Module Handbook

for the

Master Programme "Computer Science"

at

Rheinischen Friedrich-Wilhelms-Universität Bonn

revised version: October 29, 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:

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

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

Contents

1 Algorithmics

Module MA-INF 1102	**Combinatorial Optimization**		
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** at least every year
Module coordinator	Prof. Dr. Jens Vygen		
Lecturer(s)	All lecturers of Discrete Mathematics		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1. or 2.
Technical skills	Advanced knowledge of combinatorial optimization. Modelling and development of solution strategies for combinatorial 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, submodular function minimization, travelling salesman problem, polyhedral combinatorics, NP-hard problems		
Prerequisites	none		

Format

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Exam achievements	Oral exam (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	
Literature	• B. Korte, J. Vygen: Combinatorial Optimization: Theory and Algorithms. Springer, 6th edition, 2018 • A. Schrijver: Combinatorial Optimization: Polyhedra and Efficiency. Springer, 2003 • W. Cook, W. Cunningham, W. Pulleyblank, A. Schrijver: Combinatorial Optimization. Wiley, 1997 • A. Frank: Connections in Combinatorial Optimization. Oxford University Press, 2011

Module MA-INF 1103	**Cryptography**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Dr. Michael Nüsken				
Lecturer(s)	Dr. Michael Nüsken				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1. or 2.		
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	Oral presentation (in tutorial groups), written presentation (of exercise solutions), team collaboration in solving homework problems, critical assessment				
Contents	Basic private-key and public-key cryptosystems: AES, RSA, group-based. Security reductions. Key exchange, cryptographic hash functions, signatures, identification; factoring integers and discrete logarithms; lower bounds in structured models.				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		4	60 T / 105 S	5.5
	Exercises		2	30 T / 75 S	3.5
	T = face-to-face teaching; S = independent study				
Exam achievements	Written exam (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature	• Stinson, Cryptography: Theory and Practice, 2nd edition • Course notes				

Module MA-INF 1104	**Advanced Algorithms**
Workload 270 h	**Credit points** 9 CP; **Duration** 1 semester; **Frequency** every year
Module coordinator	Prof. Dr. Heiko Röglin
Lecturer(s)	Prof. Dr. Anne Driemel, Prof. Dr. Thomas Kesselheim, Prof. Dr. Heiko Röglin, PD Dr. Elmar Langetepe, Dr. Herman Haverkort, Senior Prof. Dr. Marek Karpinski
Classification	**Programme** M. Sc. Computer Science; **Mode** Optional; **Semester** 1.
Technical skills	Deeper insights into selected methods and techniques of modern algorithmics.
Soft skills	Presentation of solutions and methods, critical discussion of applied methods and techniques.
Contents	Advanced algorithmic techniques from e.g. approximation, randomized and exact exponential time algorithms. We will also revisit some essential topics such as linear programs and network flows.
Prerequisites	none
Format	see below
Exam achievements	Written exam (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	
Literature	

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 1201	**Approximation Algorithms**			
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** at least every year	
Module coordinator	Prof. Dr. Jens Vygen			
Lecturer(s)	All lecturers of Discrete Mathematics, Senior Prof. Dr. Marek Karpinski			
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.	
Technical skills	Introduction to design and analysis of most important approximation algorithms for NP-hard combinatorial optimization problems, and various techniques for proving lower and upper bounds, probabilistic methods and applications			
Soft skills	Presentation of solutions and methods, critical discussion of applied methods and techniques			
Contents	Approximation Algorithms and Approximation Schemes. Design and Analysis of Approximation algorithms for selected NP-hard problems, like Set-Cover, and Vertex-Cover problems, MAXSAT, TSP, Knapsack, Bin Packing, Network Design, Facility Location. Introduction to various approximation techniques (like Greedy, LP-Rounding, Primal-Dual, Local Search, randomized techniques and Sampling, and MCMC-Methods), and their applications. Analysis of approximation hardness and PCP-Systems.			
Prerequisites	**Recommended:** Introductory knowledge of foundations of algorithms and complexity theory is essential.			
Format				
Exam achievements	Oral exam (graded)			
Study achievements	Successful exercise participation (not graded)			
Forms of media				
Literature	• S. Arora, C. Lund: Hardness of Approximations. In: Approximation Algorithms for NP-Hard Problems (D. S. Hochbaum, ed.), PWS, 1996 • M. Karpinski: Randomisierte und approximative Algorithmen für harte Berechnungsprobleme, Lecture Notes (5th edition), Universität Bonn, 2007 • B. Korte, J. Vygen: Combinatorial Optimization: Theory and Algorithms (6th edition), Springer, 2018 • V. V. Vazirani: Approximation Algorithms, Springer, 2001 • D. P. Williamson, D. B. Shmoys: The Design of Approximation Algorithms, Cambridge University Press, 2011			

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 1202	**Chip Design**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Jens Vygen				
Lecturer(s)	All lecturers of Discrete Mathematics				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1. or 2.		
Technical skills	Knowledge of the central problems and algorithms in chip design. Competence to develop and apply algorithms for solving real-world problems, also with respect to technical constraints. Techniques to develop and implement efficient algorithms for very large instances.				
Soft skills	Mathematical modelling of problems occurring in chip design, development of efficient algorithms, abstract thinking, presentation of solutions to exercises				
Contents	Problem formulation and design flow for chip design, logic synthesis, placement, routing, timing analysis and optimization				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		4	60 T / 105 S	5.5
	Exercises		2	30 T / 75 S	3.5
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral exam (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature	• C.J. Alpert, D.P. Mehta, S.S. Sapatnekar: The Handbook of 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: Methods and Applications" (V. Chvátal, ed.), IOS Press, Amsterdam 2011, pp. 33-96 • S. Held, J. Vygen: Chip Design. Lecture Notes (distributed during the course) • L. Lavagno, I.L. Markov, G. Martin, and L.K. Scheffer, eds.: Electronic Design Automation for IC Implementation, Circuit Design, and Process Technology. CRC Press, 2nd edition, 2016				

Module MA-INF 1203	**Discrete and Computational Geometry**		
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Anne Driemel		
Lecturer(s)	Prof. Dr. Anne Driemel, PD Dr. Elmar Langetepe, Dr. Herman Haverkort		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1-4.
Technical skills	Knowledge of fundamental theorems and concepts in the area of discrete and computational geometry; design and analysis of geometric algorithms; combinatorial analysis of the complexity of geometric configurations; to apply this knowledge autonomously in solving new problems.		
Soft skills	Social competence (communication, presenting one's own solutions, goal-oriented discussions in teams), methodical competence (analysis, abstraction, proofs), individual competence (commitment and willingness to learn, creativity, endurance).		
Contents	Fundamentals of convex sets, Voronoi diagrams, hyperplane arrangements, well-separated pair decomposition, spanners, metric space embedding, dimension reduction, VC-dimension, epsilon-nets, visibility, point location, range searching, randomized incremental construction, geometric distance problems in dimension two and higher.		
Prerequisites	**Recommended:** BA-INF 114 – Grundlagen der algorithmischen Geometrie		

Format

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Exam achievements	Oral exam (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	
Literature	• Jiri Matousek. Lectures on Discrete Geometry. Springer Graduate Texts in Mathematics. ISBN 0-387-95374-4. • Mark de Berg, Otfried Cheong, Marc van Kreveld, and Mark Overmars. Computational Geometry — Algorithms and Applications (Third Edition). Springer. ISBN 978-3-540-77973-5. • Narasimhan/Smid, Geometric Spanner Networks • Klein, Concrete and Abstract Voronoi Diagrams

Module MA-INF 1205	**Graduate Seminar Discrete Optimization**				
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Jens Vygen				
Lecturer(s)	All lecturers of Discrete Mathematics				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Competence to understand new research results based on original literature, to put such results in a broader context and present such results and relations.				
Soft skills	Ability to read and understand research papers, abstract thinking, presentation of mathematical results in a talk				
Contents	A current research topic in discrete optimization will be chosen each semester and discussed based on original literature.				
Prerequisites	**Recommended:** MA-INF 1102 – Combinatorial Optimization				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	4	60 T / 120 S	6
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature	The topics and the relevant literature will be announced towards the end of the previous semester.				

Module MA-INF 1206	**Seminar Randomized and Approximation Algorithms**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Heiko Röglin				
Lecturer(s)	Prof. Dr. Anne Driemel, Prof. Dr. Thomas Kesselheim, Prof. Dr. Heiko Röglin, PD Dr. Elmar Langetepe, Dr. Herman Haverkort, Senior Prof. Dr. Marek Karpinski				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Ability to perform individual literature search, critical reading, understanding, and clear presentation.				
Soft skills	Presentation of solutions and methods, critical discussion of applied methods and techniques				
Contents	Current topics in design and analysis of randomized and approximation algorithms based on lastest research literature				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature	The relevant literature will be announced in time.				

Module MA-INF 1207	**Lab Combinatorial Algorithms**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Jens Vygen				
Lecturer(s)	All lecturers of Discrete Mathematics				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Competence to implement advanced combinatorial algorithms, handling nontrivial data structures, testing, documentation. Advanced software techniques.				
Soft skills	Efficient implementation of complex algorithms, abstract thinking, documentation of source code				
Contents	Certain combinatorial algorithms will be chosen each semester. The precise task will be explained in a meeting in the previous semester.				
Prerequisites	**Recommended:** MA-INF 1102 – Combinatorial Optimization				
Format	**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					
Literature	The topics and the relevant literature will be announced towards the end of the previous semester				

Module MA-INF 1209	**Seminar Advanced Topics in Cryptography**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator	Dr. Michael Nüsken				
Lecturer(s)	Dr. Michael Nüsken				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	Understanding research publications, often written tersely. Distilling this into a presentation. Determination of relevant vs. irrelevant material. Developing a presentation that fascinates fellow students.				
Soft skills	Understanding and presenting material both orally and in visual media. Motivating other students to participate. Critical assessment of research results.				
Contents	A special topic within cryptography, changing from year to year, is studied in depth, based on current research literature				
Prerequisites	**Required:** MA-INF 1103 – Cryptography and one further course in cryptography like The Art of Cryptography or eSecurity.				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature	Current conference publications, to be announced in time				

<table>
<tr><td>Module
MA-INF 1213</td><td colspan="3">Randomized Algorithms and Probabilistic Analysis</td></tr>
<tr><td>Workload
270 h</td><td>Credit points
9 CP</td><td>Duration
1 semester</td><td>Frequency
every year</td></tr>
<tr><td>Module coordinator</td><td colspan="3">Prof. Dr. Heiko Röglin</td></tr>
<tr><td>Lecturer(s)</td><td colspan="3">Prof. Dr. Heiko Röglin</td></tr>
<tr><td>Classification</td><td>Programme
M. Sc. Computer Science</td><td>Mode
Optional</td><td>Semester
2. or 4.</td></tr>
<tr><td>Technical skills</td><td colspan="3">Understanding of models and techniques for the probabilistic analysis of algorithms as well as for the design and analysis of randomized algorithms</td></tr>
<tr><td>Soft skills</td><td colspan="3">Oral and written presentation of solutions and methods, abstract thinking</td></tr>
<tr><td>Contents</td><td colspan="3">Design and analysis of randomized algorithms
• complexity classes
• Markov chains and random walks
• tail inequalities
• probabilistic method
smoothed and average-case analysis
• simplex algorithm
• local search algorithms
• clustering algorithms
• combinatorial optimization problems
• multi-objective optimization</td></tr>
<tr><td>Prerequisites</td><td colspan="3">none</td></tr>
<tr><td>Format</td><td colspan="3"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lecture</td><td></td><td>4</td><td>60 T / 105 S</td><td>5.5</td></tr><tr><td>Exercises</td><td></td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="3">Oral exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="3">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="3"></td></tr>
<tr><td>Literature</td><td colspan="3">• lecture notes
• research articles
• Motwani, Raghavan, Randomized Algorithms, Cambridge University Press, 1995
• Mitzenmacher, Upfal, Probability and Computing, Cambridge University Press, 2nd edition, 2017</td></tr>
</table>

Module MA-INF 1217	**Seminar Theoretical Foundations of Data Science**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Heiko Röglin				
Lecturer(s)	Prof. Dr. Anne Driemel, Prof. Dr. Thomas Kesselheim, Prof. Dr. Heiko Röglin, PD Dr. Elmar Langetepe, Dr. Herman Haverkort				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	Ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.				
Contents	Current conference and journal papers				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature					

Module MA-INF 1218	**Algorithms and Uncertainty**					
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** at least every 2 years			
Module coordinator	Prof. Dr. Thomas Kesselheim					
Lecturer(s)	Prof. Dr. Thomas Kesselheim					
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.			
Technical skills	Understanding approaches for modeling uncertainty in algorithmic theory. Designing and analyzing algorithms with performance guarantees in the context of uncertainty.					
Soft skills	Oral and written presentation of solutions and methods					
Contents	• Advanced Online Algorithms • Markov Decisions Processes • Stochastic and Robust Optimization • Online Learning Algorithms and Online Convex Optimization • Sample Complexity					
Prerequisites	none					
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**	
	Lecture		4	60 T / 105 S	5.5	
	Exercises		2	30 T / 75 S	3.5	
	T = face-to-face teaching; S = independent study					
Exam achievements	Oral exam (graded)					
Study achievements	Successful exercise participation (not graded)					
Forms of media						
Literature	lecture notes, research articles					

Module MA-INF 1219	**Seminar Algorithmic Game Theory**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Thomas Kesselheim				
Lecturer(s)	Prof. Dr. Thomas Kesselheim				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	Ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to perform individual literature search, critical reading, and clear didactic presentation				
Contents	Advanced topics in Algorithmic Game Theory and Algorithmic Mechanism Design based on current conference and journal papers				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature					

Module MA-INF 1220	**Seminar Algorithms for Computational Analytics**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** at least every year		
Module coordinator	Prof. Dr. Petra Mutzel				
Lecturer(s)	Prof. Dr. Petra Mutzel				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	Ability to perform individual literature search, critical reading, understanding, and clear didactic presentation.				
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.				
Contents	Current topics in algorithms for computational analytics based on recent research literature.				
Prerequisites	**Recommended:** Interest in Algorithms				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature	The relevant literature will be announced in time.				

Module MA-INF 1221	**Lab Computational Analytics**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Petra Mutzel				
Lecturer(s)	Prof. Dr. Petra Mutzel				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	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	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	Design of efficient exact and approximate algorithms and data structures for computational analytics problems.				
Prerequisites	**Recommended:** Interests in algorithms				
Format	**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					
Literature	The relevant literature will be announced in time.				

Module MA-INF 1222	**Lab High Performance Optimization**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Petra Mutzel				
Lecturer(s)	Prof. Dr. Petra Mutzel, Dr. Sven Mallach				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	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	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	none				
Format	**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					
Literature	The relevant literature will be announced in time.				

Module MA-INF 1301	**Algorithmic Game Theory**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every 2 years		
Module coordinator	Prof. Dr. Thomas Kesselheim				
Lecturer(s)	Prof. Dr. Thomas Kesselheim, Senior Prof. Dr. Marek Karpinski				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	The goal is to provide basic techniques and methods related to the Game Theory for analyzing modern Internet-based communication networks and for designing algorithms for the underlying problems of transmission control, resource allocation, mechanism design, market equilibria, combinatorial auctions, and the network cost allocation				
Soft skills	Presentation of solutions and methods, critical discussion of applied methods and techniques				
Contents	The most defining characteristic of the Internet 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. We will address new broadly applicable and unifying techniques that have emerged recently in the above areas and discuss new fundamental paradigms in design of the relevant algorithms.				
Prerequisites	**Recommended:** Introductory knowledge of foundations of algorithms and complexity theory is essential.				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		4	60 T / 105 S	5.5
	Exercises		2	30 T / 75 S	3.5
	T = face-to-face teaching; S = independent study				
Exam achievements	Written exam (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature	• D. P. Bertsekas, A. Nedic, A. E. Ozdaglar: 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 Univ. Press, 1990 • 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, MIT Press, 2001				

Module MA-INF 1304	**Seminar Computational Geometry**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Anne Driemel				
Lecturer(s)	Prof. Dr. Anne Driemel, PD Dr. Elmar Langetepe, Dr. Herman Haverkort				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2-4.		
Technical skills	To independently study problems at research level, based on research publications, to prepare a concise summary, to present the summary in a scientific talk, to lead a critical discussion with other seminar participants.				
Soft skills					
Contents	Current topics in computational geometry.				
Prerequisites	**Recommended:** BA-INF 114 – Grundlagen der algorithmischen Geometrie; MA-INF 1203 – Discrete and Computational Geometry				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media	Multimedia projector, black board.				
Literature	The relevant literature will be announced.				

<table>
<tr><td>Module
MA-INF 1305</td><td colspan="3">Graduate Seminar Chip Design</td></tr>
<tr><td>Workload
180 h</td><td>Credit points
6 CP</td><td>Duration
1 semester</td><td>Frequency
every year</td></tr>
<tr><td>Module coordinator</td><td colspan="3">Prof. Dr. Jens Vygen</td></tr>
<tr><td>Lecturer(s)</td><td colspan="3">All lecturers of Discrete Mathematics</td></tr>
<tr><td>Classification</td><td>Programme
M. Sc. Computer Science</td><td>Mode
Optional</td><td>Semester
3.</td></tr>
<tr><td>Technical skills</td><td colspan="3">Competence to understand new theoretical results and practical solutions in VLSI design and related applications, as well as presentation of such results</td></tr>
<tr><td>Soft skills</td><td colspan="3">Ability to read and understand research papers, abstract thinking, presentation of mathematical results in a talk</td></tr>
<tr><td>Contents</td><td colspan="3">Current topics in chip design and related applications</td></tr>
<tr><td>Prerequisites</td><td colspan="3">Recommended:
At least 1 of the following:
MA-INF 1102 – Combinatorial Optimization
MA-INF 1202 – Chip Design</td></tr>
<tr><td>Format</td><td colspan="3"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Seminar</td><td>10</td><td>4</td><td>60 T / 120 S</td><td>6</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="3">Oral presentation, written report (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="3">(not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="3"></td></tr>
<tr><td>Literature</td><td colspan="3">The topics and the relevant literature will be announced towards the end of the previous semester</td></tr>
</table>

Module MA-INF 1307	**Seminar Advanced Algorithms**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Thomas Kesselheim				
Lecturer(s)	Prof. Dr. Anne Driemel, Prof. Dr. Thomas Kesselheim, Prof. Dr. Heiko Röglin, PD Dr. Elmar Langetepe, Dr. Herman Haverkort				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.		
Technical skills	Presentation of selected advanced topics in algorithm design and various applications				
Soft skills	Ability to perform individual literature search, critical reading, understanding, and clear didactic presentation				
Contents	Advanced topics in algorithm design based on newest research literature				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature	The relevant literature will be announced in time.				

Module MA-INF 1308	**Lab Algorithms for Chip Design**		
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Jens Vygen		
Lecturer(s)	All lecturers of Discrete Mathematics		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.
Technical skills	Competence to implement algorithms for VLSI design, efficient handling of very large instances, testing, documentation. Advanced software techniques.		
Soft skills	Efficient implementation of complex algorithms, abstract thinking, modelling of optimization problem in VLSI design, documentation of source code		
Contents	A currently challenging problem will be chosen each semester. The precise task will be explained in a meeting in the previous semester.		
Prerequisites	**Recommended:** At least 3 of the following: MA-INF 1102 – Combinatorial Optimization MA-INF 1202 – Chip Design MA-INF 1205 – Graduate Seminar Discrete Optimization		
Format	see below		
Exam achievements	Oral presentation, written report (graded)		
Study achievements	(not graded)		
Forms of media			
Literature	The topics and the relevant literature will be announced towards the end of the previous semester		

Format:

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

Module MA-INF 1309	**Lab Efficient Algorithms: Design, Analysis and Implementation**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** at least every year		
Module coordinator	Prof. Dr. Heiko Röglin				
Lecturer(s)	Prof. Dr. Anne Driemel, Prof. Dr. Thomas Kesselheim, Prof. Dr. Heiko Röglin, PD Dr. Elmar Langetepe, Dr. Herman Haverkort				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.		
Technical skills	Ability to design, analyze and implement efficient algorithms for selected computational problems.				
Soft skills	ability to work on advanced algorithmic implementation projects, to work in small teams, clear didactic presentation and critical discussion of results				
Contents	Design of efficient exact and approximate algorithms and data structures for selected computational problems.				
Prerequisites	none				
Format	**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					
Literature	The relevant literature will be announced in time.				

Module MA-INF 1312	**The Art of Cryptography**		
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Dr. Michael Nüsken		
Lecturer(s)	Dr. Michael Nüsken		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.
Technical skills	Insights into the theoretical foundations behind security concerns and measures, and of the interplay between computing power, and security requirements. Mastery of advanced techniques for cryptosystems and cryptanalysis.		
Soft skills	Oral presentation (in tutorial groups), written presentation (of exercise solutions), team collaboration in solving homework problems, critical assessment		
Contents	Possible topics are • pseudorandomness and zero-knowledge, • security reductions, • lattices.		
Prerequisites	**Recommended:** MA-INF 1103 – Cryptography		

Format

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Exam achievements	Written exam (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	
Literature	Varying

Module MA-INF 1314	**Online Motion Planning**		
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	PD Dr. Elmar Langetepe		
Lecturer(s)	Prof. Dr. Rolf Klein, PD Dr. Elmar Langetepe		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1-4.
Technical skills	To acquire fundamental knowledge on topics and methods in online motion planning		
Soft skills			
Contents	Search and exploration in unknown environments (e.g., graphs, cellular environmwents, polygons, strets), online algorithms, competitive analysis, competitive complexity,functional optimization, shortest watchman route, tethered robots, marker algorithms, spiral search, approximation of optimal search paths.		
Prerequisites	**Recommended:** BA-INF 114 – Grundlagen der algorithmischen Geometrie		
Format	see below		
Exam achievements	Oral exam (graded)		
Study achievements	Successful exercise participation (not graded)		
Forms of media	Java applets of geometry lab		
Literature	Scientific research articles will be recommended in the lecture.		

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 1315	**Lab Computational Geometry**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Anne Driemel				
Lecturer(s)	Prof. Dr. Anne Driemel, PD Dr. Elmar Langetepe, Dr. Herman Haverkort				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Ability to design, analyze, implement and document efficient algorithms for selected problems in computational geometry.				
Soft skills	Ability to properly present, defend and discuss design and implementation decisions, to document software according to given rules and to collaborate with other students in small groups.				
Contents	Various problems in computational geometry.				
Prerequisites	none				
Format	**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					
Literature	The relevant literature will be announced in time.				

Module MA-INF 1320	**Lab Advanced Algorithms**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** at least every 2 years		
Module coordinator	Prof. Dr. Thomas Kesselheim				
Lecturer(s)	Prof. Dr. Thomas Kesselheim, Prof. Dr. Heiko Röglin				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	Implementation of algorithms from advanced algorithmic theory, evaluating these algorithm on suitably chosen instances, and discussing how theoretical results transfer to practice.				
Soft skills	Ability to properly present, defend and discuss design and implementation decisions and observed conclusions, and to collaborate with other students in small groups.				
Contents	Various problems from current research and courses on algorithmic theory.				
Prerequisites	none				
Format	**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					
Literature	The relevant literature will be announced in time.				

<table>
<tr><td>Module
MA-INF 1321</td><td colspan="3">Binary Linear and Quadratic Optimization</td></tr>
<tr><td>Workload
180 h</td><td>Credit points
6 CP</td><td>Duration
1 semester</td><td>Frequency
at least every 2 years</td></tr>
<tr><td>Module coordinator</td><td colspan="3">Dr. Sven Mallach</td></tr>
<tr><td>Lecturer(s)</td><td colspan="3">Dr. Sven Mallach</td></tr>
<tr><td>Classification</td><td>Programme
M. Sc. Computer Science</td><td>Mode
Optional</td><td>Semester
2. or 3.</td></tr>
<tr><td>Technical skills</td><td colspan="3">Deeper understanding of computational methods to solve potentially large-scale mixed-integer programs in practice. Application-specific modelling and reformulation of combinatorial optimization problems, handling quadratic objective functions, algorithm design.</td></tr>
<tr><td>Soft skills</td><td colspan="3">Social, methodological, and analytical competences via communication, own development, presentation, and critical assessment of problem formulations, algorithms, and solutions covered in the course or the excercises. Learning to abstract, but also learning the limitations of abstraction.</td></tr>
<tr><td>Contents</td><td colspan="3">Computational methods in (mixed-)integer programming such as cutting plane separation and branch-and-bound along with a short and accessible introduction into their theoretical basis. Study of practically relevant binary linear and binary quadratic optimization problems, e.g., Maximum Cut, Linear Ordering and variants of the Traveling Salesman problem, along with the particular separation problems arising there. If there is time, linearizations of quadratic objective functions and more sophisticated formulations of binary quadratic problems are discussed.</td></tr>
<tr><td>Prerequisites</td><td colspan="3">none</td></tr>
<tr><td>Format</td><td colspan="3"><table>
<tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr>
<tr><td>Lecture</td><td></td><td>2</td><td>30 T / 45 S</td><td>2.5</td></tr>
<tr><td>Exercises</td><td></td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr>
</table>
T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="3">Oral exam (default, possibly changed to written exam during the term) (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="3">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="3"></td></tr>
<tr><td>Literature</td><td colspan="3"></td></tr>
</table>

2 Graphics, Vision, Audio

Module MA-INF 2111	**Foundations of Graphics**		
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Reinhard Klein		
Lecturer(s)	Prof. Dr. Reinhard Klein, Prof. Dr. Andreas Weber, Prof. Dr. Matthias Hullin		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1. or 2.
Technical skills	Knowledge of basic mathematical techniques commonly used in Graphics with a strong emphasis on their application to real world problems.		
Soft skills	Research abilities, information retrieval abilities, collaboration abilities, self management, creativity.		
Contents	Affine and projective transformations with applications to image formation (rigid body motion, cinematic chains); Parametric curves and surfaces with applications to 3D modelling; Ordinary differential equations with applications to physical based modelling		
Prerequisites	**Required:** MA-INF 2101 - Foundations of Graphics, Vision and Audio has not been passed.		
Format	see below		
Exam achievements	Written exam (graded)		
Study achievements	Successful exercise participation (not graded)		
Forms of media			
Literature			

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 2113	**Foundations of Audio Signal Processing**		
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	apl. Prof. Dr. Frank Kurth		
Lecturer(s)	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1.
Technical skills	• Introduction to basic concepts of analog and digital signal processing; • Applications in the field of Audio Signal Processing; • Signal Processing Algorithms; • Implementing basic Signal Processing Algorithms		
Soft skills	Solving basic Signal Processing Problems; Implementing Signal Processing Algorithms using state-of-the-art software frameworks; Capability to analyze; Time management; Presentation skills; Discussing own solutions and solutions of others, and working in groups.		
Contents	Theoretical introduction to analog and digital Signal Processing; Fourier Transforms; Analog to digital Conversion; Digital Filters; Audio Signal Processing Applications; Filter banks; Windowed Fourier Transform; 2D-Signal Processing		
Prerequisites	none		
Format	see below		
Exam achievements	Written exam (graded)		
Study achievements	Successful exercise participation (not graded)		
Forms of media	Slides, Blackboard, Whiteboard		
Literature			

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

<table>
<tr><td>Module
MA-INF 2201</td><td colspan="5">Computer Vision</td></tr>
<tr><td>Workload
270 h</td><td>Credit points
9 CP</td><td>Duration
1 semester</td><td colspan="3">Frequency
every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Jürgen Gall</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Jürgen Gall</td></tr>
<tr><td>Classification</td><td colspan="2">Programme
M. Sc. Computer Science</td><td>Mode
Optional</td><td colspan="2">Semester
1. or 2.</td></tr>
<tr><td>Technical skills</td><td colspan="5">Students will learn about various mathematical methods and their applications to computer vision problems.</td></tr>
<tr><td>Soft skills</td><td colspan="5">Productive work in small teams, development and realization of individual approaches and solutions, critical reflection of competing methods, discussion in groups.</td></tr>
<tr><td>Contents</td><td colspan="5">The class will cover a number of mathematical methods and their applications in computer vision. For example, linear filters, edges, derivatives, Hough transform, segmentation, graph cuts, mean shift, active contours, level sets, MRFs, expectation maximization, background subtraction, temporal filtering, active appearance models, shapes, optical flow, 2d tracking, cameras, 2d/3d features, stereo, 3d reconstruction, 3d pose estimation, articulated pose estimation, deformable meshes, RGBD vision.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Recommended:
Basic knowledge of linear algebra, analysis, probability theory, C++ programming</td></tr>
<tr><td rowspan="4">Format</td><td>Teaching format</td><td>Group size</td><td>h/week</td><td>Workload[h]</td><td>CP</td></tr>
<tr><td>Lecture</td><td></td><td>4</td><td>60 T / 105 S</td><td>5.5</td></tr>
<tr><td>Exercises</td><td></td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr>
<tr><td colspan="5">T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Written exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">• R. Hartley, A. Zisserman: Multiple View Geometry in Computer Vision
• R. Szeliski: Computer Vision: Algorithms and Applications
• S. Prince: Computer Vision: Models, Learning, and Inference</td></tr>
</table>

Module MA-INF 2202	**Computer Animation**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Andreas Weber				
Lecturer(s)	Prof. Dr. Andreas Weber				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Students will learn fundamental paradigms used in computer animation. They will learn to use mathematical models of motions to come up with algorithmic solutions of problems of the synthesis of motions of virtual characters.				
Soft skills	Social competences (work in groups), communicative skills (written and oral presentation)				
Contents	Fundamentals of computer animation; kinematics; representations of motions; motion capturing; motion editing; motion synthesis; facial animations				
Prerequisites	**Recommended:** MA-INF 2111 – Foundations of Graphics				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		4	60 T / 105 S	5.5
	Exercises		2	30 T / 75 S	3.5
	T = face-to-face teaching; S = independent study				
Exam achievements	Written exam (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature	• Dietmar Jackel, Stephan Neunreither, Friedrich Wagner: Methoden der Computeranimation, Springer 2006 • Rick Parent: Computer Animation: Algorithms and Techniques, Morgan Kaufman Publishers 2002 • Frederic I. Parke , Keith Waters: Computer Facial Animation. A K Peters, Ltd. 1996				

Module MA-INF 2203	**Selected Topics in Signal Processing**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	apl. Prof. Dr. Frank Kurth				
Lecturer(s)	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Learning advanced as well as state of the art topics and techniques in digital signal processing. Study examples from the field of digital audio signal processing with a focus on music audio. Develop skills for analysing audio signals and designing audio features for selected application scenarios. Mathematical modelling of signal processing problems in practical applications. Design and implementation of corresponding algorithms and data structures solving those problems. Efficiency issues.				
Soft skills	Capability to analyze. Time management. Strength of purpose. Discussing own solutions and solutions of others.				
Contents	Advanced techniques for filter design, design and extraction of features describing multimedia signals, efficient DSP algorithms, general concepts for content-based analysis of multimedia signals. Selected signal processing applications, for example content-based music analysis, signal compression, denoising, source separation.				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		4	60 T / 105 S	5.5
	Exercises		2	30 T / 75 S	3.5
	T = face-to-face teaching; S = independent study				
Exam achievements	Written exam (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature	• Lecture script and selected research publications • Hayes: Statistical Digital Signal Processing and Modelling, John Wiley, 1996 • Proakis, Manolakis: Digital Signal Processing, Prentice Hall, 1996 • Klapuri, Davy: Signal Processing, Methods for Music Transcription, Springer, 2006				

Module MA-INF 2204	**Rendering Techniques I**				
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Reinhard Klein				
Lecturer(s)	Prof. Dr. Reinhard Klein				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Analytical formulation of problems related to image synthesis and knowledge of techniques and algorithms for the generation of photorealistic image data. 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.				
Soft skills	Analytical problem description, creativity, self-dependent 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 material properties and light sources; transport, volume visualization and rendering equation; algorithms and techniques for the solution of the volume visualization and rendering equation; advanced methods for photorealistic image generation in real-time applications like 3D games. In addition, results from state of the art research will be presented.				
Prerequisites	**Recommended:** Algorithms and data structures, basic knowledge on multidimensional analysis und linear algebra, basic knowledge in stochastics and statistics, numerical analysis and numerical linear algebra, C++				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		2	30 T / 45 S	2.5
	Exercises		2	30 T / 75 S	3.5
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral exam (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature	• L. Szirmay-Kalos: Monte-Carlo Methods in Global Illumination, Institute of Computer Graphics, Vienna University of Technology, Vienna. URL: citeseer.ist.psu.edu/szirmay-kalos00montecarlo.html, 1999/ • P. Dutre, K. Bala, P. Bekaert: Advanced Global Illumination, 2nd ed., B&T, 2006 • M. Pharr, G. Humphreys: Physically Based Rendering, Elsevier, 2004 • J. Kautz, J. Lehtinen, P.-P. Sloan: Precomputed Radiance Transfer: Theory and Practice, Siggraph Course Notes, 2005				

<table>
<tr><td>Module
MA-INF 2205</td><td colspan="5">Geometry Processing I</td></tr>
<tr><td>Workload
180 h</td><td>Credit points
6 CP</td><td>Duration
1 semester</td><td colspan="3">Frequency
every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Reinhard Klein</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Reinhard Klein</td></tr>
<tr><td>Classification</td><td colspan="2">Programme
M. Sc. Computer Science</td><td>Mode
Optional</td><td colspan="2">Semester
2.</td></tr>
<tr><td>Technical skills</td><td colspan="5">Analytical formulation of problems related to geometry processing and knowledge of techniques and algorithms to optimize, process and store geometry data. Especially, learning of techniques to generate highly detailed three-dimensional digital models of real objects and to implement current geometry processing algorithms.</td></tr>
<tr><td>Soft skills</td><td colspan="5">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, self-management</td></tr>
<tr><td>Contents</td><td colspan="5">Topics among other will be: Methods for the generation of polygonal meshes (Laser scanning, registration and integration of single mesh parts, etc.), Point based representations, Reconstruction techniques, Efficient mesh data structures and mesh compression, Optimization: denoising and smoothing, Mesh decimation and refinement, Hierarchical representations: coarse-to-fine und fine-to-coarse, Editing of polygonal meshes. In addition results from state of the art research will be presented.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Recommended:
Algorithms and data structures, basic knowledge on multidimensional analysis und linear algebra, basic knowledge in stochastics and statistics, numerical analysis and numerical linear algebra, C++</td></tr>
<tr><td rowspan="4">Format</td><td>Teaching format</td><td>Group size</td><td>h/week</td><td>Workload[h]</td><td>CP</td></tr>
<tr><td>Lecture</td><td></td><td>2</td><td>30 T / 45 S</td><td>2.5</td></tr>
<tr><td>Exercises</td><td></td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr>
<tr><td colspan="5">T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Oral exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">• R. Scopigno, C. Andujar, M. Goesele, H. Lensch: 3D Data Acquistion, Eurographics Tutorial, 2002
• E. Grinspun, M. Desbrun (organizers): Discrete Differential Geometry: An Applied Introduction, Siggraph Course Notes, 2006
• M. Botsch, M. Pauly: Geometric Modeling Based on Triangle Meshes, Siggraph Course Notes, 2006</td></tr>
</table>

Module MA-INF 2206	**Seminar Vision**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator	Prof. Dr. Jürgen Gall				
Lecturer(s)	Prof. Dr. Jürgen Gall				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	Ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.				
Contents	Current conference and journal papers.				
Prerequisites	**Required:** MA-INF 2201 – Computer Vision				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature					

Module MA-INF 2207	**Seminar Graphics**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator	Prof. Dr. Reinhard Klein				
Lecturer(s)	Prof. Dr. Reinhard Klein				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	Ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.				
Contents	Current conference and journal papers.				
Prerequisites	**Recommended:** Mathematical background (multidimensional analysis and linear algebra, basic numerical methods) Basic knowledge in Computer Graphics				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature					

Module MA-INF 2208	**Seminar Audio**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator	apl. Prof. Dr. Frank Kurth				
Lecturer(s)	apl. Prof. Dr. Frank Kurth, Dr. Michael Clausen				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.				
Contents	Current conference and journal papers.				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature					

Module MA-INF 2209	**Advanced Topics in Computer Graphics I**
Workload 270 h	**Credit points** 9 CP · **Duration** 1 semester · **Frequency** every year
Module coordinator	Prof. Dr. Reinhard Klein
Lecturer(s)	Prof. Dr. Reinhard Klein
Classification	**Programme** M. Sc. Computer Science · **Mode** Optional · **Semester** 2. or 3.
Technical skills	Analytical formulation of problems related to geometry processing and 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.
Soft skills	Based on the knowledge and skills acquired students should be able to • read and judge current scientific literature in the area of geometry processing and rendering • identify the major literature concerning a given problem in geometry processing or rendering and gain an overview of the current state of the art • discuss problems concerning geometry processing or rendering with researchers from different application fields • present and propose different solutions and work in a team to solve a mesh processing or rendering problem • and should have acquired key-competences like motivation to deliver results, flexibility, scientific integrity, ability to adapt to changes and ability to communicate
Contents	Topics among other will be: • methods for the generation of polygonal meshes from point clouds • efficient mesh data structures and mesh compression • mesh optimization techniques: denoising, smoothing, decimation, refinement • mesh editing techniques • optical material properties and light sources • light transport and rendering equation • algorithms and techniques for the solution of the rendering equation • advanced methods for photorealistic image generation. In addition, results from state of the art research will be presented.
Prerequisites	**Required:** Basic knowledge in computer graphics, data structures, multidimensional analysis und linear algebra, numerical analysis and numerical linear algebra, C++
Format	see table below
Exam achievements	Oral presentation, written report (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	
Literature	• M. Botsch, L. Kobbelt, M. Pauly, P. Alliez, B. Levy, Polygon Mesh Processing, A K Peters (7. Oktober 2010) • M. Gross, HP. Pfister, Point-Based Graphics, Morgan Kaufmann (21. Juni 2007) • R. Scopigno, C. Andujar, M. Goesele, H. Lensch: 3D Data Acquistion, Eurographics Tutorial, 2002 • E. Grinspun, M. Desbrun (organizers): Discrete Differential Geometry: An Applied Introduction, Siggraph Course Notes, 2006 • L. Szirmay-Kalos: Monte-Carlo Methods in Global Illumination, Institute of Computer Graphics, Vienna University of Technology, Vienna. URL: citeseer.ist.psu.edu/szirmay-kalos00montecarlo.html, 1999/ • P. Dutre, K. Bala, P. Bekaert: Advanced Global Illumination, 2nd ed., B&T, 2006 • M. Pharr, G. Humphreys: Physically Based Rendering, Elsevier, 2nd revised edition. (26. August 2010)

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 2210	**Seminar Computer Animation**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator	Prof. Dr. Andreas Weber				
Lecturer(s)	Prof. Dr. Andreas Weber				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.				
Contents	Current conference and journal papers.				
Prerequisites	**Recommended:** At least 1 of the following: MA-INF 2202 – Computer Animation; MA-INF 2311 – Lab Computer Animation				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature					

Module MA-INF 2212	**Pattern Matching and Machine Learning for Audio Signal Processing**		
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	apl. Prof. Dr. Frank Kurth		
Lecturer(s)	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.
Technical skills	• Introduction into selected topics of digital signal processing; • Applications in the field of Audio Signal Processing; • Methods of Automatic Pattern Recognition		
Soft skills	Audio Signal Processing Applications; Extended programming skills for signal processing applications; Capability to analyze; Time management; Presentation skills; Discussing own solutions and solutions of others, and working in groups.		
Contents	The lecture is presented in modular form, where each module is motivated from the application side. The presented topics are: Windowed Fourier transforms; Audio Identifications; Audio Matching; Signal Classification; Hidden Markov Models; Support Vector Machines		
Prerequisites	none		

Format

Teaching format	**Group size**	**h/week**	**Workload[h]**	**CP**
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 (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	Slides, Blackboard, Whiteboard
Literature	

Module MA-INF 2213	**Computer Vision II**				
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Jürgen Gall				
Lecturer(s)	Prof. Dr. Jürgen Gall				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	Students will learn about various learning methods and their applications to computer vision problems.				
Soft skills	Productive work in small teams, development and realization of individual approaches and solutions, critical reflection of competing methods, discussion in groups.				
Contents	The class will cover a number of learning methods and their applications in computer vision. For example, linear methods for classification and regression, boosting, random forests, neural networks, SVMs, prototype methods, nearest neighbors, Gaussian processes, metric learning, structured learning, image classification, object detection, action recognition, pose estimation, face analysis, tracking.				
Prerequisites	**Required:** MA-INF 2201 – Computer Vision				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		3	45 T / 45 S	3
	Exercises		1	15 T / 75 S	3
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral exam (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature					

Module MA-INF 2214	**Computational Photography**
Workload 180 h	**Credit points** 6 CP · **Duration** 1 semester · **Frequency** every year
Module coordinator	Prof. Dr. Matthias Hullin
Lecturer(s)	Prof. Dr. Matthias Hullin
Classification	**Programme** M. Sc. Computer Science · **Mode** Optional · **Semester** 2. or 3.
Technical skills	Foundations in optics and image sensors. Signal processing and inverse problems in imaging. Color spaces and perception. Image alignment and blending. High-dimensional representations of light transport (light fields, reflectance fields, reflectance distributions). Computational illumination.
Soft skills	• to read and understand current literature in the field • to implement standard computational photography techniques • to propose and implement solutions to a given problem • to follow good scientific practice by planning, documenting and communicating their work
Contents	• Image sensors • Optics • Panoramas • Light fields • Signal processing and inverse problems • Color, perception and HDR • Reflectance fields and light transport matrices
Prerequisites	**Required:** Basic knowledge in computer graphics, data structures, multidimensional analysis und linear algebra, numerical analysis and numerical linear algebra, C++ or MATLAB
Format	see below
Exam achievements	Oral exam (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	
Literature	

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 2215	**Seminar Digital Material Appearance**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Matthias Hullin				
Lecturer(s)	Prof. Dr. Matthias Hullin				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.				
Contents	Current conference and journal papers				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature					

Module MA-INF 2216	**Lab Visual Computing**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Jun-Prof. Dr. Angela Yao				
Lecturer(s)	Jun-Prof. Dr. Angela Yao				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1-4.		
Technical skills	The students will carry out a practical task (project) in the context of computer vision, including test and documentation of the implemented software/system.				
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	This lab introduces computer vision methods and applications. You will get a chance to study the methods in depth by implementing them and running experiments. At the end of the semester, you will present the method, give a short demonstration and hand in a report describing the method and experimental outcomes.				
Prerequisites	none				
Format	**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					
Literature					

Module MA-INF 2217	**Advanced Deep Learning for Graphics**				
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Reinhard Klein				
Lecturer(s)	Dr. Michael Weinmann				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1-4.		
Technical skills	Students will be introduced to adapt and apply deep learning techniques to various applications in computer graphics.				
Soft skills	Productive work in small teams, development and realization of individual approaches and solutions, critical reflection of competing methods, discussion in groups.				
Contents	This course focuses on cutting-edge Deep Learning techniques for computer graphics. After a brief review of CNNs the focus will be laid on autoencoders, generative models and the extension of these methods to graph- and manifold-structured data. Applications discussed will include inverse problems in computer graphics and the synthesis of models including data 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).				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	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 (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature	No required text, supplemental readings will be given in class.				

Module MA-INF 2218	**Video Analytics**					
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** at least every 2 years			
Module coordinator	Prof. Dr. Jürgen Gall					
Lecturer(s)	Prof. Dr. Jürgen Gall					
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2-4.			
Technical skills	Students will learn advanced techniques for analyzing video data.					
Soft skills	Productive work in small teams, development and realization of a state-of-the-art system for video analysis.					
Contents	The class will discuss state-of-the-art methods for several tasks of video analysis. For example, video clip classification, temporal video segmentation, spatio-temporal action detection, video context, spatio-temporal modeling of humans and objects, anticipation, affordance, video summarization, semantic video segmentation.					
Prerequisites	**Required:** MA-INF 2201 – Computer Vision					
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**	
	Lecture		2	30 T / 45 S	2.5	
	Exercises		2	30 T / 75 S	3.5	
	T = face-to-face teaching; S = independent study					
Exam achievements	Oral exam (graded)					
Study achievements	Successful exercise participation (not graded)					
Forms of media						
Literature						

Module MA-INF 2219	**Seminar Visualization and Medical Image Analysis**		
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every semester
Module coordinator	Prof. Dr. Thomas Schultz		
Lecturer(s)	Prof. Dr. Thomas Schultz		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.
Technical skills	Ability to understand new research results presented in original scientific papers.		
Soft skills	Ability to present and to critically discuss scientific results in the context of the current state of the art. Ability to perform an independent search for relevant scientific literature.		
Contents	Current conference and journal papers		
Prerequisites	**Recommended:** At least one of the following: • MA-INF 2222 – Visual Data Analysis • MA-INF 2312 – Image Acquisition and Analysis in Neuroscience		
Format	see below		
Exam achievements	Oral presentation, written report (graded)		
Study achievements	(not graded)		
Forms of media			
Literature			

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching; S = independent study

Module MA-INF 2220	**Lab Visualization and Medical Image Analysis**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator	Prof. Dr. Thomas Schultz				
Lecturer(s)	Prof. Dr. Thomas Schultz				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	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	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	**Recommended:** At least one of the following: • MA-INF 2222 – Visual Data Analysis • MA-INF 2312 – Image Acquisition and Analysis in Neuroscience				
Format	**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					
Literature					

Module MA-INF 2221	**Seminar Visual Computing**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator	Jun-Prof. Dr. Angela Yao				
Lecturer(s)	Jun-Prof. Dr. Angela Yao				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	Ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.				
Contents	Current conference and journal papers				
Prerequisites	**Required:** At least 1 of the following: MA-INF 2201 – Computer Vision MA-INF 2217 – Advanced Deep Learning for Graphics MA-INF 2313 – Deep Learning for Visual Recognition MA-INF 4315 – Probabilistic Graphical Models				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature					

Module MA-INF 2222	**Visual Data Analysis**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Thomas Schultz				
Lecturer(s)	Prof. Dr. Thomas Schultz, Prof. Dr. Reinhard Klein				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1-4.		
Technical skills	Ability to design, implement, and make proper use of systems for visual data analysis. Knowledge of algorithms and techniques for the visualization of multi-dimensional data, graphs, as well as scalar, vector, and tensor fields.				
Soft skills	Productive work in small teams, self-dependent solution of practical problems in the area of visual data analysis, critical reflection on visualization design, presentation of solution strategies and implementations, self management				
Contents	This class provides a broad overview of principles and algorithms for data analysis via interactive visualization. Specific topics include perceptual principles, luminance and color, visualization analysis and design, integration of visual with statistical data analysis and machine learning, as well as specific algorithms and techniques for the display of multidimensional data, dimensionality reduction, graphs, direct and indirect volume visualization, vector field and flow visualization, as well as tensor field visualization.				
Prerequisites	**Recommended:** Students are recommended to have a basic knowledge in linear algebra and calculus, as well as proficiency in programming.				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		4	60 T / 105 S	5.5
	Exercises		2	30 T / 75 S	3.5
	T = face-to-face teaching; S = independent study				
Exam achievements	Written exam (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature	A.C. Telea, Data Visualization: Principles and Practice. CRC Press, Second Edition, 2015 M. Ward et al., Interactive Data Visualization: Foundations, Techniques, and Applications. CRC Press, 2010 T. Munzner, Visualization Analysis and Design, A K Peters, 2015				

Module MA-INF 2302	**Physics-based Modelling**
Workload 180 h	**Credit points** 6 CP · **Duration** 1 semester · **Frequency** at least every 2 years
Module coordinator	Prof. Dr. Andreas Weber
Lecturer(s)	Prof. Dr. Andreas Weber
Classification	**Programme** M. Sc. Computer Science · **Mode** Optional · **Semester** 3.
Technical skills	Students learn the fundamental techniques of physics-based modelling for computer graphics and computer animation. The students shall be able to choose appropriate mathematical models. Knowing the algorithmic techniques and algorithmic issues, they shall be able to come up with software solutions for specific problems.
Soft skills	Social competences (work in groups), communicative skills (written and oral presentation)
Contents	Initial value problems; particle simulation; rigid body simulation; multi-body-systems; collision detection; collisions response; cloth modelling; hair modelling; physics-based motion synthesis
Prerequisites	**Recommended:** MA-INF 2111 – Foundations of Graphics
Format	see table below
Exam achievements	Oral exam (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	
Literature	• Dietmar Jackel, Stephan Neunreither, Friedrich Wagner: Methoden der Computeranimation, Springer 2006 • David M. Bourg: Physics for Game Developers, O'Reilly • Advanced course notes on physics-based modelling

Format

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 2304	**Rendering Techniques II**				
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Reinhard Klein				
Lecturer(s)	Prof. Dr. Reinhard Klein				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.		
Technical skills	Analytical formulation of problems related to image based rendering and knowledge of advanced techniques in the field of rendering. Knowledge of methods and models for the acquisition and description of light sources and optical material properties for Computer Graphics applications. Knowledge of methods and models for the acquisition and description of image based rendering techniques and digital photography. Self-dependent implementation of the basic algorithms.				
Soft skills	Analytical problem description, creativity, self-dependent solution of practical problems in the area of image based rendering and digital photography, presentation of solution strategies and implementations, self-dependent literature research, collaboration abilities, self-management				
Contents	Topics among others will be: advanced material acquisition and modelling techniques; algorithms and techniques of image based rendering; digital photography for image based scene modelling and rendering; computational photography				
Prerequisites	**Recommended:** Algorithms and data structures, basic knowledge on multidimensional analysis und linear algebra, basic knowledge in stochastics and statistics, numerical analysis and numerical linear algebra, C++				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		2	30 T / 45 S	2.5
	Exercises		2	30 T / 75 S	3.5
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral exam (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature	• H.P.A. Lensch, M. Goesele (organizers): Realistic Materials in Computer Graphics, Siggraph Course Notes, 2005 • P. Debevec, E. Reinhard (organizers): High-Dynamic-Range Imaging: Theory and Applications, Siggraph Course Notes, 2006 • N. Hoffman (organizer): Physically Based Reflectance for Games, Siggraph Course Notes, 2006 • R. Raskar, J. Tumblin (organizers): Computational Photography, Siggraph Course Notes, 2006				

Module MA-INF 2305	**Geometry Processing II**		
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Reinhard Klein		
Lecturer(s)	Prof. Dr. Reinhard Klein		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.
Technical skills	Analytical formulation of problems related to geometry processing, shape analysis and shape retrieval as well as knowledge of advanced algorithms and techniques from these fields. Self-dependent implementation of the algorithms.		
Soft skills	Analytical problem description, creativity, self-dependent solution of practical problems in the area of image based rendering and digital photography, presentation of solution strategies and implementations, self-dependent literature research, collaboration abilities, self-management		
Contents	This class is focussed on advanced topics in the field of geometry processing. Students will get familiar with recent developments in the area of shape analysis and shape retrieval. Topics among others will be • Parameterization of surfaces • Shape segmentation and shape similarity • Shape classification and content based retrieval • Shape spaces and statistical shape analysis		
Prerequisites	**Recommended:** Algorithms and data structures, basic knowledge on multidimensional analysis und linear algebra, basic knowledge in stochastics and statistics, numerical analysis and numerical linear algebra, C++		
Format	see table below		
Exam achievements	Oral exam (graded)		
Study achievements	Successful exercise participation (not graded)		
Forms of media			
Literature	• 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 Wiley & Sons, 1998 • H. Krim, Jr, A. Yezzi (editors): Statistics and Analysis of Shapes (Modeling an Simulation in Science, Engineering and Technology), Birkhäuser Boston, 2006		

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 2306	**Virtual Reality**				
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Reinhard Klein				
Lecturer(s)	Prof. Dr. Reinhard Klein				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.		
Technical skills	Basic knowledge of hard- and software components of current VR-Systems, Broad knowledge of tracking-, collision detection- and real-time rendering algorithms, knowledge of methods to integrate haptic and sound, knowledge of GPU programming with emphasis on special effect generation, ability to implement components of a VR-System				
Soft skills	Analytical problem description, creativity, self-dependent solution of practical problems in the area of Virtual Reality, presentation of solution strategies and implementations, self-dependent literature research, collaboration abilities, self-management				
Contents	Scene Graphs, Stereo Seeing (HW, SW), Tracking (HW, SW), Acceleration Techniques (LOD; Culling), Collision detection, Haptics, Sound, Special effects (GPU-Programming)				
Prerequisites	**Recommended:** Mathematical background (multidimensional analysis and linear algebra, foundations of numerical methods), good knowledge of the foundations of computer graphics				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		2	30 T / 45 S	2.5
	Exercises		2	30 T / 75 S	3.5
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral exam (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature	• K. Stanney (ed.): Handbook of Virtual Environments. Lawrence Erlbaum Associates, 2002 • W. Sherman, A. Craig: Understanding Virtual Reality. Morgan Kaufman, 2002 • D. Pape: Commodity-Based Projection VR, Siggraph Course Notes, 2006 • N. Tatarchuk (organizer): Advanced Real-Time Rendering in ğD Graphics and Games, Siggraph Course Notes, 2006				

Module MA-INF 2307	**Lab Vision**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator	Prof. Dr. Jürgen Gall				
Lecturer(s)	Prof. Dr. Jürgen Gall				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	The students will carry out a practical task (project) in the context of RGB-D cameras.				
Soft skills	Ability to properly present and defend design decisions, to prepare 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	RGBD cameras: research topics and applications				
Prerequisites	**Required:** MA-INF 2201 – Computer Vision Good C++ programming skills				
Format	**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					
Literature	A. Fossati, J. Gall, H. Grabner, X. Ren, K. Konolige. Consumer Depth Cameras for Computer Vision: Research Topics and Applications				

Module MA-INF 2308	**Lab Graphics**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator	Prof. Dr. Reinhard Klein				
Lecturer(s)	Prof. Dr. Reinhard Klein				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.		
Technical skills	The students will carry out a practical task (project) in the context of geometry processing, rendering, scientific visualization or human computer interaction, including test and documentation of the implemented software/system.				
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	Varying selected topics close to current research in the area of geometry processing, rendering, scientific visualization or human computer interaction.				
Prerequisites	none				
Format	**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					
Literature					

Module MA-INF 2309	**Lab Audio**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	apl. Prof. Dr. Frank Kurth				
Lecturer(s)	apl. Prof. Dr. Frank Kurth, Prof. Dr. Michael Clausen				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.		
Technical skills	The students will carry out a practical task (project) in the context of audio and music processing, including test and documentation of the implemented software/system.				
Soft skills	Ability to 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	none				
Format	**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					
Literature					

Module MA-INF 2310	**Advanced Topics in Computer Graphics II**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Reinhard Klein				
Lecturer(s)	Prof. Dr. Reinhard Klein				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.		
Technical skills	• apply methods of geometry and digital appearance processing to real world problems and design and implement novel application software in these areas • apply methods of shape segmentation and shape similarity to novel problems • design novel shape retrieval applications • apply basic concepts of statistical shape analysis and shape spaces to real world applications • apply geometric and radiometric calibration algorithms to camera based acquisition systems • select and apply light source and optical material models for computer graphics applications • incorporate basic image based algorithms into rendering applications				
Soft skills	Analytical problem description, creativity, self-dependent solution of practical problems, presentation of solution strategies and implementations, self-dependent literature research, collaboration abilities, self-management.				
Contents	This class is focused on advanced topics in the field of geometry and digital appearance processing. Students will get familiar with recent developments in the area of shape analysis, shape retrieval, material acquisition and modeling techniques. Topics among others will be • Parameterization of surfaces • Shape segmentation and shape similarity • Shape classification and content based retrieval • Shape spaces and statistical shape analysis • Optical material acquisition and modelling techniques • Algorithms and techniques of image based rendering • Digital photography for image based scene modelling and rendering • Basic computational photography				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		4	60 T / 105 S	5.5
	Exercises		2	30 T / 75 S	3.5
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral exam (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature					

Module MA-INF 2311	**Lab Computer Animation**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** at least every year		
Module coordinator	Prof. Dr. Andreas Weber				
Lecturer(s)	Prof. Dr. Andreas Weber				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.		
Technical skills	The students will carry out a practical task (project) in the context of computer animation, including test and documentation of the implemented software/system.				
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	Varying selected topics close to current research in the area of computer animation.				
Prerequisites	**Recommended:** At least 1 of the following: MA-INF 2202 – Computer Animation MA-INF 2302 – Physics-based Modelling				
Format	**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					
Literature					

Module MA-INF 2312	**Image Acquisition and Analysis in Neuroscience**
Workload 180 h	**Credit points**: 6 CP; **Duration**: 1 semester; **Frequency**: at least every 2 years
Module coordinator	Prof. Dr. Thomas Schultz
Lecturer(s)	Prof. Dr. Thomas Schultz
Classification	**Programme**: M. Sc. Computer Science; **Mode**: Optional; **Semester**: 1-4.
Technical skills	Students will learn about image acquisition and analysis pipelines which are used in neuroscience. They will understand algorithms for image reconstruction, artifact removal, image registration and segmentation, as well as relevant statistical and machine learning techniques. A particular focus will be on data from Magnetic Resonance Imaging and on mathematical models for functional and diffusion MRI data.
Soft skills	Productive work in small teams, self-dependent solution of practical problems in the area of biomedical image processing, presentation of solution strategies and implementations, self management, critical reflection of conclusions drawn from complex experimental data.
Contents	This course covers the full image formation and analysis pipeline that is typically used in biomedical studies, from image acquisition to image processing and statistical analysis.
Prerequisites	**Recommended:** Mathematical background (calculus, linear algebra, statistics); imperative programming.
Format	see table below T = face-to-face teaching; S = independent study
Exam achievements	Oral exam (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	
Literature	• 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 Functional MRI Data Analysis. Cambridge University Press, 2011 • D.K. Jones: Diffusion MRI: Theory, Method, and Applications, Oxford University Press, 2011

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		3	45 T / 45 S	3
Exercises		1	15 T / 75 S	3

Module MA-INF 2313	**Deep Learning for Visual Recognition**		
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Reinhard Klein		
Lecturer(s)	Dr. Michael Weinmann		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1-4.
Technical skills	Students will be introduced to the theory of neural networks and study various applications in computer vision and other topics in AI.		
Soft skills	Productive work in small teams, development and realization of individual approaches and solutions, critical reflection of competing methods, discussion in groups.		
Contents	Deep learning has taken over the machine learning community by storm, with success both in research and commercially. Deep learning is applicable over a range of fields such as computer vision, speech recognition, natural language processing, robotics, etc. This course will introduce the fundamentals of neural networks and then progress to state-of-the-art convolutional and recurrent neural networks as well as their use in applications for visual recognition. Students will get a chance to learn how to implement and train their own network for visual recognition tasks such as object recognition, image segmentation and caption generation.		
Prerequisites	**Recommended:** Students are recommended to have a basic knowledge in probability and statistics and linear algebra as well as proficiency in programming (python or Matlab or C++).		

Format

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Exam achievements	Oral exam (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	
Literature	No required text. Supplemental readings will be provided in the lecture.

Module MA-INF 2314	**Image Processing, Search and Analysis I**						
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year				
Module coordinator	Prof. Dr. Christian Bauckhage						
Lecturer(s)	Prof. Dr. Christian Bauckhage						
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.				
Technical skills	Upon completion, students should be able to • implement basic and advanced methods for digital image processing • implement simple and advanced algorithms for image filtering • implement algorithms for creating artistic image effects • implement algorithms for image warping • implement algorithms for image morphing • implement algorithms for color and intensity manipulation • design and implement their own algorithms for image processing						
Soft skills	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	• technical foundations / hardware aspects of digital photography • mathematical representations of digital images • coordinate systems and coordinate transformations • Fourier transforms and convolutions • low- band-, and high pass filtering • mean- and Gaussian filtering • median filtering and morphological operations • efficient implementations of various kinds of filters • interpolation methods • artistic image effects • image warping • image morphing • physiological foundations of color perception • color spaces • color manipulation						
Prerequisites	none						
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**		
	Lecture		4	60 T / 105 S	5.5		
	Exercises		2	30 T / 75 S	3.5		
	T = face-to-face teaching; S = independent study						
Exam achievements	Written exam (graded)						
Study achievements	Successful exercise participation (not graded)						
Forms of media	• lecture slides are made available online • lecture notes with programming examples are made available online						
Literature	• Gonzales and Woods, "Digital Image Processing" • Jähne, "Digital Image Processing"						

Module MA-INF 2315	**Seminar Computational Photography**			
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year	
Module coordinator	Prof. Dr. Matthias Hullin			
Lecturer(s)	Prof. Dr. Matthias Hullin			
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.	
Technical skills				
Soft skills				
Contents				
Prerequisites	none			

Format

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Exam achievements	Schriftliche Prüfung	(graded)
Study achievements	Erfolgreiche Übungsteilnahme	(not graded)
Forms of media		
Literature		

Module MA-INF 2316	**Lab Digital Material Appearance**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Matthias Hullin				
Lecturer(s)	Prof. Dr. Matthias Hullin				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills					
Soft skills					
Contents					
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		4	60 T / 105 S	5.5
	Exercises		2	30 T / 75 S	3.5
	T = face-to-face teaching; S = independent study				
Exam achievements	Schriftliche Prüfung (graded)				
Study achievements	Erfolgreiche Übungsteilnahme (not graded)				
Forms of media					
Literature					

3 Information and Communication Management

Module MA-INF 3106	**Privacy in Ubiquitous Computing**				
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Jun.-Prof. Dr. Delphine Christin				
Lecturer(s)	Jun.-Prof. Dr. Delphine Christin				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1-3.		
Technical skills	Students gain knowledge about key concepts of privacy (including legal and economical aspects) and field of ubiquitous computing. They are able to identify threats to privacy in given application scenarios. They learn fundamental techniques to protect users' privacy. Relying on this background, they are able to understand and analyze cutting-edge solutions.				
Soft skills	Written and oral communicative skills, critical thinking and problem solving skills, teamwork, and time management				
Contents	Introduction to privacy and ubiquitous computing, privacy threats, privacy-enhancing systems in selected scenarios, usable privacy				
Prerequisites	**Recommended:** MA-INF 3202 – Mobile Communication				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		2	30 T / 45 S	2.5
	Exercises		2	30 T / 75 S	3.5
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral exam (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature	John Krumm, Ubiquitous Computing Fundamentals, Crc Pr Inc, 2009 Alessandro Acquisti, Stefans Gritzalis, Costos Lambrinoudakis, Digital Privacy: Theory, Technologies, and Practices, Auerbach Pubn, 2007 Mireille Hildebrandt, Kieron O'Hara, Michael Waidner, Robert Madelin, Digital Enlightenment Yearbook 2013: The Value of Personal Data, Ios Press, 2013 Jan Camenisch, Simone Fischer-Hübner, Kai Rannenberg, Privacy and Identity Management for Life, Springer, 2011 Additional research literature will be announced during the lecture				

Module MA-INF 3201	**Network Security**		
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Peter Martini		
Lecturer(s)	Prof. Dr. Peter Martini, Dr. Dr. habil. Robert Koch		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.
Technical skills	The students learn fundamental concepts of network security. This includes risks and vulnerabilities of today's computer networks, concepts to increase and testăthe level of security in theseănetworks, a real-life oriented introduction to encryption techniques, their applications and their weaknesses and a discussion of upcoming new technologies.		
Soft skills	Theoretical exercises to support in-depth understanding of lecture topics and to stimulate discussions, practical exercises in teamwork to support time management, targeted organisation of practical work and critical discussion of own and others' results.		
Contents	Threats and attack scenarios, cyber kill chain, organizational aspects, technical aspects: securing networks using different concepts like firewalls and IDS (intrusion detection systems), security protocols for different protocol layers, penetration testing, high security networks, security aspects of IPv6, privacy protection, encryption.		
Prerequisites	**Recommended:** Bachelor level knowledge of basics of communication systems (e.g. BA-INF 101 "Kommunikation in Verteilten Systemen" (German Bachelor Programme Informatik, English lecture slides available)		
Format	see below		
Exam achievements	Written exam (graded)		
Study achievements	Successful exercise participation (not graded)		
Forms of media			
Literature	• William Stallings, Lawrie Brown, Computer Security: Principles and Practice (3rd Edition), Pearson • Christoph Busch, Stephen D. Wolthusen: Netzwerksicherheit, Spektrum Akademischer Verlag • Matt Bishop: Introduction to Computer Security, Addison Wesley		

Format:

Teaching format	**Group size**	**h/week**	**Workload[h]**	**CP**
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

<table>
<tr><td>Module
MA-INF 3202</td><td colspan="3">Mobile Communication</td></tr>
<tr><td>Workload
180 h</td><td>Credit points
6 CP</td><td>Duration
1 semester</td><td>Frequency
every year</td></tr>
<tr><td>Module coordinator</td><td colspan="3">Prof. Dr. Peter Martini</td></tr>
<tr><td>Lecturer(s)</td><td colspan="3">Prof. Dr. Peter Martini, Dr. Matthias Frank</td></tr>
<tr><td>Classification</td><td>Programme
M. Sc. Computer Science</td><td>Mode
Optional</td><td>Semester
2. or 3.</td></tr>
<tr><td>Technical skills</td><td colspan="3">Knowledge about key concepts of mobile communication including mobility management (both technology independent and technology dependent), knowledge about wireless technologies and their interaction with other protocol layers and/or other network technologies, ability to evaluate and assess scenarios with communication of mobile devices. In-depth understanding of communication paradigms of wireless/mobile systems and network elements, productive work in small groups, strengthening skills on presentation and discussion of solutions to current challenges</td></tr>
<tr><td>Soft skills</td><td colspan="3">Theoretical exercises to support in-depth understanding of lecture topics and to stimulate discussions, practical exercises in teamwork to support time management, targeted organisation of practical work and critical discussion of own and others' results</td></tr>
<tr><td>Contents</td><td colspan="3">Mobility Management in the Internet, Wireless Communication Basics, Wireless Networking Technologies, Cellular/Mobile Communication Networks (voice and data communication), Ad-hoc and Sensor Networks.</td></tr>
<tr><td>Prerequisites</td><td colspan="3">Recommended:
Bachelor level knowledge of basics of communication systems (e.g. BA-INF 101 "Kommunikation in Verteilten Systemen" (German Bachelor Programme Informatik, English lecture slides available) and/or MA-INF 3105 – Principles of Distributed Systems</td></tr>
<tr><td>Format</td><td colspan="3"><table>
<tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr>
<tr><td>Lecture</td><td></td><td>2</td><td>30 T / 45 S</td><td>2.5</td></tr>
<tr><td>Exercises</td><td></td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr>
</table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="3">Oral exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="3">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="3"></td></tr>
<tr><td>Literature</td><td colspan="3">• Jochen Schiller: Mobile Communications, Addison-Wesley, 2003
• William Stallings: Wireless Communications and Networking, Prentice Hall, 2002
• Further up-to-date literature will be announced in due course before the beginning of the lecture</td></tr>
</table>

Module MA-INF 3207	**Advanced Logic Programming**		
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Dr. Günter Kniesel		
Lecturer(s)	Dr. Günter Kniesel		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.
Technical skills	Ability to master advanced logic programing techniques and to write clean but highly efficient Prolog programs using these techniques; competence in problem solving using the declarative paradigm; competence in using the non-logical features of Prolog;		
Soft skills	Skills in written and oral presentation of the solutions to programming assignments, collaboration with other students in small teams		
Contents	Quick refresh of logic programming basics and a Prolog development environment, searching, understanding backtracking and the cut, context arguments, difference lists, data structures, constraint programming, meta-programming, meta-interpreters, partial evaluation, partial evaluation of meta-interpreters, efficient Prolog programming, logic program analysis.		
Prerequisites	**Recommended:** Good knowledge of the foundations of Logic Programming		
Format	see table below		
Exam achievements	Written exam (graded)		
Study achievements	Successful exercise participation (not graded)		
Forms of media			
Literature	• W. Clocksin, C. Mellish: Programming in Prolog, Springer. • L. Sterling, E. Shapiro (ed.): The Art of Prolog (2nd ed.) MIT Press. • Richard O'Keefe: The Craft of Prolog, MIT Press.		

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 3209	**Seminar Selected Topics in Communication Management**		
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** at least every year
Module coordinator	Prof. Dr. Peter Martini		
Lecturer(s)	Prof. Dr. Peter Martini, Prof. Dr. Michael Meier		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.
Technical skills	Ability to understand new research results presented in original scientific papers.		
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.		
Contents	Current conference and journal papers, current standardization drafts		
Prerequisites	**Required:** Successful completion of at least one of the following lectures: Principles of Distributed Systems (MA-INF3105), Network Security (MA-INF3201), Mobile Communication (MA-INF3202), IT Security (MA-INF3236)		

Format

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

T = face-to-face teaching; S = independent study

Exam achievements	Oral presentation, written report (graded)
Study achievements	(not graded)
Forms of media	
Literature	The relevant literature will be announced towards the end of the previous semester

Module MA-INF 3215	**Seminar Selected Topics in Malware Analysis and Computer/Network Security**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** at least every year		
Module coordinator	Prof. Dr. Peter Martini				
Lecturer(s)	Prof. Dr. Peter Martini, Prof. Dr. Michael Meier				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	Ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.				
Contents	Current conference and journal papers, current standardization drafts - with a specific topic focus on Malware Analysis, Computer and Network Security				
Prerequisites	**Required:** Successful completion of at least one of the following lectures: Principles of Distributed Systems (MA-INF3105), Network Security (MA-INF3201), Mobile Communication (MA-INF3202), IT Security (MA-INF3236)				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature					

Module MA-INF 3216	**Seminar Sensor Data Fusion**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	P.D. Dr. Wolfgang Koch				
Lecturer(s)	P.D. Dr. Wolfgang Koch				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.				
Contents	Current conference and journal papers				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature	The relevant literature will be announced at the beginning of the seminar.				

Module MA-INF 3218	**Seminar Model-Driven Software Engineering**
Workload 120 h	**Credit points** 4 CP · **Duration** 1 semester · **Frequency** every year
Module coordinator	Dr. Günter Kniesel
Lecturer(s)	Dr. Günter Kniesel
Classification	**Programme** M. Sc. Computer Science · **Mode** Optional · **Semester** 2.
Technical skills	• Understand the differences between model driven and traditional software development • Describe the common features and peculiarities of different model driven development approaches • Assess the suitability of a model driven approach for a given project • Select appropriate tools for model driven development tasks • Explain the individual scientific topic prepared
Soft skills	• Refinement of scientific writing and presentation skills • 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
Contents	Model driven software development concepts, tools and methods. In 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 other software development approaches • Best practice and research issues in model based development
Prerequisites	**Recommended:** MA-INF 3207 – Advanced Logic Programming
Format	see table below T = face-to-face teaching; S = independent study
Exam achievements	Oral presentation, written report (graded)
Study achievements	(not graded)
Forms of media	• Web page: https://sewiki.iai.uni-bonn.de/teaching/seminars/start • Slides (Powerpoint/PDF) • Mailing list for students
Literature	• "Model-Driven Software Development: Technology, Engineering, Management". Thomas Stahl, Markus Voelter, Wiley 2006. • "Model-Driven Software Development". Sami Beydeda , Matthias Book, Volker Gruhn (Eds), ISBN 978-3-540-25613-7, Springer 2005 • David S. Frankel: Model Driven Architecture: Applying MDA to Enterprise Computing, John Wiley

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Seminar	10	2	30 T / 90 S	4

Module MA-INF 3219	**Lab Model-Driven Software Engineering**
Workload 270 h	**Credit points** 9 CP · **Duration** 1 semester · **Frequency** every year
Module coordinator	Dr. Günter Kniesel
Lecturer(s)	Dr. Günter Kniesel
Classification	**Programme** M. Sc. Computer Science · **Mode** Optional · **Semester** 2.
Technical skills	On successful completion of this module, students should be able to: • Describe the process of model driven software development (MDSD) and support this description with personal experiences • Connect model driven software development guidelines to concrete practical examples • Be able to use one or several concrete MDSD tools and techniques and explain their use to others
Soft skills	Students should be able to: • Run a software project based on MDSD tools, techniques and methods • Establish and iteratively evolve a project plan • Collaborate in a team • Estimate the required time and other resources for given tasks • Manage a software development project with time constraints
Contents	Model driven software development methods are the key to a new level 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 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 format:** Lab · **Group size:** 8 · **h/week:** 4 · **Workload[h]:** 60 T / 210 S · **CP:** 9 T = face-to-face teaching; S = independent study
Exam achievements	Oral presentation, written report (graded)
Study achievements	(not graded)
Forms of media	• Web page: https://sewiki.iai.uni-bonn.de/teaching/labs/start • Slides (Powerpoint/PDF) • Wiki as a shared knowledge base • Task Tracking System (Electronical or Physical) • Shared repository for source code and development documents • Mailing list
Literature	• "Model-Driven Software Development: Technology, Engineering, Management". Thomas Stahl, Markus Voelter, Wiley 2006. • "Model-Driven Software Development". Sami Beydeda , Matthias Book, Volker Gruhn (Eds), ISBN 978-3-540-25613-7, Springer 2005 • David S. Frankel: Model Driven Architecture: Applying MDA to Enterprise Computing, John Wiley • Modellgetriebene Softwareentwicklung, Techniken, Engineering, Management. dPunkt, 2005

Module MA-INF 3222	**eSecurity**			
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year	
Module coordinator	Prof. Dr. Joachim von zur Gathen			
Lecturer(s)	Prof. Dr. Joachim von zur Gathen, Dr. Michael Nüsken			
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.	
Technical skills	Understanding of security concerns and measures, and of the interplay between computing power and security requirements in the realm of real-world applications, in particular internet-based ones. Mastery of advanced techniques for the design of cryptosystems and practical cryptanalysis.			
Soft skills	Oral presentation (in tutorial groups), written presentation (of exercise solutions), team collaboration in solving homework problems, critical assessment.			
Contents	First focus: security on the internet and secure protocols. Furthermore: at least one real world application, for example • electronic health cards, • electronic elections, or • electronic passports.			
Prerequisites	**Required:** MA-INF 1103 – Cryptography			
Format	see below			
Exam achievements	Written exam (graded)			
Study achievements	Successful exercise participation (not graded)			
Forms of media				
Literature	Varying according to the selected topic			

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 3227	**Seminar Anonymity and Privacy on the Internet**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Björn Scheuermann				
Lecturer(s)	Prof. Dr. Björn Scheuermann				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.				
Contents	Current conference and journal papers.				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature					

Module MA-INF 3229	**Lab IT-Security**		
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every semester
Module coordinator	Prof. Dr. Michael Meier		
Lecturer(s)	Prof. Dr. Michael Meier		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.
Technical skills	The students will carry out a practical task (project) in the context of IT Security, including test and documentation of the implemented software/system.		
Soft skills	Ability to 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	none		
Format			
Exam achievements	Oral presentation, written report (graded)		
Study achievements	(not graded)		
Forms of media			
Literature			

Format:

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

Module MA-INF 3233	**Advanced Sensor Data Fusion in Distributed Systems**					
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year			
Module coordinator	PD Dr. Wolfgang Koch					
Lecturer(s)	Dr. Felix Govaers					
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.			
Technical skills	For challenging state estimation tasks, algorithms which enhance the situational awareness by fusing sensor information are inevitable. Nowadays it has become very popular to improve the performance of systems by linking multiple sensors. This implies some challenges to the sensor data fusion methodologies such as sensor registration, communication delays, and correlations of estimation errors. In particular, if the communication links have 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 formula, the Federated Kalman Filter, naive fusion, the distributed Kalman filter and the least squares estimate.					
Soft skills	Mathematical derivation of algorithms, application of mathematical results on estimation theory.					
Contents	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 fusion, product representation					
Prerequisites	**Recommended:** At least 1 of the following: BA-INF 137 – Einführung in die Sensordatenfusion MA-INF 3310 – Introduction to Sensor Data Fusion - Methods and Applications					
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**	
	Lecture		2	30 T / 45 S	2.5	
	Exercises		2	30 T / 75 S	3.5	
	T = face-to-face teaching; S = independent study					
Exam achievements	Oral exam (graded)					
Study achievements	Successful exercise participation (not graded)					
Forms of media	Power Point					
Literature	W. Koch: "Tracking and Sensor Data Fusion: Methodological Framework and Selected Applications", Springer, 2014. D. Hall, C.-Y. Chong, J. Llinas, and M. L. II: "Distributed Data Fusion for Network-Centric Operations", CRC Press, 2014.					

Module MA-INF 3234	**Lab Mobile Sensing Systems**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Jun.-Prof. Dr. Delphine Christin				
Lecturer(s)	Jun.-Prof. Dr. Delphine Christin				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	The students will design and implement practical solutions specially tailored to the requirements of mobile sensing systems, including programming mobile devices and the corresponding infrastructure.				
Soft skills	Organized in small teams, the students will interact and cooperate to fulfill the assignment. They will analyze the design space and make design decisions based on this analysis. The design decisions and the resulting solution will be documented in a written report and presented to other students.				
Contents	Mobile sensing systems leverage mobile phones as a new generation of sensing platforms. Embedded sensors, such as cameras, microphone, GPS, and accelerometers, are used to capture contextual information about the users and their surrounding environment. Within the scope of this lab, the students will explore and contribute to this challenging research field by addressing selected topics, such as: • New mobile sensing scenarios and applications • Reputation mechanisms to identify erroneous contributions • Incentive schemes to encourage users' contributions • Usable privacy interfaces				
Prerequisites	**Recommended:** MA-INF 3202 – Mobile Communication				
Format	**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					
Literature	Burke, J., Estrin, D., Hansen, M., Parker, A., Ramanathan, N., Reddy, S., Srivastava, M., 2006. Participatory sensing. In: Proceedings of the 1st Workshop on World- Sensor-Web (WSW), pp. 1–5. Campbell, A., Eisenman, S., Lane, N., Miluzzo, E., Peterson, R., 2006. People-centric urban sensing. In: Proceedings of the 2nd Annual International Wireless Internet Conference (WICON), pp. 18–31. Campbell, A., Eisenman, S., Lane, N., Miluzzo, E., Peterson, R., Lu, H., Zheng, X., Musolesi, M., Fodor, K., Eisenman, S., Ahn, G., 2008. The rise of people-centric sensing. IEEE Internet Computing 12, 12–21. Christin, D., Reinhardt, A., Kanhere, S., Hollick, M., A survey on privacy in mobile participatory sensing applications, Journal of Systems and Software, Volume 84, Issue 11, 2011,1928-1946.				

Module MA-INF 3235	**Usable Security and Privacy**			
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year	
Module coordinator	Prof. Dr. Matthew Smith			
Lecturer(s)	Prof. Dr. Matthew Smith			
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1.	
Technical skills	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 scientific literature • Communication skills • Team working skills			
Contents	The lecture on Usable Security and Privacy deals with many aspects of human factors and usability in the context of security and privacy. The lecture includes both the foundations of usable security and privacy as well as a selection of cutting edge international research in this area. Topics include: • Evaluation of usability issues of existing security & privacy models or technology • Design and evaluation of new usable security & privacy technology • Impact of organizational policy on security and privacy interaction • Lessons learned from designing, deploying, managing or evaluating security & privacy technologies • Foundations of usable security & privacy • Methodology for usable security & privacy research • Ethical, psychological, sociological and economic aspects of security & privacy technologies			
Prerequisites	**Required:** Knowledge about IT Security is advantageous but not mandatory. **Recommended:** At least 1 of the following: BA-INF 138 – IT-Sicherheit BA-INF 136 – Reaktive Sicherheit MA-INF 1103 – Cryptography MA-INF 3229 – Lab IT-Security			
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]** / **CP**
	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 (graded)			
Study achievements	Successful exercise participation (not graded)			
Forms of media				
Literature				

Module MA-INF 3236	**IT Security**		
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Michael Meier		
Lecturer(s)	Prof. Dr. Michael Meier		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1. or 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	• security threats • advanced network security: internet routing security, network attack detection, network information hiding • cryptographic key management • building automation security • advanced host security • security patterns • privacy and pseudonymization		
Prerequisites	**Required:** Fundamental knowledge in the following areas: operating systems, networks, security		
Format	see below		
Exam achievements	Written exam (graded)		
Study achievements	Successful exercise participation (not graded)		
Forms of media			
Literature			

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 3237	**Array Signal and Multi-channel Processing**		
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Wolfgang Koch		
Lecturer(s)	Dr. Marc Oispuu		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.
Technical skills	Localization of multiple sources using passive sensors is a fundamental task encountered in various fields like wireless communication, radar, sonar, and seismology. In this lecture, a unified framework for electromagnetic and acoustic signals and signal processing techniques are presented. Furthermore, the sensor calibration, direction finding, and bearings-only localization problem are considered. Special applications are emphasized, like small airborne arrays for unmanned aerial vehicles (UAVs).		
Soft skills	Mathematical derivation of algorithms, applications of mathematical results on estimation theory		
Contents	Estimation theory, Sensor model, Cramér-Rao analysis, conventional beamforming, Multiple Signal Classification (MUSIC), sensor calibration, Bearings-only localization, Direct Position Determination (DPD), Applications		
Prerequisites	**Recommended:** Recommended: F. Kurth: “Foundations of Audio Signal Processing” (MA-INF 2113)		

Format

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Exam achievements	Oral Exam (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	Power Point
Literature	H. L. van Trees, Optimum Array Processing. Part IV of Detection, Estimation, and Modulation Theory. New York: Wiley-Interscience, 2002.

Module MA-INF 3304	**Lab Communication and Communicating Devices**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator	Prof. Dr. Peter Martini				
Lecturer(s)	Prof. Dr. Peter Martini, Prof. Dr. Michael Meier				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	The students will carry out a practical task (project) in the context of communication systems, including test and documentation of the implemented software/system.				
Soft skills	Work in small teams and cooperate with other teams in a group; ability to make design decisions in a practical task; present and discuss (interim and final) results in the team/group and to other students; prepare written documentation of the work carried out				
Contents	Selected topics close to current research in the area of communication systems, network security, mobile communication and communicating devices.				
Prerequisites	**Required:** Successful completion of at least one of the following lectures: Principles of Distributed Systems (MA-INF3105), Network Security (MA-INF3201), Mobile Communication (MA-INF3202), IT Security (MA-INF3236)				
Format	**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					
Literature	The relevant literature will be announced towards the end of the previous semester.				

Module MA-INF 3305	**Lab Information Systems**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** at least every year		
Module coordinator	Dr. Thomas Bode				
Lecturer(s)	Dr. Thomas Bode				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	The students will carry out a practical task (project) in the context of information systems, including test and documentation of the implemented software/system.				
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	Varying selected topics close to current research in the area of database- and information systems.				
Prerequisites	none				
Format	**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					
Literature	The relevant literature will be announced towards the end of the previous semester.				

Module MA-INF 3309	**Lab Malware Analysis**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator	Prof. Dr. Peter Martini				
Lecturer(s)	Prof. Dr. Peter Martini, Prof. Dr. Michael Meier				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.		
Technical skills	The students will carry out a practical task (project) in the context of communication systems with a specific topic focus 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 discuss (interim and final) results in the team/group and to other students; prepare written documentation of the work carried out				
Contents	Selected topics close to current research in the area of communication systems, malware analysis, computer and network security.				
Prerequisites	**Required:** Successful completion of at least one of the following lectures: Principles of Distributed Systems (MA-INF3105), Network Security (MA-INF3201), Mobile Communication (MA-INF3202), IT Security (MA-INF3236)				
Format	**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					
Literature					

Module MA-INF 3310	**Introduction to Sensor Data Fusion - Methods and Applications**				
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	P.D. Dr. Wolfgang Koch				
Lecturer(s)	P.D. Dr. Wolfgang Koch				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.		
Technical skills	All participants shall get known to the basic theory of sensor data fusion. The lecture starts with preliminaries on how to handle uncertain data and knowledge within analytical calculus. Then, the fundamental and well-known Kalman filter is derived. Based on this tracking scheme, further approaches to a wide spectrum of applications will be shown. All algorithms will be motivated by examples from ongoing research projects, industrial cooperations, and impressions of current demonstration hardware. Because of inherent practical issues, every sensor measures certain properties up to an error. This lecture shows how to model and overcome this error by an application of theoretical tools such as Bayes' rule and further derivations. Moreover, solutions to possible false-alarms, miss-detections, maneuvering phases, and much more will be presented.				
Soft skills	Mathematical derivation of algorithms, application of mathematical results on estimation theory.				
Contents	Gaussian probability density functions, Kalman filter, Multi-Hypothesis-Trackier, Interacting Multiple Model Filter, Retrodiction, Smoothing, Maneuver Modeling				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		2	30 T / 45 S	2.5
	Exercises		2	30 T / 75 S	3.5
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral exam (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature	W. Koch: "Tracking and Sensor Data Fusion: Methodological Framework and Selected Applications", Springer, 2014. Y. Bar-Shalom: "Estimation with Applications to Tracking and Navigation", Wiley-Interscience, 2001.				

Module MA-INF 3311	**Topics in Applied Cryptography**		
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Joachim von zur Gathen		
Lecturer(s)	Prof. Dr. Joachim von zur Gathen, Dr. Michael Nüsken		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.
Technical skills	Gain deeper understanding in a special area of cryptography close to current research.		
Soft skills	Oral presentation (in tutorial groups), written presentation (of exercise solutions), team collaboration in solving homework problems, critical assessment.		
Contents	One varying, advanced topic related to current research in applied cryptography, e.g. • mobile security, or • design and analysis of hash functions.		
Prerequisites	**Required:** MA-INF 1103 – Cryptography and one further course in cryptography like The Art of Cryptography or eSecurity.		
Format	see table below		
Exam achievements	Written exam (graded)		
Study achievements	Successful exercise participation (not graded)		
Forms of media			
Literature			

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 3312	**Lab Sensor Data Fusion**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	P.D. Dr. Wolfgang Koch				
Lecturer(s)	P.D. Dr. Wolfgang Koch				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 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 part in the context of a main goal. Results will be exchanged and integrated via software interfaces.				
Contents	Varying selected topics on sensor data fusion.				
Prerequisites	none				
Format	**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					
Literature	The relevant literature will be announced at the beginning of the lab.				

Module MA-INF 3317	**Seminar Selected Topics in IT Security**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Michael Meier				
Lecturer(s)	Prof. Dr. Michael Meier, Prof. Dr. Peter Martini				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.				
Contents	Current conference and journal papers				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature					

Module MA-INF 3318	**Seminar Verification of Complex Systems**			
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** at least every 2 years	
Module coordinator	Jun.-Prof. Dr. Janis Voigtländer			
Lecturer(s)	Jun.-Prof. Dr. Janis Voigtländer			
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.	
Technical skills	Knowledge in topics in the area of specifying and verifying behaviour of complex systems such as software. Competence to mine for profound knowledge about a given subject, in particular acquiring and studying original literature. Understanding scientific publications, often written tersely. Distilling this into suitable presentations; determination of relevant vs. irrelevant material. Presenting research results to others, in writing and in oral presentations, and discussing them with an audience. Ability to discuss and evaluate presentations of fellow students, and to constructively deal with critical feedback by others.			
Soft skills	Communication skills (preparing and presenting talks, using visual media, preparing a structured written document), social skills (motivating other students, ability to accept and formulate 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 software. Theoretical foundations for such techniques, as well as consideration of practical tools. Spectrum ranging from formal to semi-formal; positioning of techniques within this spectrum. Specific themes of interest include: • Specification formalisms and languages • Decision problems • Modelling desired properties of a system • Model checking • Theorem proving • Static (flow) analysis, abstract interpretation • Code analysis using heuristics • Testing (approaches, frameworks, coverage criteria) • Runtime verification (instrumentation, monitoring) • Applications and pragmatics of verification A selection of topics will be made in each semester.			
Prerequisites	none			
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]** / **CP**
	Seminar	10	2	30 T / 90 S / 4
	T = face-to-face teaching; S = independent study			
Exam achievements	Oral presentation, written report (graded)			
Study achievements	(not graded)			
Forms of media				
Literature	The relevant literature will be announced in time.			

Module MA-INF 3319	**Lab Usable Security and Privacy**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Matthew Smith				
Lecturer(s)	Prof. Dr. Matthew Smith				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	The students will carry out a practical task (project) in the 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 degree of freedom to chose their own topics within the context of human aspects of security and privacy.				
Prerequisites	**Required:** MA-INF 3235 – Usable Security and Privacy				
Format	**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					
Literature					

Module MA-INF 3320	**Lab Security in Distributed Systems**
Workload 270 h	**Credit points** 9 CP; **Duration** 1 semester; **Frequency** every year
Module coordinator	Prof. Dr. Matthew Smith
Lecturer(s)	Prof. Dr. Matthew Smith
Classification	**Programme** M. Sc. Computer Science; **Mode** Optional; **Semester** 2.
Technical skills	The students will carry out a practical task (project) in the context of distributed security, including documentation of the implemented software/system. 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 distributed systems, including amongst others: • Secure Messaging • App Security • SSL/HTTPS • API Security • Machine Learning for Security • Passwords • Intrusion Detection Systems • Anomaly Detection • Security Visualisation
Prerequisites	none
Format	see below
Exam achievements	Oral presentation, written report (graded)
Study achievements	(not graded)
Forms of media	
Literature	

Format:

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

Module MA-INF 3321	**Seminar Usable Security and Privacy**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Matthew Smith				
Lecturer(s)	Prof. Dr. Matthew Smith				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.				
Contents	Current conference and journal papers				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature					

Module MA-INF 3322	**Program Analysis and Binary Exploitation**				
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Peter Martini				
Lecturer(s)	Prof. Dr. Peter Martini, Dr. Elmar Padilla				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 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 Discovery in Computer Programs, Application of taught Techniques, Working with Binary Representations, Assembly				
Contents	Our computers run a lot of closed source binary programs meaning that the source code of those programs is not available. Naturally, those programs contain bugs, mistakes that the programmer made during the development. Those bugs could (under certain circumstances) be exploited by attackers and thus may lead to arbitrary code execution. In this lecture we aim to teach you how to find well known exploitable bugs and how to exploit them. 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:** none **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) and also know basic Python programming.				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	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 exam (depending on number of qualified students) (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature	The relevant literature will be announced at the beginning of the lecture				

Module MA-INF 3323	**Lab Fuzzing Bootcamp**					
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year			
Module coordinator	Prof. Dr. Matthew Smith					
Lecturer(s)	Prof. Dr. Matthew Smith					
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 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 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	none					
Format	**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						
Literature						

Module MA-INF 3324	**Lab Design of Usable Security Mechanisms**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Matthew Smith				
Lecturer(s)	Dr. Emmanuel von Zezschwitz				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. 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 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	none				
Format	**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					
Literature					

4 Intelligent Systems

<table>
<tr><td>Module
MA-INF 4111</td><td colspan="5">Intelligent Learning and Analysis Systems: Machine Learning</td></tr>
<tr><td>Workload
180 h</td><td>Credit points
6 CP</td><td>Duration
1 semester</td><td colspan="3">Frequency
every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Stefan Wrobel</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Stefan Wrobel</td></tr>
<tr><td>Classification</td><td colspan="2">Programme
M. Sc. Computer Science</td><td>Mode
Optional</td><td colspan="2">Semester
1. or 2.</td></tr>
<tr><td>Technical skills</td><td colspan="5">This module is one of two complementary modules in which students gain an understanding of the most important paradigms and methods of intelligent learning systems as they are used in data analysis and/or for implementing adaptive behaviour (machine learning, data mining, knowledge discovery in databases). This module concentrates on the core task of predictive learning from examples and on agent learning, and teaches the main classes of algorithms for these tasks. At the end of the module, students will be capable of choosing appropriate methods and systems for particular predictive learning applications and use them to arrive at convincing results, and will know where to start whenever adaptation or further development of algorithms and systems is necessary. This module complements MA-INF 4112 and can be taken before or after that module.</td></tr>
<tr><td>Soft skills</td><td colspan="5">Communicative skills (oral and written presentation of solutions, discussions in small teams), self competences (ability to accept and formulate criticism, ability to analyze problems)</td></tr>
<tr><td>Contents</td><td colspan="5">Types of learning and analysis tasks, most important non-parametric and parametric methods for supervised learning (e.g., decision trees, rules, linear methods, neural networks, neighbourhood methods, kernel methods, probabilistic approaches), reinforcement learning, evaluation and learning theory.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Required:
MA-INF 4102 - Intelligent Learning and Analysis Systems has not been passed.
Recommended:
Prior knowledge of probability theory, linear algebra, artificial intelligence, information systems and data bases</td></tr>
<tr><td rowspan="3">Format</td><td>Teaching format</td><td>Group size</td><td>h/week</td><td>Workload[h]</td><td>CP</td></tr>
<tr><td>Lecture
Exercises</td><td></td><td>2
2</td><td>30 T / 45 S
30 T / 75 S</td><td>2.5
3.5</td></tr>
<tr><td colspan="5">T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Written exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5">Lectures, exercises, software packages</td></tr>
<tr><td>Literature</td><td colspan="5">- Tom Mitchell, Machine Learning, McGraw-Hill, 1997
- Ian Witten, Eibe Frank, Data Mining, Morgan Kauffmann, 2000</td></tr>
</table>

Module MA-INF 4112	**Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery**
Workload 180 h	**Credit points** 6 CP; **Duration** 1 semester; **Frequency** every year
Module coordinator	Prof. Dr. Stefan Wrobel
Lecturer(s)	Prof. Dr. Wrobel
Classification	**Programme** M. Sc. Computer Science; **Mode** Optional; **Semester** 1. or 2.
Technical skills	This module is one of two complementary modules in which students gain an understanding of the most important paradigms and methods of intelligent learning systems as they are used in data analysis and/or for implementing adaptive behaviour (machine learning, data mining, knowledge discovery in databases). This module concentrates on the core tasks of pattern discovery in databases and teaches the main classes of algorithms for this task (subgroups discovery. At the end of the module, students will be capable of choosing appropriate methods and systems for particular pattern discovery applications and use them to arrive at convincing results, and will know where to start whenever adaptation or further development of algorithms and systems is necessary. This module complements MA-INF 4111 and can be taken before or after that module.
Soft skills	Communicative skills (oral and written presentation of solutions, discussions in small teams), self competences (ability to accept and formulate criticism, ability to analyze problems)
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.
Prerequisites	**Required:** MA-INF 4102 - Intelligent Learning and Analysis Systems has not been passed. **Recommended:** Prior knowledge of probability theory, linear algebra, artificial intelligence, information systems and data bases
Format	see table below
Exam achievements	Written exam (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	Lectures, exercises, software packages
Literature	- Ian Witten, Eibe Frank, Data Mining, Morgan Kauffmann, 2000 - Jiawei Han, Micheline Kamber, Data Mining: Concepts and Techniques, Morgan Kaufmann, 2000

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 4113	**Cognitive Robotics**		
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Sven Behnke		
Lecturer(s)	Prof. Dr. Sven Behnke		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1. or 2.
Technical skills	This lecture is one of two introductory lectures of the intelligent systems track. The lecture covers cognitive capabilities of robots, like self-localization, mapping, object perception, and action-planning in complex environments. This module complements MA-INF 4114 and can be taken before or after that module.		
Soft skills	Communicative skills (oral and written presentation of solutions, discussions in small teams), self competences (ability to accept and formulate criticism, ability to analyze problems)		
Contents	Probabilistic approaches to state estimation (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, path planning, place- and person recognition, object recognition.		
Prerequisites	**Required:** MA-INF 4101 - Theory of Sensorimotor Systems has not been passed.		
Format	see table below		
Exam achievements	Written exam (graded)		
Study achievements	Successful exercise participation (not graded)		
Forms of media			
Literature	• S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005. • B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008. • R. Szeliski: Computer Vision: Algorithms and Applications, Springer 2010.		

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

<table>
<tr><td>Module
MA-INF 4114</td><td colspan="5">Robot Learning</td></tr>
<tr><td>Workload
180 h</td><td>Credit points
6 CP</td><td colspan="2">Duration
1 semester</td><td colspan="2">Frequency
every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Sven Behnke</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Sven Behnke, Dr. Nils Goerke</td></tr>
<tr><td>Classification</td><td colspan="2">Programme
M. Sc. Computer Science</td><td colspan="2">Mode
Optional</td><td>Semester
1. or 2.</td></tr>
<tr><td>Technical skills</td><td colspan="5">This lecture is one of two introductory lectures of the intelligent 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 learning approach to get closer towards human-like performance in robotics, such as reinforcement learning, learning 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.</td></tr>
<tr><td>Soft skills</td><td colspan="5">Communicative skills (oral and written presentation of solutions, discussions in small teams), self competences (ability to accept and formulate criticism, ability to analyze problems)</td></tr>
<tr><td>Contents</td><td colspan="5">Reinforcement learning, Markov decision processes, dynamic programming, Monte Carlo methods, temporal-difference methods, function approximation, liear quadratic regulation, differential dynamic programming, partially observable MDPs, policy gradient methods, inverse reinforcement learning, imitation learning, learning kinematic models, perceiving and handling of objects.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">none</td></tr>
<tr><td rowspan="4">Format</td><td>Teaching format</td><td>Group size</td><td>h/week</td><td>Workload[h]</td><td>CP</td></tr>
<tr><td>Lecture</td><td></td><td>2</td><td>30 T / 45 S</td><td>2.5</td></tr>
<tr><td>Exercises</td><td></td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr>
<tr><td colspan="5">T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Oral exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">• R. Sutton and A. Barto: Reinforcement Learning, MIT-Press, 1998.
• O. Sigaud and J. Peters (Eds.): From Motor Learning to Interaction Learning in Robots. Springer, 2010.</td></tr>
</table>

Module MA-INF 4201	**Artificial Life**		
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Sven Behnke		
Lecturer(s)	Prof. Dr. Sven Behnke, Dr. Nils Goerke		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1-3.
Technical skills	Detailed understanding of the most important approaches and principles of artificial life. Knowledge and understanding of the current state of research in the field of artificial life		
Soft skills	Capability to identify the state of the art in artificial life, and to present and defend the found solutions within the exercises in front of a group of students. Critical discussion of the results of the homework.		
Contents	Foundations of artificial life, cellular automata, Conway's "Game of Life"; mechanisms for structural development; foundations of nonlinear dynamical systems, Lindenmeyer-systems, evolutionary methods and genetic algorithms, reinforcement learning, artificial immune systems, adaptive behaviour, self-organising criticality, multi-agent systems, and swarm intelligence, particle swarm optimization.		
Prerequisites	none		

Format

Teaching format	Group size	h/week	Workload[h]	CP
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 (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	Pencil and paper work, explain solutions in front of athe exercise group, implementation of small programs, use of simple simulation tools.
Literature	• Christoph Adami: Introduction to Artificial Life, The Electronic Library of Science, TELOS, Springer-Verlag • Eric Bonabeau, Marco Dorigo, Guy Theraulaz: Swarm Intelligence: From Natural to Artificial Systems, Oxford University Press, Santa Fe Institute Studies in the Science of Complexity. • Andrzej Osyczka: Evolutionary Algorithms for Single and Multicriteria Design Optimization, Studies in Fuzzyness and Soft Computing, Physica-Verlag, A Springer-Verlag Company, Heidelberg

Module MA-INF 4203	**Autonomous Mobile Systems**		
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Sven Behnke		
Lecturer(s)	Dr. Dirk Schulz, Prof. Dr. Sven Behnke		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.
Technical skills	Profound knowledge of development and test regarding structure and function of learning, autonomous, mobile systems; Knowledge of the computational, mathematical, and technical requirements for the design of autonomous systems for specific applications and for specific functional environments		
Soft skills	The students will be capable to assess applications for autonomous mobile systems. They will be capable to identify what part of the applications might be improved by using state of the art developments. The student will learn how to plan and implement a software project in small working groups.		
Contents	Requirements for the implementation of autonomous mobile systems, e.g. for: map making, dead reckoning, localisation, SLAM-methods, various principles of robot path planning; methods for action planning. Comparison of different learning paradigms for specific applications.		
Prerequisites	**Recommended:** all of the following: MA-INF 4101 – Theory of Sensorimotor Systems MA-INF 4113 – Cognitive Robotics		

Format

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Exam achievements	Oral exam	(graded)
Study achievements	Successful exercise participation	(not graded)
Forms of media		
Literature	• J. Buchli: Mobile Robots: Moving Intelligence, Published by Advanced Robotic Systems and Pro Literatur Verlag • Sebastian Thrun, Wolfram Burgard, Dieter Fox: Probabilistic Robotics, MIT Press, 2005 • Howie Choset et al.: Principles of Robot Motion, MIT-Press, 2005	

Module MA-INF 4204	**Technical Neural Nets**			
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year	
Module coordinator	Prof. Dr. Joachim K. Anlauf			
Lecturer(s)	Prof. Dr. Joachim K. Anlauf, Dr. Nils Goerke			
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 1-3.	
Technical skills	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 will be capable to propose several paradigms from neural networks that are capable to solve a given task. They can discuss the pro and cons with respect to efficency and risk. The will be capable to plan and implement a small project with state of the art neural network solutions.			
Contents	Multi-layer perceptron, radial-basis function nets, Hopfield nets, self organizing maps (Kohonen), adaptive resonance theory, learning vector quantization, recurrent networks, back-propagation of error, reinforcement learning, Q-learning, support vector machines, pulse processing neural networks. Exemplary applications of neural nets: function approximation, prediction, quality control, image processing, speech processing, action planning, control of technical processes and robots. Implementation of neural networks in hardware and software: tools, simulators, analog and digital neural hardware.			
Prerequisites	none			
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]** / **CP**
	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 (graded)			
Study achievements	Successful exercise participation (not graded)			
Forms of media				
Literature	• Christopher M. Bishop: Neural Networks for Pattern Recognition, Oxford University Press, ISBN-10: 0198538642, ISBN-13: 978-0198538646 • Ian T. Nabney: NETLAB. Algoriths for Pattern Recognition, Springer, ISBN-10: 1852334401, ISBN-13: 978-1852334406			

Module MA-INF 4207	**Dynamically Reconfigurable Systems**				
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** at least every 2 years		
Module coordinator	Prof. Dr. Joachim K. Anlauf				
Lecturer(s)	Prof. Dr. Joachim K. Anlauf				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Knowledge of the most important FPGA architectures, ability to select appropriate FPGAs for a given application, overview of programming tools				
Soft skills	Communicative skills (oral and written presentation of solutions), social skills (ability to solve problems in small teams, discussions of solution concepts) self competences (ability to accept and formulate criticism, ability to analyze problems)				
Contents	Architecture of FPGAs, Configurable Logic Blocks, Wiring Ressources, Special Blocks, Hardware Description Languages, Synthesis, Technology Mapping, Place and Route, FPGA Computing, Partial Reconfigurability				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Lecture		2	30 T / 45 S	2.5
	Exercises		2	30 T / 75 S	3.5
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral exam (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media					
Literature	Current research papers and technical documentation				

<table>
<tr><td>Module
MA-INF 4208</td><td colspan="5">Seminar Vision Systems</td></tr>
<tr><td>Workload
120 h</td><td>Credit points
4 CP</td><td colspan="2">Duration
1 semester</td><td colspan="2">Frequency
every semester</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Sven Behnke</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Sven Behnke, Prof. Dr. Joachim K. Anlauf,
Dr. Nils Goerke</td></tr>
<tr><td>Classification</td><td colspan="2">Programme
M. Sc. Computer Science</td><td colspan="2">Mode
Optional</td><td>Semester
2. or 3.</td></tr>
<tr><td>Technical skills</td><td colspan="5">• Knowledge in advanced topics in the area of technical vision systems, such as image segmentation, feature extraction, and object recognition.
• Ability to understand new research results presented in original scientific papers and to present them in a research talk as well as in a seminar report.</td></tr>
<tr><td>Soft skills</td><td colspan="5">Self-competences (time management, literature search, self-study), communication skills (preparation and clear didactic presentation of research talk, scientific discussion, structured writing of seminar report), social skills (ability to formulate and accept criticism, critical examination of research results).</td></tr>
<tr><td>Contents</td><td colspan="5">Current research papers from conferences and journals in the field of vision systems covering fundamental techniques and applications.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Recommended:
At least 1 of the following:
MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning
MA-INF 4204 – Technical Neural Nets</td></tr>
<tr><td>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Seminar</td><td>10</td><td>2</td><td>30 T / 90 S</td><td>4</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Oral presentation, written report (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">(not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">• R. Szeliski: Computer Vision: Algorithms and Applications, Springer 2010.
• C. M. Bishop: Pattern Recognition and Machine Learning, Springer 2006.
• D. A. Forsyth and J. Ponce: Computer Vision: A Modern Approach, Prentice Hall, 2003.</td></tr>
</table>

Module MA-INF 4209	**Seminar Principles of Data Mining and Learning Algorithms**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Stefan Wrobel				
Lecturer(s)	Prof. Dr. Stefan Wrobel				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	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 it to others and discuss it with a knowledgeable scientific auditorium. Learn how to scientifically present prior work by others, in writing and in presentations.				
Soft skills	Communicative skills (preparing and presenting talks, written presentation of contents in a longer document), self competences (time management with long-ranging deadlines, ability to accept and formulate criticism, ability to analyse, creativity).				
Contents	Theoretical, statistical and algorithmical principles of data mining and learning algorithms. Search and optimization algorithms. Specialized learning algorithms from the frontier of research. Fundamental results from neighbouring areas.				
Prerequisites	**Recommended:** At least 1 of the following: MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media	Scientific papers and websites, interactive presentations.				
Literature	The relevant literature will be announced towards the end of the previous semester.				

Module MA-INF 4210	**Seminar Advanced Topics in Technical Informatics**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** at least every 2 years		
Module coordinator	Prof. Dr. Joachim K. Anlauf				
Lecturer(s)	Prof. Dr. Joachim K. Anlauf				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	Current Topics in Technical Informatics				
Soft skills	Communicative skills (preparing and presenting talks, preparing a structured written document), social skills (ability to accept and formulate criticism, discussions of current content) self competences (time management with long-ranging deadlines, understanding of research topics from original literature)				
Contents	Current topics such as: new architectures of computers or FPGAs (field programmable gate arrays) or new applications of dynamically reconfigurable systems				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature	Current research papers				

Module MA-INF 4211	**Seminar Cognitive Robotics**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator	Prof. Dr. Sven Behnke				
Lecturer(s)	Prof. Dr. Sven Behnke, Dr. Nils Goerke				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	Knowledge in advanced topics in the area of cognitive robotics, such as robot perception, action planning, and robot learning. Ability to understand new research results presented in original scientific papers and to present them in a research talk as well as in a seminar report.				
Soft skills	Self-competences (time management, literature search, self-study), communication skills (preparation and clear didactic presentation of research talk, scientific discussion, structured writing of seminar report), social skills (ability to formulate and accept criticism, critical examination of research results).				
Contents	Current research papers from conferences and journals in the field of cognitive robotics covering fundamental techniques and applications.				
Prerequisites	**Recommended:** At least 1 of the following: MA-INF 4113 – Cognitive Robotics MA-INF 4114 – Robot Learning				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature	• S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005. • B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008. • Selected papers.				

<table>
<tr><td>Module
MA-INF 4212</td><td colspan="5">Data Science and Big Data</td></tr>
<tr><td>Workload
180 h</td><td>Credit points
6 CP</td><td>Duration
1 semester</td><td colspan="3">Frequency
every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Stefan Wrobel</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Dr. Tamas Horvath, PD Dr. Michael Mock</td></tr>
<tr><td>Classification</td><td>Programme
M. Sc. Computer Science</td><td>Mode
Optional</td><td colspan="3">Semester
3. or 4.</td></tr>
<tr><td>Technical skills</td><td colspan="5">Participants acquire in-depth knowledge of different aspects of big data analytics and systems, including distributed processing systems and big data databases, as well as algorithmic techniques for analyzing structured and unstructured data that cannot be stored in a single computer because it has enormous size and/or continuously arrives with such a high rate that requires immediate processing.</td></tr>
<tr><td>Soft skills</td><td colspan="5">Communicative skills (oral and written presentation of solutions, discussions in teams), self-competences (ability to accept and formulate criticism, ability to analyse, creativity in the context of an "open end" task), social skills (effective team work and project planning).</td></tr>
<tr><td>Contents</td><td colspan="5">The module is offered every year, each time concentrating on one or more specific issues, such as
- architectures and procols for big data systems,
- distributed batch and stream processing systems,
- non-standard databases for big data,
- databases for structured data,
- similarity search,
- synopses for massive data,
- classical data mining tasks for massive data and/or data streams,
- mining massive graphs,
- applications.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Recommended:
All of the following:
MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning
MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery</td></tr>
<tr><td>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lecture</td><td></td><td>2</td><td>30 T / 45 S</td><td>2.5</td></tr><tr><td>Exercises</td><td></td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Written exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5">lectures, exercises, software systems</td></tr>
<tr><td>Literature</td><td colspan="5">- N. Marz and J. Warren: Big Data. Principles and best practices of scalable realtime data systems. Manning Pubn, 2014.
- T. White: Hadoop The Definitive Guide. O'REILLY, 2012.
- A. Rajaraman and J.D. Ullman.: Mining of Massive Datasets. Cambridge University Press, 2011.
- G. Cormode, M. Garofalakis, P.J. Haas, and C. Jermaine: Synopses for Massive Data: Samples, Histograms, Wavelets, Sketches. Foundations and Trends in Databases 4(1-3): 1-294 (2012).</td></tr>
</table>

Module MA-INF 4213	**Seminar Humanoid Robots**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator	Prof. Dr. Maren Bennewitz				
Lecturer(s)	Prof. Dr. Maren Bennewitz				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Knowledge in advanced topics in the area of humanoid robotics, such as environment perception, state estimation, navigation, or motion planning. Ability to understand new research results of scientific papers and to present them in a talk as well as in a self-written summary.				
Soft skills	Self-competences (time management, literature search, self-study), communication skills (preparation of the talk, clear didactic presentation of techniques and experimental results, scientific discussion, structured writing of summary), social skills (ability to formulate and accept criticism, critical examination of algorithms and experimental results).				
Contents	Current research papers from conferences and journals in the field of humanoid robotics covering fundamental techniques and applications.				
Prerequisites	**Recommended:** At least 1 of the following: MA-INF 4215 – Humanoid Robotics MA-INF 4113 – Cognitive Robotics				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature	- 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 - Selected papers.				

Module MA-INF 4214	**Lab Humanoid Robots**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator	Prof. Dr. Maren Bennewitz				
Lecturer(s)	Prof. Dr. Maren Bennewitz				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 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:** At least 1 of the following: MA-INF 4215 – Humanoid Robotics; MA-INF 4113 – Cognitive Robotics				
Format	**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					
Literature	- 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 - Selected papers.				

Module MA-INF 4215	**Humanoid Robotics**
Workload 180 h	**Credit points** 6 CP · **Duration** 1 semester · **Frequency** at least every 2 years
Module coordinator	Prof. Dr. Maren Bennewitz
Lecturer(s)	Prof. Dr. Maren Bennewitz
Classification	**Programme** M. Sc. Computer Science · **Mode** Optional · **Semester** 2-4.
Technical skills	This lecture covers techniques for humanoid robots such as perception, navigation, and motion planning.
Soft skills	Communicative skills (oral and written presentation of solutions, discussions in small teams), ability to analyze problems.
Contents	Self-calibration with least squares, 3D environment representations, self-localization with particle filters, footstep planning, inverse kinematics, whole-body motion planning with rapidly exploring random trees, statistical testing.
Prerequisites	**Recommended:** MA-INF 4113 – Cognitive Robotics
Format	see below
Exam achievements	Oral exam (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	
Literature	• S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005. • B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics • K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer • Selected research papers.

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		2	30 T / 45 S	2.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 4216	**Data Mining and Machine Learning Methods in Bioinformatics**		
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Dr. Holger Fröhlich		
Lecturer(s)	Dr. Holger Fröhlich		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.
Technical skills	- understanding and knowledge of fundamental data mining and machine learning methods - understanding of their application in bioinformatics		
Soft skills	- communication: oral and written presentation of solutions to exercises - self-competences: ability to analyze application problems and to formulate possible solutions - practical skills: ability to practically implement solutions - social skills: working in a small team with other students		
Contents	This lecture gives a broad overview about frequently used statistical techniques as well as data mining and machine learning algorithms. The use of the respective methods to solve problems in bioinformatics is explained. The goal is to understand the explained methods, being able to apply them correctly and partially implement them. More detailed, the following topics are covered in the context of their application in bioinformatics: - Short introduction to Bioinformatics and Biomedicine - Statistical Basics: Probability distributions and Bayesian inference, statistical hypothesis testing, linear models, logistic regression, Principal Component Analysis - Clustering - Hidden Markov Models - Principles of Supervised Machine Learning - Elastic Net - Basics of deep learning		
Prerequisites	none		

Format

Teaching format	Group size	h/week	Workload[h]	CP
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 (graded)
Study achievements	Successful exercise participation (not graded)
Forms of media	
Literature	T. Hastie, R. Tibshirani, J. Friedman, The Elements of Statistical Learning, Springer, 2008 S.Boslaugh, P. Watters, Statistics in a Nutshell, O'Reilly, 2008 N. Jones, P. Pevzner, An Introduction to Bioinformatics Algorithms, MIT Press, 2004

Module MA-INF 4217	**Seminar Machine Learning Methods in the Life Sciences**			
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every year	
Module coordinator	Dr. Holger Fröhlich			
Lecturer(s)	Dr. Holger Fröhlich			
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 4.	
Technical skills	- understanding and knowledge of machine learning methods and their application in modern life sciences, e.g. biomedicine			
Soft skills	- communication: oral scientific presentation of a defined topic - self-competences: ability to identify relevant literature for a given topic; ability to read, understand and analyze scientific publications - social skills: ability to discuss a scientific topic with other students and the staff			
Contents	Machine learning techniques play a crucial role in modern life sciences, including biomedicine. The goal of this seminar is to discuss a variety of machine learning techniques in the context of their application to solve real-world problems in biomedicine. Topics will be selected from the following areas: - Ensemble learning - Survival and disease progression models - Bayesian Networks - Stochastic processes, e.g. Gaussian Proceses, Dirichlet Process Mixture Models - MCMC methods - Deep learning methods, e.g. DNNs, CNNs, Deep Belief Networks - feature selection and non-linear embedding methods - multi-modal data fusion techniques Attendees will be asked to perform research about their topic in a self-responsible manner.			
Prerequisites	**Recommended:** MA-INF 4216 – Data Mining and Machine Learning Methods in Bioinformatics			
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]** / **CP**
	Seminar	10	2	30 T / 90 S / 4
	T = face-to-face teaching; S = independent study			
Exam achievements	Oral presentation, written report (graded)			
Study achievements	(not graded)			
Forms of media	powerpoint			
Literature	selected journal and conference papers			

<table>
<tr><td>Module
MA-INF 4218</td><td colspan="5">Lab Modeling and Simulation</td></tr>
<tr><td>Workload
270 h</td><td>Credit points
9 CP</td><td>Duration
1 semester</td><td colspan="3">Frequency
every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Andreas Weber</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Andreas Weber, Prof. Dr. Holger Fröhlich</td></tr>
<tr><td>Classification</td><td colspan="2">Programme
M. Sc. Computer Science</td><td>Mode
Optional</td><td colspan="2">Semester
2.</td></tr>
<tr><td>Technical skills</td><td colspan="5">- ability to describe a system via a model
- ability to conduct a simulation study, visualize and interpret its results
- ability to implement self-written program modules in MATLAB, R or via usage of some other software</td></tr>
<tr><td>Soft skills</td><td colspan="5">- ability to communicate effectively in order to implement learned methods together with a team of other students
- ability to present and explain results and to defend design decisions</td></tr>
<tr><td>Contents</td><td colspan="5">Simulation and analysis of complex systems that arise, for example, in systems biology. Covered modelling approaches are:
- Boolean Networks
- ODEs</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Recommended:
MA-INF 4217 – Seminar Machine Learning Methods in the Life Sciences</td></tr>
<tr><td rowspan="3">Format</td><td>Teaching format</td><td>Group size</td><td>h/week</td><td>Workload[h]</td><td>CP</td></tr>
<tr><td>Lab</td><td>8</td><td>4</td><td>60 T / 210 S</td><td>9</td></tr>
<tr><td colspan="5">T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Oral presentation, written report (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">(not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5">powerpoint</td></tr>
<tr><td>Literature</td><td colspan="5">- U. Alon, An Introduction to Systems Biology, CRC Press, 2007
- E.S. Allman & J.A. Rhodes “Mathematical Models in Biology” Cambr.Univ.Press 2004</td></tr>
</table>

Module MA-INF 4226	**Lab Parallel Computing for Mobile Robotics**		
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Maren Bennewitz		
Lecturer(s)	Prof. Dr. Maren Bennewitz		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.
Technical skills	Students will make practical experience with the design and implementation of parallelized algorithms in the context of motion planning and navigation.		
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			
Prerequisites	none		
Format	see below		
Exam achievements	Oral presentation, written report (graded)		
Study achievements	(not graded)		
Forms of media			
Literature			

Format:

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

Module MA-INF 4228	**Foundations of Data Science**		
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Emmanuel Müller		
Lecturer(s)	Prof. Dr. Emmanuel Müller, Dr. Michael Nüsken		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.
Technical skills	Knowledge: Peculiarities of high dimensional spaces in geometry and probabilities. Singular vector decomposition. Basics in machine learning and clustering. Skills: Understanding of mathematical tools.		
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 model for real world phenomena.		
Prerequisites	none		

Format

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Exam achievements	Schriftliche Prüfung	(graded)
Study achievements	Erfolgreiche Übungsteilnahme	(not graded)
Forms of media		
Literature	Avrim Blum, John Hopcroft, and Ravindran Kannan (2018+). Foundations of Data Science.	

Module MA-INF 4229	**Pattern Recognition (1)**		
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Christian Bauckhage		
Lecturer(s)	Prof. Dr. Christian Bauckhage		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.
Technical skills	Upon completion, students should be able to • devise mathematical models for problems in data analysis, clustering, and classification • implement basic and advanced algorithms for model fitting and optimization • implement basic and advanced algorithms for data clustering and classification • implement basic and advanced algorithms for pattern recognition		
Soft skills	Students will learn about the mathematical and algorithmic foundations of machine learning for pattern recognition. They will learn about basic and advanced mathematical models in this area, how to implement them on their own, and how to put them into practice.		
Contents	• fundamental concepts, prerequisites, and procedures in pattern recognition • basic and advanced concepts in linear algebra • basic and advanced concepts in probability theory and statistics • least squares techniques for model fitting • maximum likelihood techniques • maximum a-posteriori techniques • Bayesian inference methods • fundamental aspects of learning theory and the VC dimension • the curse of dimensionality • methods and algorithms for data clustering • Gaussian mixture models • the method of Lagrange multipliers and the KKT conditions • quadratic and linear discriminant analysis • algorithms for constrained optimization • support vector machines • the kernel trick • neural networks • Hebbian learning		
Prerequisites	**Recommended:** Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.		
Format	see table below		
Exam achievements	Schriftliche Prüfung (graded)		
Study achievements	Erfolgreiche Übungsteilnahme (not graded)		
Forms of media	• lecture slides are made available online • lecture notes with programming examples are made available online		
Literature	Bishop, "Pattern Recognition and Machine Learning" Duda, Stork, Hart, "Pattern Classification" MacKay, "Information Theory, Inference, and Learning Algorithms"		

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 4302	**Advanced Learning Systems**				
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Stefan Wrobel				
Lecturer(s)	Prof. Dr. Stefan Wrobel, Dr. Thomas Gärtner				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 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, students acquire the necessary social and communication skills for effective team work and project planning, and learn how to present software projects to others.				
Contents	The module is offered every year, each time concentrating on one or more specific algorithm classes, e.g. • kernel machines • neural networks • probabilistic and statistical learning approaches • logic-based learning approaches • reinforcement learning				
Prerequisites	**Recommended:** all of the following: MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	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 (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media	lectures, exercises, software systems				
Literature	• 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 Learning, The University of Edinburgh, 2006 • David MacKay, Information Theory, Inference, and Learning Algorithms, 2003 • Richard Duda, Peter Hart, David Stork, Pattern Classification, John Wiley and Sons, 2001				

Module MA-INF 4303	**Learning from Non-Standard Data**				
Workload 180 h	**Credit points** 6 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Stefan Wrobel				
Lecturer(s)	Prof. Dr. Stefan Wrobel, Dr. Tamas Horvath				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	Participants deepen their knowledge of learning systems with respect to one particular non-standard data type, i.e., non-tabular data, as they are becoming increasingly important 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 projects to others.				
Soft skills	Communicative skills (oral and written presentation of solutions, discussions in teams), self-competences (ability to accept and formulate criticism, ability to analyse, creativity in the context of an "open end" task)				
Contents	The module will offered every year, concentrating on one particular non-standard data type each time, including: Text Mining, Multimedia Mining, Graph Mining. Learning from structured data, Spatial Data Mining				
Prerequisites	**Recommended:** all of the following: MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning; MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	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 (graded)				
Study achievements	Successful exercise participation (not graded)				
Forms of media	lectures, exercises, software systems.				
Literature	• Gennady Andrienko, Natalia Andrienko, Exploratory Analysis of Spatial and Temporal Data, Springer, 2006 • Diane J. Cook, Lawrence B. Holder, Mining Graph Data, Wiley & Sons, 2006 • Saso Dzeroski, Nada Lavrac, Relational Data Mining, Springer, 2001 • Sholom M. Weiss, Nitin Indurkhya, Tong Zhang, Fred J. Damerau, Text Mining. Predictive Methods for Analyzing Unstructured Information, Springer, 2004				

Module MA-INF 4304	**Lab Cognitive Robotics**		
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every semester
Module coordinator	Prof. Dr. Sven Behnke		
Lecturer(s)	Prof. Dr. Sven Behnke		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.
Technical skills	Participants acquire practical experience and in-depth knowledge in the design and implementation of perception and control algorithms for complex robotic systems. In a small group, they analyze a problem, realize a state-of-the-art solution, and evaluate its performance.		
Soft skills	Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions), communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of implementations)		
Contents	Robot middleware (ROS), simultaneous localization and mapping (SLAM), 3D representations of objects and environments, object detection and recognition, person detection and tracking, action recognition, action planning and control, mobile manipulation, human-robot interaction.		
Prerequisites	**Recommended:** At least 1 of the following: MA-INF 4113 – Cognitive Robotics MA-INF 4114 – Robot Learning		
Format	see below		
Exam achievements	Oral presentation, written report (graded)		
Study achievements	(not graded)		
Forms of media			
Literature	• S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005. • B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008. • Selected research papers.		

Format:

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

Module MA-INF 4306	**Lab Development and Application of Data Mining and Learning Systems**		
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year
Module coordinator	Prof. Dr. Stefan Wrobel		
Lecturer(s)	Prof. Dr. Stefan Wrobel		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.
Technical skills	Students will acquire in-depth knowledge in the construction and development of intelligent learning systems for machine learning and data mining. They learn how to work with existing state-of-the-art systems and apply them to application problems, usually extending them for the requirements of their particular task.		
Soft skills	Communicative skills (appropriate oral presentation and written documentation of project results), social skills (ability to work in teams), self-competences (time management, aiming at long-range goals under limited ressources, ability to work under pressure, ability to accept/formulate ciriticsm)		
Contents	Data storage and process models of data analysis. Common open source frameworks for the construction of data analysis systems, specialized statistical packages. Pre-processing tools. Mathematical libraries for numerical computation. Search and optimization methods. User interfaces and visualization for analysis systems. Data analysis algorithms for embedded and distributed systems. Ubiquitous discovery systems.		
Prerequisites	**Recommended:** At least 1 of the following: MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery		
Format	see below		
Exam achievements	Oral presentation, written report (graded)		
Study achievements	(not graded)		
Forms of media	Computer Software, Documentation, Research Papers.		
Literature	The relevant literature will be announced towards the end of the previous semester.		

Format:

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

Module MA-INF 4307	**Lab Field Programmable Gate Arrays**		
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** at least every 2 years
Module coordinator	Prof. Dr. Joachim K. Anlauf		
Lecturer(s)	Prof. Dr. Joachim K. Anlauf		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.
Technical skills	Development and simulation of digital circuits in VHDL and SystemC, experience with synthesizable subsets, knowledge of the design path from the idea to a realized circuit implemented in an FPGA (field programmable gate array)		
Soft skills	Communicative skills (oral and written presentation of results), social skills (ability to cooperate in small teams, discussions of solution concepts) self competences (ability to accept and formulate criticism, ability to analyze and find practical solutions to problems)		
Contents	VHDL for Hardware Description, Simulation, and Synthesis, SystemC for Hardware Description, Simulation, and Synthesis, Synthesizable Subsets, Test of Implementations on FPGA Evaluation Boards		
Prerequisites	**Recommended:** MA-INF 4207 - Dynamically Reconfigurable Systems		
Format	see below		
Exam achievements	Oral presentation, written report (graded)		
Study achievements	(not graded)		
Forms of media			
Literature	Technical documentation		

Format

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

Module MA-INF 4308	**Lab Vision Systems**		
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every semester
Module coordinator	Prof. Dr. Sven Behnke		
Lecturer(s)	Dr. Nils Goerke		
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 3.
Technical skills	Students will acquire knowledge of the design and implementation of parallel algorithms on GPUs. They will apply these techniques to accelerate standard machine learning algorithms for data-intensive computer vision tasks.		
Soft skills	Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions), communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of implementations)		
Contents	Basic matrix and vector computations with GPUs (CUDA). Classification algorithms, such as multi-layer perceptrons, support-vector machines, k-nearest neighbors, linear-discriminant analysis. Image preprocessing and data handling. Quantitative performance evaluation of learning algorithms for segmentation and categorization.		
Prerequisites	**Recommended:** At least 1 of the following: MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning MA-INF 4204 – Technical Neural Nets		
Format	see below		
Exam achievements	Oral presentation, written report (graded)		
Study achievements	(not graded)		
Forms of media			
Literature	• R. Szeliski: Computer Vision: Algorithms and Applications, Springer 2010. • C. M. Bishop: Pattern Recognition and Machine Learning, Springer 2006. • NVidia CUDA Programming Guide, Version 4.0, 2011.		

Format:

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

Module MA-INF 4309	**Lab Sensor Data Interpretation**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** at least every 2 years		
Module coordinator	PD. Dr. Volker Steinhage				
Lecturer(s)	PD. Dr. Volker Steinhage				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 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, documentation of source code.				
Contents	Varying selected up-to-date topics on sensor data interpretation				
Prerequisites	**Required:** All of the following: MA-INF 2201 – Computer Vision MA-INF 4206 – Selected Topics in Sensor Data Interpretation				
Format	**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					
Literature	Relevant literature will be announced at start of the lab.				

<table>
<tr><td>Module
MA-INF 4310</td><td colspan="5">Lab Mobile Robots</td></tr>
<tr><td>Workload
270 h</td><td colspan="2">Credit points
9 CP</td><td colspan="2">Duration
1 semester</td><td>Frequency
at least every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Sven Behnke</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Sven Behnke, Dr. Nils Goerke</td></tr>
<tr><td>Classification</td><td colspan="3">Programme
M. Sc. Computer Science</td><td>Mode
Optional</td><td>Semester
2. or 3.</td></tr>
<tr><td>Technical skills</td><td colspan="5">Participants acquire basic knowledge and practical experience in the design and implementation of control algorithms for simple structured robotic systems using real mobile robots.
Fundamental paradigms for mobile robots will be identified and implemented in 2 person groups.</td></tr>
<tr><td>Soft skills</td><td colspan="5">Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions), communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of implementations)</td></tr>
<tr><td>Contents</td><td colspan="5">Robot middleware (e.g. ROS), robot simulation tools, basic capabilities for mobile robots: reactive control, SMPA architecture, navigation, path planning, localisation, simultaneous localization and mapping (SLAM), visual based object detection, learning robot control.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Recommended:
At least 1 of the following:
BA-INF 132 – Grundlagen der Robotik
BA-INF 131 – Intelligente Sehsysteme
MA-INF 1314 – Online Motion Planning
MA-INF 2201 – Computer Vision
MA-INF 4113 – Cognitive Robotics
MA-INF 4114 – Robot Learning
MA-INF 4203 – Autonomous Mobile Systems</td></tr>
<tr><td>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lab</td><td>8</td><td>4</td><td>60 T / 210 S</td><td>9</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Oral presentation, written report (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">(not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5">Robots simulation environments, robot control middleware, computer vision libraries, programming, demonstration of robot capabilities (real robotic systems), presentation and written report of approach and results.</td></tr>
<tr><td>Literature</td><td colspan="5">• S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.
• J. Buchli: Mobile Robots: Moving Intelligence, Published by Advanced Robotic Systems and Pro Literatur Verlag
• B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008.
• Additional State-of-the-art publications.</td></tr>
</table>

<table>
<tr><td>Module
MA-INF 4312</td><td colspan="3">Semantic Data Web Technologies</td></tr>
<tr><td>Workload
180 h</td><td>Credit points
6 CP</td><td>Duration
1 semester</td><td>Frequency
every year</td></tr>
<tr><td>Module coordinator</td><td colspan="3">Prof. Dr. Jens Lehmann</td></tr>
<tr><td>Lecturer(s)</td><td colspan="3">Prof. Dr. Jens Lehmann, Dr. Christoph Lange,
Dr. Maria Maleschkova</td></tr>
<tr><td>Classification</td><td>Programme
M. Sc. Computer Science</td><td>Mode
Optional</td><td>Semester
1.</td></tr>
<tr><td>Technical skills</td><td colspan="3">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.</td></tr>
<tr><td>Soft skills</td><td colspan="3"></td></tr>
<tr><td>Contents</td><td colspan="3">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
• Semantic text analysis and information retrieval systems</td></tr>
<tr><td>Prerequisites</td><td colspan="3">none</td></tr>
<tr><td>Format</td><td colspan="3"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lecture</td><td></td><td>2</td><td>30 T / 45 S</td><td>2.5</td></tr><tr><td>Exercises</td><td></td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="3">Written exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="3">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="3"></td></tr>
<tr><td>Literature</td><td colspan="3"></td></tr>
</table>

Module MA-INF 4313	**Seminar Semantic Data Web Technologies**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** at least every year		
Module coordinator	Prof. Dr. Jens Lehmann				
Lecturer(s)	Dr. Christoph Lange, Dr. Maria Maleshkova				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2.		
Technical skills	Through the seminar, students will learn to work with tools and technologies of the Semantic Web as well as assess their capabilities for given problems. They will gain the ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to present and to critically discuss technologies and research results in the framework of Semantic Web technologies.				
Contents	• technologies such as triple stores, link discovery frameworks, NLP pipelines. • recent conference and journal papers				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature					

<table>
<tr><td>Module
MA-INF 4314</td><td colspan="5">Lab Semantic Data Web Technologies</td></tr>
<tr><td>Workload
270 h</td><td colspan="2">Credit points
9 CP</td><td>Duration
1 semester</td><td colspan="2">Frequency
every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Jens Lehmann</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Jens Lehmann, Dr. Maria Maleschkova</td></tr>
<tr><td>Classification</td><td colspan="2">Programme
M. Sc. Computer Science</td><td>Mode
Optional</td><td colspan="2">Semester
2.</td></tr>
<tr><td>Technical skills</td><td colspan="5">The students will carry out a practical task (project) in the context of Semantic Web technologies, including test and documentation of the implemented software/system.</td></tr>
<tr><td>Soft skills</td><td colspan="5">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 own results with regard to the state-of-the-art</td></tr>
<tr><td>Contents</td><td colspan="5"></td></tr>
<tr><td>Prerequisites</td><td colspan="5">none</td></tr>
<tr><td rowspan="3">Format</td><td>Teaching format</td><td>Group size</td><td>h/week</td><td>Workload[h]</td><td>CP</td></tr>
<tr><td>Lab</td><td>8</td><td>4</td><td>60 T / 210 S</td><td>9</td></tr>
<tr><td colspan="5">T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Oral presentation, written report (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">(not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5"></td></tr>
</table>

Module MA-INF 4318	**Seminar Representation Learning for Big Data Analytics**			
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every year	
Module coordinator	Prof. Dr. Emmanuel Müller			
Lecturer(s)	Prof. Dr. Emmanuel Müller			
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.	
Technical skills	Ability to understand new research results presented in original scientific papers.			
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.			
Contents	Smart representations (such as embeddings, kernels, and dimensionality reduction methods) are useful models that allow the abstraction of data within a well-defined mathematical formalism. The representations we aim at are conceptual abstractions of real world phenomena (such as social interactions, chemical reactions and biological processes) into the world of statistics and discrete mathematics in such a way that the powerful tools developed in those areas are available for complex analyses in a simple and elegant manner. The focus will be the understanding and comparison of smart representations and their explicit/implicit data transformation models. We will study limitations and advantages of different techniques, and how the data representation changes the problem setup, reduces complexity, introduces robustness, or other valuable properties for big data analytics.			
Prerequisites	**Recommended:** Open-minded for new problem settings, Programming in different languages (C++, Python, Java), Critical approach to existing solutions, Research curiosity			
Format	**Teaching format**: Seminar	**Group size**: 10	**h/week**: 2	**Workload[h]**: 30 T / 90 S; **CP**: 4
	T = face-to-face teaching; S = independent study			
Exam achievements	Oral presentation, written report (graded)			
Study achievements	(not graded)			
Forms of media				
Literature	[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. [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.			

<table>
<tr><td>Module
MA-INF 4319</td><td colspan="5">Game AI</td></tr>
<tr><td>Workload
270 h</td><td>Credit points
9 CP</td><td colspan="2">Duration
1 semester</td><td colspan="2">Frequency
every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Christian Bauckhage</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Christian Bauckhage</td></tr>
<tr><td>Classification</td><td colspan="2">Programme
M. Sc. Computer Science</td><td colspan="2">Mode
Optional</td><td>Semester
2. or 3.</td></tr>
<tr><td>Technical skills</td><td colspan="5">Upon completion, students should be able to
• know about fundamental concepts of artificial intelligence and how they apply to computer games
• know about basic and advanced methods for planning, problem solving, and behavior modelling
• implement basic and advanced algorithms for planning, problem solving, and behavior modelling
• implement numerically robust data clustering and classification</td></tr>
<tr><td>Soft skills</td><td colspan="5">Students will learn about mathematical and algorithmic foundations of artificial intelligence. They will learn about basic and more advanced techniques for planning, problem solving, and behavior modelling, how to implement them on their own, and how to put them into practice especially in the context of artificial computer game agents.</td></tr>
<tr><td>Contents</td><td colspan="5">• historical overview of game AI
• basic terms and definitions for AI in games
• backward induction and the minmax algorithm
• alpha-beta pruning, depth restircted searches, features, and evaluation functions
• (traditional, uninformed) tree search algorithms
• Monte Carlo tree search
• algorithms for path- and motion planning, A* search
• mathematical models and computer algorithms for data clustering
• self organizing maps
• finite state machines for behavior modeling / programming
• fuzzy logic / fuzzy control for behavior modeling / programming
• probability theory and Bayesian networks
• Markov chains / Markov models
• hidden Markov models for behavior modeling and analysis
• Markov decision processes and reinforcement learning
• the Bellman equations for reinforcement learning
• temporal difference learning
• Q learning
• genetic algorithms and genetic programming</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Recommended:
Students should good working knowledge in linear algebra, probability theory, and statistics as well as programming experience.</td></tr>
<tr><td rowspan="4">Format</td><td>Teaching format</td><td>Group size</td><td>h/week</td><td>Workload[h]</td><td>CP</td></tr>
<tr><td>Lecture</td><td></td><td>4</td><td>60 T / 105 S</td><td>5.5</td></tr>
<tr><td>Exercises</td><td></td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr>
<tr><td colspan="5">T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Oral exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5">• lecture slides are made available online
• lecture notes with programming examples are made available online</td></tr>
<tr><td>Literature</td><td colspan="5">Russell and Norvig, "Artificial Intelligence: A Modern Approach"
Millington, "Artificial Intelligence For Games"
MacKay, "Information Theory, Inference, and Learning Algorithms"</td></tr>
</table>

Module MA-INF 4320	**Lab Representation Learning on Graphs**				
Workload 270 h	**Credit points** 9 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Emmanuel Müller				
Lecturer(s)	Prof. Dr. Emmanuel Müller				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	The students will carry out a practical task (project) in the context of representation learning on graphs, including test and documentation of the implemented software/system.				
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					
Prerequisites	none				
Format	**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					
Literature					

Module MA-INF 4321	**Seminar Learning from Time Series**				
Workload 120 h	**Credit points** 4 CP	**Duration** 1 semester	**Frequency** every year		
Module coordinator	Prof. Dr. Emmanuel Müller				
Lecturer(s)	Prof. Dr. Emmanuel Müller				
Classification	**Programme** M. Sc. Computer Science	**Mode** Optional	**Semester** 2. or 3.		
Technical skills	Ability to understand new research results presented in original scientific papers.				
Soft skills	Ability to present and to critically discuss these results in the framework of the corresponding area.				
Contents	Current conference and journal papers				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Seminar	10	2	30 T / 90 S	4
	T = face-to-face teaching; S = independent study				
Exam achievements	Oral presentation, written report (graded)				
Study achievements	(not graded)				
Forms of media					
Literature					

Module MA-INF 4323	**Pattern Recognition (2)**
Workload 270 h	**Credit points** 9 CP — **Duration** 1 semester — **Frequency** every year
Module coordinator	Prof. Dr. Christian Bauckhage
Lecturer(s)	Prof. Dr. Christian Bauckhage
Classification	**Programme** M. Sc. Computer Science — **Mode** Optional — **Semester** 2. or 3.
Technical skills	Upon completion, students should be able to • know about aspects of numerical computing and how these may affect practical implementations of machine learning / pattern recognition algorithms • know about iterative algorithms for machine learning / pattern recognition with large data sets • implement numerically robust algorithms for data dimensionality reduction • implement numerically robust data clustering and classification
Soft skills	Students will learn about mathematical and algorithmic foundations of robust implementations of machine learning algorithms for data analysis and pattern recognition. They will learn about iterative algorithms and dynamical systems approaches in this area, how to implement them on their own, and how to put them into practice.
Contents	• advanced concepts from linear algebra • QR-, spectral-, and singular value decompositions • iterative algorithms for least squares optimization • iterative algorithms for principal component analysis • Hebbian learning and Oja's rule for principal compoentn analysis • auto-encoder networks • associative memory networks • Hopfield networks • Hopfield networks for pattern recognition • Hopfield networks for problem solving • energy minimization methods in machine learning and pattern recognition • latent factor models for data analysis • data matrix factorization techniques • multidimensional scaling • manifold learning • basic graph theory • graph cuts and graph clustering • graph diffusion processes • radial basis functions for interpolation • radial basis functions for classification • radial basis functions for density estimation
Prerequisites	**Recommended:** Students should good working knowledge in linear algebra, probability theory, and statistics. Ideally, they will have attended the lecture Pattern Recognition (1).
Format	see table below T = face-to-face teaching; S = independent study
Exam achievements	Schriftliche Prüfung (graded)
Study achievements	Erfolgreiche Übungsteilnahme (not graded)
Forms of media	• lecture slides are made available online • lecture notes with programming examples are made available online
Literature	MacKay, "Information Theory, Inference, and Learning Algorithms" Haykin, "Neural Networks and Learning Machines" Bishop, "Neural Networks for Pattern Recognition" Elden, "Matrix Methods in Data Mining and Pattern Recognition" Skillicorn, "Understanding Complex Datasets"

Format:

Teaching format	Group size	h/week	Workload[h]	CP
Lecture		4	60 T / 105 S	5.5
Exercises		2	30 T / 75 S	3.5

T = face-to-face teaching; S = independent study

Module MA-INF 4324	**Seminar Advanced Topics in Data Science**
Workload 120 h	**Credit points**: 4 CP; **Duration**: 1 semester; **Frequency**: every year
Module coordinator	Prof. Dr. Elena Demidova
Lecturer(s)	Prof. Dr. Elena Demidova
Classification	**Programme**: M. Sc. Computer Science; **Mode**: Optional; **Semester**: 2. or 3.
Technical skills	This module concentrates on specialized topics in data science. The students obtain skills in the independent, in-depth study of state-of-the-art scientific literature on specific topics, discussion with their peers and presentation to the scientific audience.
Soft skills	• Communication skills: oral and written presentation of scientific content. • Self-competences: the ability to analyze problems, time management, creativity.
Contents	Statistical and machine learning-based methods of data analytics, including typical steps of the data science process: data generation, integration, cleaning, exploration, modelling and evaluation. Specialized data representation and analytics methods for selected data types and applications in specific domains.
Prerequisites	**Recommended:** BA-INF 150 - Einführung in die Data Science
Format	**Teaching format**: Seminar; **Group size**: 10; **h/week**: 2; **Workload[h]**: 30 T / 90 S; **CP**: 4 T = face-to-face teaching; S = independent study
Exam achievements	Oral presentation, written report (graded)
Study achievements	None (not graded)
Forms of media	
Literature	Relevant literature will be announced at the beginning of the seminar

Module MA-INF 4325	**Lab Data Science in Practice**
Workload 270 h	**Credit points**: 9 CP **Duration**: 1 semester **Frequency**: every year
Module coordinator	Prof. Dr. Elena Demidova
Lecturer(s)	Prof. Dr. Elena Demidova
Classification	**Programme**: M. Sc. Computer Science **Mode**: Optional **Semester**: 2. or 3.
Technical skills	This module concentrates on practical experience in data analytics. Participants acquire basic knowledge and practical experience in the design and implementation of data science workflows for specific data types and applications.
Soft skills	• Communication skills: the ability to work in teams. • Self-competences: the ability to analyse problems and find practical solutions. Time management, creativity, presentation of results.
Contents	Practical application of statistical and machine learning-based methods to solve data analytics problems on real-world datasets and evaluate proposed solutions.
Prerequisites	**Recommended:** BA-INF 150 - Einführung in die Data Science MA-INF 4324 - Seminar Advanced Topics in Data Science
Format	see table below T = face-to-face teaching; S = independent study
Exam achievements	Oral presentation, written report (graded)
Study achievements	None (not graded)
Forms of media	
Literature	

Teaching format	Group size	h/week	Workload[h]	CP
Lab	8	4	60 T / 210 S	9

5 Master Thesis

Module MA-INF 0401	**Master Thesis**				
Workload 900 h	**Credit points** 30 CP	**Duration** 1 semester	**Frequency** every semester		
Module coordinator					
Lecturer(s)	All lecturers of computer science				
Classification	**Programme** M. Sc. Computer Science	**Mode** Compulsory	**Semester** 4.		
Technical skills	Ability to solve a well-defined, significant research problem under supervision, but in principle independently				
Soft skills	Ability to write a scientific documentation of considerable length according to established scientific principles of form and style, in particular reflecting solid knowledge about the state-of-the-art in the field				
Contents	Topics of the thesis may be chosen from any of the areas of computer science represented in the curriculum				
Prerequisites	none				
Format	**Teaching format**	**Group size**	**h/week**	**Workload[h]**	**CP**
	Independent preparation of a scientific thesis with individual coaching		0	900 S	30
	T = face-to-face teaching; S = independent study				
Exam achievements	Master Thesis (graded)				
Study achievements	(not graded)				
Forms of media					
Literature	Individual bibliographic research required for identifying relevant literature (depending on the topic of the thesis)				

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