent s	study			
Exam achievements	Oral presentat	ion, written	report		(gra	ided)		
Study achievements			<u> </u>		(not gra	ded)		
Forms of media								
Literature								

Module MA-INF 4228	Foundations	s of Data S	cience					
Workload	Credit points	Duration	Freque	nav				
270 h	9 CP	1 semester	every	-				
Module	Prof. Dr. Emi			year				
coordinator	1101. D1. EIIII	nanuei wiune	1					
	Drof Dr Emr	Prof. Dr. Emmanuel Müller, Dr. Michael Nüsken						
Lecturer(s)	Programme	nanuei wiune	$\frac{1, D1. M}{\text{Mode}}$	Seme				
Classification	M. Sc. Compu	itor Scionco						
Technical skills					spaces in geom	otru		
Technical skins			_		•	ену		
	_	_		ecomposi	tion. Basics in			
	machine learni		Ü					
	Skills: Underst							
Soft skills	_	Competences: Application to data science problems and ability to assess similar methods.						
Contents	Data science aims at making sense of big data. To that end, various tools have to be understood for helping in analyzing the arising structures.  Often data comes as a collection of vectors with a large number of components. To understand their common structure is the first main objective of understanding the data. The geometry and the linear algebra behind them becomes relevant and enlightning. Yet, the intuition from low-dimensional space turns out to be often misleading. We need to be aware of the particular properties of high-dimensional spaces when working with such data. Fruitful methods for the analysis include singular vector decomposition from linear algebra and supervised and unsupervised machine learning. If time permits, we also consider random graphs, which are the second most used							
Prerequisites	model for real none	*						
	Teaching forms	at Gro	up 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-fa	ce teaching: 9	 		,	1		
Exam achievements	Schriftliche Pr		) — mae	репцепт 8		ided)		
	Erfolgreiche Ü		mo		(0			
Study achievements	Errorgreiche U	bungstennan	ше		(not gra	idea)		
Forms of media	A . D1	. 1 TT - 0	1.15	• 1	T/ /0010	. \		
Literature	Avrim Blum, Foundations of	_		avındran	Kannan (2018-	⊢).		

Module MA-INF 4229	Pattern Rec	cognition	(1)				
Workload	Credit points	Duration	Freque	encv			
270 h	9 CP	1 semeste	_	-			
Module	Prof. Dr. Chris						
coordinator							
Lecturer(s)	Prof. Dr. Chris	tian Bauckh	age				
• • • • • • • • • • • • • • • • • • • •	Programme		Mode	Semester			
Classification	M. Sc. Comput	er Science	Optional	2.			
Technical skills	Upon completic	n, students	should be	able to			
	<ul><li>devise mather clustering, and</li><li>implement ba</li></ul>	classification			a analysis, odel fitting and		
	classification				ata clustering an		
Soft skills	Students will le					'11	
Soft skills	foundations of r learn about bas	nachine lear ic and adva	ning for panced mathe	attern recognematical mod	nition. They wildels in this area	, how	
Contents	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	<ul> <li>basic and advanced concepts in linear algebra</li> <li>basic and advanced concepts in probability theory and statistics</li> <li>least squares techniques for model fitting</li> <li>maximum likelihood techniques</li> <li>maximum a-posteriori techniques</li> <li>Bayesian inference methods</li> <li>fundamental aspects of learning theory and the VC dimension</li> <li>the curse of dimensionality</li> <li>methods and algorithms for data clustering</li> <li>Gaussian mixture models</li> <li>the method of Lagrange multipliers and the KKT conditions</li> <li>quadratic and linear discriminant analysis</li> <li>algorithms for constrained optimization</li> <li>support vector machines</li> <li>the kernel trick</li> </ul>					
Prerequisites	Recommended						
- 1010 <b>q</b> and 2000	Students should theory, and stat	l good work tistics as wel	l as progra	mming expe			
Format		e teaching; S	Group size $=$ independent	4 2	Workload[h] 60 T / 105 S 30 T / 75 S	5.5 3.5	
Exam achievements	Schriftliche Prü	fung			(gra	aded)	
Study achievements	Erfolgreiche Üb	ungsteilnah	ne		(not gra	aded)	
Forms of media	• lecture slides			ine			
	• lecture notes	with program	nming exa	mples are m	ade available or	line	
	Bishop, "Patter						
Literature	Duda, Stork, Ha	art, "Pattern	Classifica	tion"			
	MacKay, "Inform	mation Theo	ry, Inferen	ice, and Lear	rning Algorithm	.s"	

Module	Advanced L	earning Sy	stems					
MA-INF 4302	110.0011000 1		200112					
Workload	Credit points	Duration	Frequer	ncv				
180 h	6 CP	1 semester	every y	-				
Module	Prof. Dr. Stefa							
coordinator								
Lecturer(s)	Prof. Dr. Stefa	an Wrobel. D	r. Thoma	as Gärtne	r			
( )	Programme	,	Mode	Semest				
Classification	M. Sc. Compu	ter Science	Optional	$1 \mid 2$ . or $3$	3.			
Technical skills	Participants specialize and require in-depth knowledge of one particular class of learning algorithms, they acquire the necessary knowledge to improve existing algorithms and construct their own within the given class, all the way up to the research frontier on the topic.							
Soft skills	In group work communication		-					
						re		
Contents	The module is	planning, and learn how to present software projects to others. The module is offered every year, each time concentrating on one or more specific algorithm classes, e.g.						
	<ul> <li>kernel machines</li> <li>neural networks</li> <li>probabilistic and statistical learning approaches</li> <li>logic-based learning approaches</li> <li>reinforcement learning</li> </ul>							
Prerequisites	Recommended all of the follow							
	MA-INF 4111 Machine Learn	_	Learning	and Ana	lysis Systems:			
	MA-INF 4112 Data Mining a	_	_		lysis Systems:			
	Teaching forma	at Gr	oup size	h/week	Workload[h]	CP		
Format	Lecture			2	30 T / 45 S	2.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-face	ce teaching: S	S = index	endent st	udv			
Exam achievements	Written exam	8,				ded)		
Study achievements	Successful exer	cise participa	ation		(not gra			
Forms of media					( 0			
Literature	<ul> <li>B. Schoelkop</li> <li>Press, 2002, C.</li> <li>John Shawe-</li> <li>Pattern Analy</li> <li>Christopher</li> <li>Learning, The</li> <li>David MacK</li> <li>Algorithms, 20</li> </ul>	ectures, exercises, software systems  B. Schoelkopf, A.J. Smola, Learning with Kernels, The MIT Press, 2002, Cambridge, MA  John Shawe-Taylor, Nello Christianini, Kernel Methods for Pattern Analysis, CUP, 2004  Christopher Bishop, Pattern Recognition and Machine Pearning, The University of Edinburgh, 2006  David MacKay, Information Theory, Inference, and Learning Algorithms, 2003  Richard Duda, Peter Hart, David Stork, Pattern						

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

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

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

Module MA-INF 4307	Lab Field P	rogramn	able Ga	te Arra	ys		
Workload	Credit points	Duration	Frequ	onev			
270 h	9 CP	1 semest	_	st every 2	vears		
Module	Prof. Dr. Joachim K. Anlauf						
coordinator	1101. D1. 50ac	шш іх. ді	iaui				
Lecturer(s)	Prof. Dr. Joac	him K Ar	lauf				
Lecturer(s)	Programme	шш к. А	Mode	Somo	gton		
Classification	Programme Mode Semeste M. Sc. Computer Science Optional 2. or 3.						
Technical skills			_		ts in VHDL and	J	
Technical skills	-		_				
	, ,		·		ets, knowledge		
	~ .	he design path from the idea to a realized circuit implemented n an FPGA (field programmable gate array)					
G 6: 1.11	,	·					
Soft skills	Communicative skills (oral and written presentation of results), social skills (ability to cooperate in small teams, discussions of						
	,	-	_			OI	
	solution conce	. ,	•	(	•		
	formulate criti	*	y to analy	yze and fir	id practical		
	solutions to pr			N. 1	1.0 .1		
Contents			_ ′		, and Synthesis	*	
	•		-	,	on, and Synthes	sis,	
	Synthesizable	,	st of Imp	lementatio	ons on FPGA		
	Evaluation Bo						
Prerequisites	Recommended		11 B		Q		
	MA-INF 4207					1	
Format	Teaching forma	at G	roup size	h/week	Workload[h]	CP	
2 01 11140	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	ided)	
Forms of media							
Literature	Technical docu	imentation					

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

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

Module	Lab Mobile	Robots	!						
MA-INF 4310	Lab Woone	100000	•						
Workload	Credit points	Duration	1	Freque	encv				
270 h	9 CP	1 semes		_	st every y	ear			
Module	Prof. Dr. Svei		,,,,,		, , , , , , , , , , , , , , , , , , ,	001			
coordinator	2101. 21. 2.01	2 20111110							
Lecturer(s)	Prof. Dr. Sver	n Behnke,	Dr.	Nils G	oerke				
	Programme	,		Mode	Seme	ster			
Classification	M. Sc. Compu	iter Scienc	ce (	Option	al 2. or	3.			
Technical skills	Participants a	cquire bas	sic kr	nowledg	ge and pra	actical experience i	in		
	the design and	l impleme	ntati	on of c	ontrol alg	orithms for simple	<u> </u>		
	structured rob	otic syste	ms u	sing re	al mobile	robots.			
	Fundamental j	paradigms	s for	mobile	robots w	ill be identified and	d		
	implemented i	n 2 persoi	n gro	ups.					
Soft skills	_	•		_	. –	iented work, ability	y		
	to analyze pro			_		, ,			
		,		_		l teams, oral and			
	written presen		solut	ions, cı	ritical exa	mination of			
<b>~</b>	_	implementations)							
Contents		Robot middleware (e.g. ROS), robot simulation tools, basic capabilities for mobile robots: reactive control, SMPA							
	_					,			
	architecture, n	_		_		M), visual based			
					- \	ivi), visuai based			
Prerequisites	Recommended	object detection, learning robot control.							
Trerequisites	At least 1 of t		ng:						
	BA-INF 132 –		_	er Rob	otik				
		•							
	BA-INF 131 -								
	MA-INF 1314				nning				
	MA-INF 2201	-							
	MA-INF 4113	– Cogniti	ive R	obotics	3				
	MA-INF 4114	- Robot 1	Learı	ning					
	MA-INF 4203	- Autono	mou	s Mobi	le System	S			
Format	Teaching forms	at	Grou	p size	h/week	Workload[h] C	C <b>P</b>		
Format	Lab		8	8	4	60 T / 210 S	9		
	T = face-to-fa	ce teachin	ng; S	= inde	pendent s	study			
Exam achievements	Oral presentat	ion, writt	en re	port		(gradeo	$\overline{\mathbf{d}}$		
Study achievements						(not graded	<u>d)</u>		
Forms of media	Robots simula	tion envir	onmo	ents, ro	bot contr	ol middleware,			
	computer vision	on librarie	s, pr	ogramr	ning, dem	onstration of robo	t		
	_ `		-	, , ,	presentati	on and written			
	report of appr								
	• S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics.								
	MIT Press, 20			<b>1</b> .	т., 11.	D 11:1 11			
T • .	• J. Buchli: Mobile Robots: Moving Intelligence, Published by Advanced Robotic Systems and Pro Literatur Verlag								
Literature						_			
	B. Siciliano, Robotics, 2008		n (E	us.): SI	лиger на	инароок ог			
	· · · · · · · · · · · · · · · · · · ·		o_art	nublic	ations				
	• Additional State-of-the-art publications.								

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

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

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

Module MA-INF 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.						
Prerequisites	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.						
Frerequisites	Recommended: Open-minded for new problem settings, Programming in different languages (C++, Python, Java), Critical approach to existing solutions, Research curiosity						
Format							
	T = face-to-face teaching; S = independent study						
Exam achievements	Oral presentation, written report (graded)						
Study achievements	(not graded)						
Forms of media	[1] Sergey Ivanov, Evgeny Burnaev. "Anonymous Walk Embeddings" ICML, 2018.						
	[2] Tsitsulin, Anton, Davide Mottin, Panagiotis Karras, and Emmanuel Müller "VERSE: Versatile Graph Embeddings from Similarity Measures." WWW, 2018.						
	[3] Yanardag, Pinar, and S. V. N. Vishwanathan. "Deep graph kernels." KDD, 2015.						
Literature	[4] Holger Dell, Martin Grohe, Gaurav Rattan "Lovász Meets Weisfeiler and Leman". ICALP, 2018						
	[5] Anton Tsitsulin, Davide Mottin, Panagiotis Karras, Alexander M. Bronstein, Emmanuel Müller "NetLSD: Hearing the Shape of a Graph". KDD, 2018						
	[6] Nino Shervashidze, Pascal Schweitzer, Erik Jan van Leeuwen, Kurt Mehlhorn, Karsten M. Borgwardt "Weisfeiler-Lehman Graph Kernels". JMLR, 2011						
	[7] Haochen Chen, Bryan Perozzi, Yifan Hu, Steven Skiena "HARP: Hierarchical Representation Learning for Networks". AAAI, 2018.						

Module	Game AI							
MA-INF 4319								
Workload	Credit points	Duration	Freque	ncy				
270 h	9 CP	1 semester	every ye	ear				
Module	Prof. Dr. Chris	tian Bauckha	ge					
coordinator								
Lecturer(s)	Prof. Dr. Chris	Prof. Dr. Christian Bauckhage						
• • • • • • • • • • • • • • • • • • • •	Programme							
Classification	M. Sc. Compute		Optional	2. or 3.				
Technical skills	Upon completio		_					
Tooming billing	-				. 11. 1.1			
	• know about fu		-	artinciai in	temgence and n	.ow		
	they apply to co			1 6 1	. 11			
	• know about b			nods for pla	nning, problem			
	solving, and bel		-	.1 6 1				
	• implement bas			thms for pla	anning, problem	L		
	solving, and bel		_					
	• implement nu							
Soft skills	Students will lea							
	artificial intellig							
	techniques for p			-				
	to implement the					ice		
	especially in the			mputer gan	ne agents.			
Contents	• historical over							
	• basic terms ar			~				
	• backward indu							
	• alpha-beta pri		restircted	searches, fe	atures, and			
	evaluation funct							
	• (traditional, u	,	ree search	algorithms				
	• Monte Carlo t							
	• algorithms for	-	_	-				
	• mathematical		computer a	algorithms i	for data clusteri	ng		
	• self organizing			/				
	• finite state ma							
	• fuzzy logic / f				g / programming	S		
	• probability th			vorks				
	Markov chains							
	• hidden Marko			_				
	Markov decisi							
	• the Bellman e			ent learning	r S			
	• temporal diffe	rence learnin	g					
	• Q learning							
	• genetic algorit		etic progra	amming				
Prerequisites	Recommended							
	Students should					oility		
	theory, and stat							
_	Teaching forms	ut G	roup size	+ ' .	Workload[h]	CP		
Format	Lecture			4	60 T / 105 S	5.5		
	Exercises			2	30 T / 75 S	3.5		
	T = face-to-face	e teaching; S	= indepen	dent study				
Exam achievements	Oral exam				(gra	aded)		
Study achievements	Successful exerc	ise participat	ion		(not gra	aded)		
Forms of media	• lecture slides	are made ava	ilable onli	ne				
	• lecture notes	with program	ming exar	nples are m	ade available on	line		
	Russell and Nor	vig, "Artificia	al Intellige	nce: A Mod	lern Approach"			
Literature	Millington, "Art	ificial Intellio	ence For 0	Games"				
					rning Algarithes	a."		
	MacKay, "Information Theory, Inference, and Learning Algorithms"							

Module	Lab Repres	entation I	earning	g on Gra	aphs		
MA-INF 4320							
Workload	Credit points	Duration	Freque	Frequency			
270 h	9 CP	1 semester	every	year			
Module	Prof. Dr. Emmanuel Müller						
coordinator							
Lecturer(s)	Prof. Dr. Emr	nanuel Müll	er				
Classification	Programme		Mode	Seme	ster		
Classification	M. Sc. Compu	iter Science	Option	al   2. or	3.		
Technical skills	The students v	will carry ou	t a pract	ical task (	(project) in the		
	context of repr	resentation l	earning o	n graphs,	including test	and	
	documentation	of the impl	emented	software/	system.		
Soft skills	Ability to prop	perly present	and defe	end design	n decisions, to		
	prepare readal	ole documen	tation of	software;	skills in		
	constructively	collaboratin	g with ot	hers in sr	nall teams over	a	
	longer period	of time; abil	ty to clas	ssify ones	own results into	o the	
	state-of-the-ar	state-of-the-art of the resp. area					
Contents							
Prerequisites	none						
Format	Teaching forms	at Gr	oup size	h/week	Workload[h]	CP	
Format	Lab		8	4	60 T / 210 S	9	
	T = face-to-fa	ce teaching;	S = inde	pendent s	study		
Exam achievements	Oral presentat	ion, written	report		(gra	ded)	
Study achievements					(not gra	ded	
Forms of media							
Literature							

Module MA-INF 4321	Seminar Learning from Time Series					
Workload	Credit points   Duration   Frequency					
120 h	4 CP	1 semester	every ye	ear		
Module	Prof. Dr. Emr	nanuel Mülle	er			
coordinator						
Lecturer(s)	Prof. Dr. Emr	nanuel Mülle	er			
Classification	Programme		Mode	Semest	ter	
Classification	M. Sc. Compu	ter Science	Optional	2. or 3	3.	
Technical skills	Ability to understand new research results presented in original					
	scientific paper	scientific papers.				
Soft skills	Ability to pres	ent and to c	ritically di	scuss the	ese results in th	ne
	framework of t	framework of the corresponding area.				
Contents	Current confer	ence and jou	ırnal pape	rs		
Prerequisites	none					
Format	Teaching forma	ıt Gı	oup size	h/week	Workload[h]	CP
rormat	Seminar		10	2	30 T / 90 S	4
	T = face-to-face	ce teaching;	S = indep	endent st	sudy	
Exam achievements	Oral presentat	ion, written	report		(gra	ded)
Study achievements		(not graded)				
Forms of media						
Literature						

Module MA-INF 4323	Pattern Recognition	on (2)							
Workload	Credit points Duratio	Credit points   Duration   Frequency							
270 h	9 CP 1 semester   every year								
Module	Prof. Dr. Christian Bauckhage								
coordinator		<u> </u>							
Lecturer(s)	Prof. Dr. Christian Bauc	khage							
Cl. 10	Programme	Mode	Semester						
Classification	M. Sc. Computer Science	M. Sc. Computer Science   Optional   2. or 3.							
Technical skills	Upon completion, studen	Jpon completion, students should be able to							
	• know about aspects of affect practical implement	know about aspects of numerical computing and how these may affect practical implementations							
	of machine learning / pat		on algorith	ms					
	• know about iterative al	_	_						
	recognition with large dat	_	пасшие теа.	imig / pattern					
	• implement numerically		hme for dat	ta dimonsionalit	<b>3</b> 7				
	reduction	robust aigorit	illis ioi dai	ta dimensionant	У				
	• implement numerically	robust data c	lustering ar	nd classification					
Soft skills	Students will learn about				ns of				
SOIL SKIIIS	robust implementations o		_		115 01				
	analysis and pattern reco								
	algorithms and dynamica	-			)				
	implement them on their								
Contents	advanced concepts from			om mee praetiee.					
	• QR-, spectral-, and sing	_		ns					
	• iterative algorithms for								
	• iterative algorithms for	-	-						
	• Hebbian learning and C		-		is				
	• auto-encoder networks		•	1					
	• associative memory net	works							
	Hopfield networks								
	• Hopfield networks for p	attern recogn	ition						
	• Hopfield networks for p	roblem solvin	g						
	• energy minimization me	ethods in mad	hine learnir	ng and pattern					
	recognition								
	• latent factor models for		3						
	• data matrix factorization	-							
	• multidimensional scalin	g							
	• manifold learning								
	• basic graph theory								
	• graph cuts and graph c	-							
	<ul><li>graph diffusion processe</li><li>radial basis functions for</li></ul>		n						
	<ul> <li>radial basis functions for</li> <li>radial basis functions for</li> </ul>	•							
	<ul> <li>radial basis functions for</li> <li>radial basis functions for</li> </ul>								
Prerequisites	Recommended:	a demany call	111001011						
1 rerequisites	Students should good wor	rking knowled	ge in lineer	algebra probab	oility				
	theory, and statistics. Ide	~	~		,111 U Y				
	Pattern Recognition (1).	, oney will	. 110,10 000011	and the recture					
	Teaching format	Group size	h/week	Workload[h]	CP				
Format	Lecture	CIOUP SIZE	4	60 T / 105 S	5.5				
2 31 111111	Exercises		2	30 T / 75 S	3.5				
		. C :l	I	1 22 2 / 10 0	1 3.0				
From ochior	T = face-to-face teaching	, s = maepen	dem study	ſ	,do4)				
Exam achievements	Schriftliche Prüfung Erfolgreiche Übungsteilna	hme			aded)				
Study achievements Forms of media	• lecture slides are made		no	(not gra	ided)				
rorms of media	• lecture sides are made • lecture notes with progr			ade available en	lino				
	MacKay, "Information The								
					S				
	Haykin, "Neural Network	s and Learnin	g Machines	П					
<b>T</b> • .	Bishop, "Neural Networks	s for Pattern l	Recognition	"					
Literature	Elden, "Matrix Methods i	in Data Minir	ng and Patte	ern Recognition	"				
	·		_						
	Skillicorn, "Understanding Complex Datasets"								

## 5 Master Thesis

MA-INF 0401	30  CP	Master Thesis	141
MA-INF 0402	2  CP	Master Seminar	142

Module	Master The	esis						
MA-INF 0401								
Workload	Credit points	Duration	Freque	•				
900 h	30 CP	30 CP   1 semester   every semester						
Module								
coordinator								
Lecturer(s)	All lecturers o	f computer s	cience					
Classification	Programme		Mode	Se	emester			
Classification	M. Sc. Compu	iter Science	Compuls	sory 4.				
Technical skills	Ability to solv	e a well-defi	ned, signif	icant res	earch problem			
	under supervis	sion, but in p	orinciple i	ndepend	ently			
Soft skills	Ability to writ	e a scientific	documen	tation of	f considerable le	ngth		
	according to e	stablished so	ientific pr	inciples	of form and styl	le, in		
	particular refle	ecting solid k	nowledge	about tl	ne state-of-the-a	rt in		
	the field	•						
Contents	Topics of the t	Topics of the thesis may be chosen from any of the areas of						
	computer scien	computer science represented in the curriculum						
Prerequisites	none							
	Teaching forms	Teaching format Group size h/week Workload[h] CP						
	Independent			0	900 S	30		
Format	preparation of	a						
	scientific thesis	s with						
	individual coa	ching						
	T = face-to-fa	ce teaching;	S = indep	endent :	study			
Exam achievements	Master Thesis				(gra	ded)		
Study achievements					(not gra	ded)		
Forms of media								
T :4	Individual bibliographic research required for identifying							
Literature	relevant literature (depending on the topic of the thesis)							

Module MA-INF 0402	Master Sen	inar					
Workload	Credit points	Duration	Freque	ncv			
60 h	2 CP	1 semester	_	emester			
Module							
coordinator							
Lecturer(s)	All lecturers o	f computer s	science				
Classification	Programme		Mode	Se	mester		
Classification	M. Sc. Compu	ter Science	Compul	sory 4.			
Technical skills	Ability to doc	ument and o	efend the	results o	of the thesis wor	k in	
	a scientifically	a scientifically appropriate style, taking into consideration the					
	state-of-the-ar	t in research	in the res	sp. area			
Soft skills							
Contents	Topic, scientifi	c context, a	nd results	of the m	aster thesis		
Prerequisites	none						
Format	Teaching forms	at G	roup size	h/week	Workload[h]	CP	
Format	Seminar			2	30 T / 30 S	2	
	T = face-to-fa	ce teaching;	S = indep	endent s	study		
Exam achievements	Oral presentat	ion of final	esults		(gra	ded)	
Study achievements					(not gra	ded)	
Forms of media							
T:4	Individual bib	liographic re	search rec	quired for	dentifying		
Literature	relevant literature (depending on the topic of the thesis)						