Module Handbook

for the

Master Programme "Computer Science"

at

Rheinische Friedrich-Wilhelms-Universität Bonn

(revised version: March 31, 2008)

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. The respective blocks start on the pages given below.

1. Algorithmics 3
2. Graphics, Vision, Audio 25
3. Information and Communication Management 41
4. Intelligent Systems 63

Master Thesis & Seminar 83

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

- **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 1st and the 3rd semester. The 4th semester is reserved for preparing the master thesis.

Module Handbook

Master Programme "Computer Science"

Area of Competence

Algorithmics

MA-INF 1101	L4E2	8 CP	**Pearls of Algorithms**	NB
MA-INF 1102	L4E2	8 CP	**Combinatorial Optimization**	JV
MA-INF 1103	L4E2	8 CP	**Cryptography**	JG
MA-INF 1201	L4E2	8 CP	**Approximation Algorithms for NP-Hard Problems**	MK
MA-INF 1202	L4E2	8 CP	**Chip Design**	JV
MA-INF 1203	L4E2	8 CP	**Discrete and Computational Geometry**	RoK
MA-INF 1204	Sem	4 CP	**Seminar Selected Topics in Information and Learning Theory**	NB
MA-INF 1205	Sem	4 CP	**Seminar Discrete Optimization**	JV
MA-INF 1206	Sem	4 CP	**Seminar Design and Analysis of Randomized and Approximation Algorithms**	MK
MA-INF 1207	Lab	8 CP	**Lab Combinatorial Algorithms**	JV
MA-INF 1208	L4E2	8 CP	**Applications of Cryptography**	JG
MA-INF 1301	L4E2	8 CP	**Algorithmic Game Theory and the Internet**	MK
MA-INF 1302	L4E2	8 CP	**Advanced Topics in Algorithmics**	MK
MA-INF 1303	L2V1	4 CP	**Selected Topics in Algorithmics**	NB
MA-INF 1304	Sem	4 CP	**Seminar Geometric Distance Problems**	RoK
MA-INF 1305	Sem	4 CP	**Seminar Chip Design**	JV
MA-INF 1306	Sem	4 CP	**Seminar Combinatorial and Geometric Optimization**	MK
MA-INF 1307	Sem	4 CP	**Seminar Advanced Algorithms**	MK
MA-INF 1308	Lab	8 CP	**Lab Algorithms for Chip Design**	JV
MA-INF 1309	Lab	8 CP	**Lab Efficient Algorithms for Selected Problems: Design, Analysis and Implementation**	MK

(L: Lecture, E: Exercise, Sem: Seminar)

Module coordinators:

Norbert Blum (NB), Marek Karpinski (MK), Rolf Klein (RoK), Jens Vygen (JV), Joachim von zur Gathen (JG)

<table>
<tr><td colspan="4">Module name:
Pearls of Algorithms</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 1101</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Norbert Blum</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Norbert Blum, Prof. Dr. Marek Karpinski, Prof. Dr. Rolf Klein</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>1st sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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</td></tr>
<tr><td>Contents</td><td colspan="4">Selected state-of-the-art topics of modern algorithmics. In particular, the topics include advanced data structures, efficient exact and approximate algorithms, problems of discrete geometry and combinatorial optimization.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Individual solving of problems in small groups, presentation and discussion in tutorials)</td><td>60
30</td><td>4
2</td><td>60 T/90 S
30 T/60 S</td><td>5
3</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Written exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">Depending on the topics varying from semester to semester, the relevant research literature will be announced before the start of the resp. semester.</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

Module name: **Combinatorial Optimization**			universitätbonn
Module No. MA-INF 1102	Workload 240 h	Credit points 8	Frequency At least every year
Module coordinator	Prof. Dr. Jens Vygen		
Lecturer(s)	Prof. Dr. Norbert Blum, Prof. Dr. Stefan Hougardy, Prof. Dr. Marek Karpinski, Prof. Dr. Bernhard Korte, Junior-Prof. Dr. Tim Nieberg, Prof. Dr. Jens Vygen		
Classification	Programme	Compulsory/ Optional	Semester
	M.Sc. Computer Science	Optional	1st or 2nd sem.
Targeted learning outcomes	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/workload/ credits	Teaching format	Group size	Hours/ week	Workload [h]	Credits
	Lecture Exercises	60 30	4 2	60 T/90 S 30 T/60 S	5 3

Exam achievements (graded)	Exam(s)
	Written exam
Study achievements (not graded)	Successful exercise participation
Forms of media	
Literature	• B. Korte, J. Vygen: Combinatorial Optimization: Theory and Algorithms. Springer, 4th edition, 2008 • A. Schrijver: Combinatorial Optimization: Polyhedra and Efficiency. Springer 2003 • W. Cook, W. Cunningham, W. Pulleyblank, A. Schrijver: Combinatorial Optimization. Wiley 1997

T = Face-to-face teaching; S = Independent study

Module name: **Cryptography**			universitätbonn
Module No. MA-INF 1103	Workload 240 h	Credit points 8	Frequency Every year
Module coordinator	Prof. Dr. Joachim von zur Gathen		
Lecturer(s)	Prof. Dr. Joachim von zur Gathen		

Classification	Programme	Compulsory/ Optional	Semester
	M.Sc. Computer Science	Optional	1st or 3rd sem.

Targeted learning outcomes	technical skills: Understanding of security concerns and measures, and of the interplay between computing power, key length, 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 logging; lower bounds in structured models
Prerequisites	None

Format/workload/ credits	Teaching format	Group size	Hours/ week	Workload [h]	Credits
	Lecture	60	4	60 T/90 S	5
	Exercises	30	2	30 T/60 S	3

Exam achievements (graded)	Exam(s) Written exam (oral exam in exceptional cases)
Study achievements (not graded)	Successful exercise participation
Forms of media	
Literature	• Course notes • Stinson, Cryptography: Theory and Practice, 2nd edition

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Approximation Algorithms for NP-Hard Problems</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 1201</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
At least every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Marek Karpinski</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Norbert Blum, Prof. Dr. Marek Karpinski, Prof. Dr. Rolf Klein, Prof. Dr. Bernhard Korte, Prof. Dr. Jens Vygen, N.N.</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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</td></tr>
<tr><td>Contents</td><td colspan="4">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.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Introductory knowledge of foundations of algorithms and complexity theory is essential.</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Individual solving of problems in small groups, presentation and discussion in tutorials)</td><td>60
30</td><td>4
2</td><td>60 T/90 S
30 T/60 S</td><td>5
3</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• 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 (4th edition), Springer, 2008
• V. V. Vazirani: Approximation Algorithms, Springer, 2001</td></tr>
</table>

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<table>
<tr><td colspan="4">Module name:
Chip Design</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 1202</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Jens Vygen</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Stefan Hougardy, Prof. Dr. Bernhard Korte,
Junior-Prof. Dr. Tim Nieberg, Prof. Dr. Jens Vygen</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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</td></tr>
<tr><td>Contents</td><td colspan="4">Problem formulation and design flow for chip design, logic synthesis, placement, routing, timing analysis and optimization, clocktree design</td></tr>
<tr><td>Prerequisites</td><td colspan="4">None</td></tr>
<tr><td rowspan="3">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises</td><td>60
30</td><td>4
2</td><td>60 T/90 S
30 T/60 S</td><td>5
3</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">As long as no recommendable literature is available, a lecture script will be used. The following sources provide a range of relevant references to individual topics:
• C.J. Alpert, D.P. Mehta, S.S. Sapatnekar: The Handbook of Algorithms for VLSI Physical Design Automation. Taylor and Francis, to appear
• B. Korte, D. Rautenbach, J. Vygen: BonnTools: Mathematical innovation for layout and timing closure of systems on a chip. Proceedings of the IEEE, 95 (2007), 555-572</td></tr>
</table>

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<table>
<tr><td colspan="4">Module name:
Discrete and Computational Geometry</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 1203</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
Every 2 years</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Rolf Klein</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Norbert Blum, Prof. Dr. Marek Karpinski,
Prof. Dr. Rolf Klein</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
To acquire insight into the combinatorial complexity of geometric problems; to be able to use this knowledge in developing efficient algorithms
soft skills:
Presentation of own and others solutions methods and critical discussion of applied methods, techniques and solutions</td></tr>
<tr><td>Contents</td><td colspan="4">We study in lower dimensions concrete and abstract Voronoi diagrams, arrangements, lower envelopes, Davenport-Schinzel sequences, visibility, and path planning problems.
In higher dimensions we consider geometric network construction, convex hulls, range queries, dimension reduction, geometric inequalities, lattices, VC-dimension, and epsilon-nets</td></tr>
<tr><td>Prerequisites</td><td colspan="4">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Individual solving of problems in small groups)</td><td>60
30</td><td>4
2</td><td>60 T/90 S
30 T/60 S</td><td>5
3</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• Matousek, Lectures on Discrete Geometry
• Narasimhan/Smid, Geometric Spanner Networks
• Klein, Concrete and Abstract Voronoi Diagrams</td></tr>
</table>

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Module name: **Seminar Selected Topics in Information and Learning Theory**						
Module No. MA-INF 1204	Workload 120 h	Credit points 4			Frequency At least every 2 years	
Module coordinator	Prof. Dr. Norbert Blum					
Lecturer(s)	Prof. Dr. Norbert Blum					
Classification	Programme		Compulsory/ Optional		Semester	
	M.Sc. Computer Science		Optional		2nd sem.	
Targeted learning outcomes	Ability to perform individual literature search, critical reading, understanding, and clear didactic presentation					
Contents	Advanced topics in information and learning theory based on modern research literature					
Prerequisites	None					
Format/workload/ credits	Teaching format		Group size	Hours/ week	Workload [h]	Credits
	Seminar		10	2	30 T / 90 S	4
Exam achievements (graded)	Exam(s)					
	Oral presentation					
Study achievements (not graded)	Regular participation, written report					
Forms of media						
Literature	The relevant literature will be announced towards the end of the previous semester.					

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Module name: **Seminar Discrete Optimization**					universitätbonn
Module No. MA-INF 1205	Workload 120 h	Credit points 4		Frequency Every year	
Module coordinator	Prof. Dr. Jens Vygen				
Lecturer(s)	Prof. Dr. Stefan Hougardy, Prof. Dr. Bernhard Korte, Junior-Prof. D. Tim Nieberg, Prof. Dr. Jens Vygen				
Classification	Programme		Compulsory/ Optional	Semester	
	M.Sc. Computer Science		Optional	2nd sem.	
Targeted learning outcomes	<u>technical skills</u>: Competence to understand new research results based on original literature, to put such results in a broader context and present such results and relations. <u>soft skills</u>: 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	<u>Required</u>: Combinatorial Optimization (MA-INF 1102)				
Format/workload/ credits	Teaching format	Group size	Hours/week	Workload [h]	Credits
	Seminar	10	2	30 T / 90 S	4
Exam achievements (graded)	Exam(s)				
	Oral presentation				
Study achievements (not graded)	Regular participation, written report				
Forms of media					
Literature	The topics and the relevant literature will be announced towards the end of the previous semester.				

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<table>
<tr><td colspan="3">Module name:
Seminar Design and Analysis of Randomized and Approximation Algorithms</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 1206</td><td>Workload
120 h</td><td>Credit points
4</td><td>Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="3">Prof. Dr. Marek Karpinski</td></tr>
<tr><td>Lecturer(s)</td><td colspan="3">Prof. Dr. Marek Karpinski</td></tr>
<tr><td rowspan="2">Classification</td><td>Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td>M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="3">Ability to perform individual literature search, critical reading, understanding, and clear didactic presentation</td></tr>
<tr><td>Contents</td><td colspan="3">Current topics in design and analysis of randomized and approximation algorithms based on lastest research literature</td></tr>
<tr><td>Prerequisites</td><td colspan="3">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td colspan="3"><table><tr><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr><tr><td>Seminar</td><td>10</td><td>2</td><td>30 T / 90 S</td><td>4</td></tr></table></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="3">Exam(s)</td></tr>
<tr><td colspan="3">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="3">Regular participation, written report</td></tr>
<tr><td>Forms of media</td><td colspan="3"></td></tr>
<tr><td>Literature</td><td colspan="3">The relevant literature will be announced in time.</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Lab Combinatorial Algorithms</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 1207</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Jens Vygen</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Stefan Hougardy, Prof. Dr. Bernhard Korte,
Junior-Prof. Dr. Tim Nieberg, Prof. Dr. Jens Vygen</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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</td></tr>
<tr><td>Contents</td><td colspan="4">Certain combinatorial algorithms will be chosen each semester. The precise task will be explained in a meeting in the previous semester.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Combinatorial Optimization (MA-INF 1102)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td colspan="2">Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td colspan="2">Lab</td><td>8</td><td>2</td><td>30 T/210 S</td><td>8</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Regular participation, software documentation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">The topics and the relevant literature will be announced towards the end of the previous semester</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Applications of Cryptography</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 1208</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Joachim von zur Gathen</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Joachim von zur Gathen, Dr. Michael Nüsken</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
Understanding, modelling and differentiating the various security requirements in transaction schemes. Overview of cryptographic tools and their potential applications. Learning about success and pitfalls.
soft skills:
Oral presentation (in tutorial groups), written presentation (of exercise solutions), team collaboration in solving homework problems, critical assessment</td></tr>
<tr><td>Contents</td><td colspan="4">The tools of cryptography are applied to various application areas: internet security, electronic cash, elections and auctions, digital passports and health cards. The topics may vary and are often chosen to be of current concern or students' interest.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Recommended:
Cryptography (MA-INF 1103)</td></tr>
<tr><td rowspan="3">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises</td><td>60
30</td><td>4
2</td><td>60 T/90 S
30 T/60 S</td><td>5
3</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Written exam (oral exam in exceptional cases)</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• Course notes
• Stinson, Cryptography: Theory and Practice, 2nd edition</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

Module name: **Algorithmic Game Theory and the Internet**			universitätbonn
Module No. MA-INF 1301	Workload 240 h	Credit points 8	Frequency Every 2 years
Module coordinator	Prof. Dr. Marek Karpinski		
Lecturer(s)	Prof. Dr. Norbert Blum, Prof. Dr. Marek Karpinski		

Classification	Programme	Compulsory/ Optional	Semester
	M.Sc. Computer Science	Optional	2nd or 3rd sem.

Targeted learning outcomes	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	Introductory knowledge of foundations of algorithms and complexity theory is essential.

Format/workload/ credits	Teaching format	Group size	Hours/ week	Workload [h]	Credits
	Lecture Exercises (Individual solving of problems in small groups, presentation and discussion in tutorials)	60 30	4 2	60 T/90 S 30 T/60 S	5 3

Exam achievements (graded)	Exam(s)
	Oral exam
Study achievements (not graded)	Successful exercise participation
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

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="5">Module name:
Advanced Topics in Algorithmics</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 1302</td><td colspan="2">Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
At least every 2 years</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Marek Karpinski</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Norbert Blum, Prof. Dr. Joachim von zur Gathen,
Prof. Dr. Marek Karpinski, Prof. Dr. Rolf Klein, Prof. Dr. Nitin Saxena</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="3">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="3">M.Sc. Computer Science</td><td>Optional</td><td>2nd or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="5">technical skills:
Introduction to current advanced research topics in algorithmic research
soft skills:
Presentation of solutions and methods, critical discussion of applied methods and techniques</td></tr>
<tr><td>Contents</td><td colspan="5">The topic will be announced before the start of the relevant semester.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Introductory knowledge of foundations of algorithms and complexity theory is essential.</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td colspan="2">Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td colspan="2">Lecture
Exercises
(Individual solving of problems in small groups, presentation and discussion in tutorials)</td><td>60
30</td><td>4
2</td><td>60 T/90 S
30 T/60 S</td><td>5
3</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="6">Exam(s)</td></tr>
<tr><td colspan="6">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="6">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="6"></td></tr>
<tr><td>Literature</td><td colspan="6">Depending on the topics varying from semester to semester, the relevant research literature will be announced before the start of the resp. semester.</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Selected Topics in Algorithmics</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 1303</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
At least every 2 years</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Norbert Blum</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Norbert Blum, Prof. Dr. Marek Karpinski, Prof. Dr. Rolf Klein</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
Introduction to current advanced research topics in algorithmic research
soft skills:
Presentation of own and others' solutions and methods, critical discussion of applied methods, techniques and solutions</td></tr>
<tr><td>Contents</td><td colspan="4">The topic will be announced before the start of the resp. semester.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Individual solving of problems in small groups, presentation and discussion in tutorials)</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 T/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">Depending on the topics varying from semester to semester, the relevant research literature will be announced before the start of the resp. semester.</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

Module name: **Seminar Geometric Distance Problems**						universitätbonn
Module No. MA-INF 1304	Workload 120 h	Credit points 4			Frequency Every year	
Module coordinator	Prof. Dr. Rolf Klein					
Lecturer(s)	Prof. Dr. Rolf Klein					
Classification	Programme		Compulsory/ Optional		Semester	
	M.Sc. Computer Science		Optional		3rd sem.	
Targeted learning outcomes	Presentation of own and others' solutions and methods, critical discussion of applied methods, techniques and solutions					
Contents	Current topics involving distance problems, e.g. clustering, dimension reduction					
Prerequisites	Required: Discrete and Computational Geometry (MA-INF 123)					
Format/workload/ credits	Teaching format		Group size	Hours/ week	Workload [h]	Credits
	Seminar		10	2	30 T/90 S	4
Exam achievements (graded)	Exam(s)					
	Oral presentation					
Study achievements (not graded)	Regular participation, written report					
Forms of media						
Literature	The relevant literature will be announced towards the end of the previous semester					

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Seminar Chip Design</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 1305</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Jens Vygen</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Stefan Hougardy, Prof. Dr. Bernhard Korte,
Junior-Prof. Dr. Tim Nieberg, Prof. Dr. Jens Vygen</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
Competence to understand new theoretical results and practical solutions in VLSI design and related applications, as well as presentation of such results
soft skills:
Ability to read and understand research papers, abstract thinking, presentation of mathematical results in a talk</td></tr>
<tr><td>Contents</td><td colspan="4">Current topics in chip design and related applications</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Combinatorial Optimization (MA-INF 1102) or
Chip Design (MA-INF 1202)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Seminar</td><td>10</td><td>2</td><td>30 T/90 S</td><td>4</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Regular participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">The topics and the relevant literature will be announced towards the end of the previous semester</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

Module name: **Seminar Combinatorial and Geometric Optimization**						universitätbonn
Module No. MA-INF 1306	Workload 120 h	Credit points 4			Frequency Every year	
Module coordinator	Prof. Dr. Marek Karpinski					
Lecturer(s)	Prof. Dr. Norbert Blum, Prof. Dr. Marek Karpinski, Prof. Dr. Rolf Klein					
Classification	Programme		Compulsory/ Optional		Semester	
	M.Sc. Computer Science		Optional		3rd sem.	
Targeted learning outcomes	technical skills: Presentation of selected topics in the above area soft skills: Ability to perform individual literature search, critical reading, understanding, and clear didactic presentation					
Contents	Current topics in combinatorial and geometric optimization based on newest research literature					
Prerequisites	None					
Format/workload/ credits	Teaching format		Group size	Hours/ week	Workload [h]	Credits
	Seminar		10	2	30 T/90 S	4
Exam achievements (graded)	Exam(s)					
	Oral presentation					
Study achievements (not graded)	Regular participation, written report					
Forms of media						
Literature	The relevant literature will be announced in time.					

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="5">Module name:
Seminar Advanced Algorithms</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 1307</td><td colspan="2">Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Marek Karpinski</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Norbert Blum, Prof. Dr. Marek Karpinski, Prof. Dr. Rolf Klein</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td colspan="2">Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td colspan="2">3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="5">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</td></tr>
<tr><td>Contents</td><td colspan="5">Advanced topics in algorithm design based on newest research literature</td></tr>
<tr><td>Prerequisites</td><td colspan="5">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td colspan="2">Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td colspan="2">Seminar</td><td>10</td><td>2</td><td>30 T/90 S</td><td>4</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="5">Exam(s)</td></tr>
<tr><td colspan="5">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="5">Regular participation, written report</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">The relevant literature will be announced in time.</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

Module name: **Lab Algorithms for Chip Design**						universitätbonn
Module No. MA-INF 1308	Workload 240 h	Credit points 8			Frequency Every year	
Module coordinator	Prof. Dr. Jens Vygen					
Lecturer(s)	Prof. Dr. Stefan Hougardy, Prof. Dr. Bernhard Korte, Junior-Prof. Dr. Tim Nieberg, Prof. Dr. Jens Vygen					
Classification	Programme		Compulsory/ Optional		Semester	
	M.Sc. Computer Science		Optional		3rd sem.	
Targeted learning outcomes	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	Required: Combinatorial Optimization (MA-INF 1102), Chip Design (MA-INF 1202); Seminar Discrete Optimization (MA-INF 1205) or Lab Combinatorial Algorithms (MA-INF 1207)					
Format/workload/ credits	Teaching format	Group size	Hours/ week	Workload [h]	Credits	
	Lab	8	2	30 T/210 S	8	
Exam achievements (graded)	Exam(s)					
	Oral presentation					
Study achievements (not graded)	Regular participation, software documentation					
Forms of media						
Literature	The topics and the relevant literature will be announced towards the end of the previous semester					

T = Face-to-face teaching; S = Independent study

Module name: **Lab Efficient Algorithms for Selected Problems: Design, Analysis and Implementation**					
Module No. MA-INF 1309	Workload 240 h	Credit points 8		Frequency At least every year	
Module coordinator	Prof. Dr. Marek Karpinski				
Lecturer(s)	Prof. Dr. Norbert Blum, Prof. Dr. Marek Karpinski, Prof. Dr. Rolf Klein				
Classification	Programme		Compulsory/ Optional	Semester	
	M.Sc. Computer Science		Optional	2nd and/or 3rd sem.	
Targeted learning outcomes	Ability to design, analyze and implement efficient algorithms for selected computational problems.				
Contents	Design of efficient exact and approximate algorithms and data structures for selected computational problems.				
Prerequisites	None				
Format/workload/ credits	Teaching format	Group size	Hours /week	Workload [h]	Credits
	Lab	8	2	30 T/210 S	8
Exam achievements (graded)	Exam(s)				
	Oral presentation				
Study achievements (not graded)	Regular participation, written documentation				
Forms of media					
Literature	The relevant literature will be announced in time.				

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<table>
<tr><td colspan="4">Module name:
Seminar Cryptography</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 1310</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Joachim von zur Gathen</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Joachim von zur Gathen</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
Understanding research publications, often written tersely. Distilling this into a presentation. Determination of relevant vs. irrelevant material. Developing a presentation (usually in PowerPoint) 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.</td></tr>
<tr><td>Contents</td><td colspan="4">A special topic within cryptography, changing from year to year, is studied in depth, based on the current research literature.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Recommended:
Cryptography (MA-INF 1103)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Seminar</td><td>10</td><td>2</td><td>30 T/90 S</td><td>4</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Regular participation, written report</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">Current conference publications, to be announced in time</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

Module Handbook

Master Programme "Computer Science"

Area of Competence

Graphics, Vision, Audio

MA-INF 2101	L4E2	8 CP	**Foundations of Graphics, Vision, and Audio**	ReK
MA-INF 2201	L4E2	8 CP	**Computer Vision**	DC
MA-INF 2202	L4E2	8 CP	**Computer Animation**	AW
MA-INF 2203	L4E2	8 CP	**Selected Topics in Signal Processing**	MC
MA-INF 2204	L2E1	4 CP	**Rendering: Global Illumination and Real-Time Photorealism**	ReK
MA-INF 2205	L2E1	4 CP	**Digital Geometric Models: Representation, Creation and Editing**	ReK
MA-INF 2206	Sem	4 CP	**Seminar Graphics, Vision, Audio**	ReK
MA-INF 2301	L2E1	4 CP	**Advanced Topics in Computer Vision**	DC
MA-INF 2302	L4E2	8 CP	**Physics-based Modelling**	AW
MA-INF 2303	L4E2	8 CP	**Selected Topics in Multimedia Retrieval**	MC
MA-INF 2304	L2E1	4 CP	**Rendering Techniques II**	ReK
MA-INF 2305	L2E1	4 CP	**Geometry Processing II**	ReK
MA-INF 2306	L2E1	4 CP	**Virtual Reality**	ReK
MA-INF 2307	Lab	8 CP	**Lab Graphics, Vision, and Audio**	ReK

(L: Lecture, E: Exercise, Sem: Seminar)

Module coordinators:
Michael Clausen (MC), Daniel Cremers (DC), Reinhard Klein (ReK),
Andreas Weber (AW),

Module name: **Foundations of Graphics, Vision, and Audio**			universitätbonn
Module No. MA-INF 2101	Workload 240 h	Credit points 8	Frequency Every year
Module coordinator	Prof. Dr. Reinhard Klein		
Lecturer(s)	Prof. Dr. Michael Clausen, Prof. Dr. Daniel Cremers, Prof. Dr. Reinhard Klein, Prof. Dr. Andreas Weber		

Classification	Programme	Compulsory/ Optional	Semester
	M.Sc. Computer Science	Optional	1st sem.

Targeted learning outcomes	technical skills: Knowledge of basic mathematical techniques commonly used in Graphics, Vision and Audio with a strong emphasis on their application to real world problems in these fields soft skills: Research abilities, information retrieval abilities, collaboration abilities, self management, creativity
Contents	• Fourier and wavelet transforms with applications to audio signal analysis and filtering • Affine and projective transformations with applications to image formation (rigid body motion, cinematic chains) • Parametric curves and surfaces with applications to 3D modelling • Elements of continuous and discrete differential geometry with application to mesh processing • Ordinary differential equations with applications to physical based modelling • Variational methods and partial differential equations with applications to image processing • Monte Carlo methods with applications to photorealistic rendering This lecture has been designed as a team-taught cycle of lectures in the field of Graphics, Vision, and Audio.
Prerequisites	Recommended: Mathematical background (multidimensional analysis and linear algebra, numerical methods)

Format/workload/ credits	Teaching format	Group size	Hours/ week	Workload [h]	Credits
	Lecture	60	4	60 T/90 S	5
	Exercise	30	2	30 T/60 S	3

Exam achievements (graded)	Exam(s)
	Written exam
Study achievements (not graded)	Successful exercise participation
Forms of media	
Literature	• P. Shirley et al.: Fundamentals of Computer Graphics, 2nd edition, A K Peters, 2005 • J. G. Proakis, D. G Manolakis: Digital Signal Processing, Prentice Hall, 1996 • J. Bigun: Vision with Direction, Springer, 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/

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<table>
<tr><td colspan="4">Module name:
Computer Vision</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 2201</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Daniel Cremers</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Daniel Cremers</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
Students will learn about various mathematical 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.</td></tr>
<tr><td>Contents</td><td colspan="4">The class will cover a number of mathematical methods and their applications in computer vision, in particular variational methods and partial differential equations for image enhancement and motion estimation, factorization techniques for 3D reconstruction from multiple views, and level set and graph cut methods for segmentation and tracking.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Foundations of Graphics, Vision, and Audio (MA-INF 2101)
Recommended:
Mathematical background (multidimensional analysis and linear algebra)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises</td><td>60
30</td><td>4
2</td><td>60 T/90 S
30 T/60 S</td><td>5
3</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• Y.Ma, S. Soatto, J. Kosecka, S. Sastry: An Invitation to 3-D Vision
• O. Faugeras, Q. Luong, T Papadopoulou: The Geometry of Multiple Images
• R. Hartley, A. Zisserman: Multiple View Geometry in Computer Vision
• S. Osher, R. Fedkiw: Level Set Methods and Dynamic Implicit Surfaces</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Computer Animation</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 2202</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Andreas Weber</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Andreas Weber</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4"><u>technical skills</u>:
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.
<u>soft skills</u>:
Social competences (work in groups), communicative skills (written and oral presentation)</td></tr>
<tr><td>Contents</td><td colspan="4">Fundamentals of computer animation; kinematics; representations of motions; motion capturing; motion editing; motion textures; motion styles; morphing techniques; facial animations; cognitive modelling hierarchy</td></tr>
<tr><td>Prerequisites</td><td colspan="4"><u>Required</u>:
Foundations of Graphics, Vision, and Audio (MA-INF 2101)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercise
(Discussions of theoretical concepts in groups; realizations of small software projects in small groups.)</td><td>60
30</td><td>4
2</td><td>60 T/90 S
30 T/60 S</td><td>5
3</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• 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</td></tr>
</table>

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<table>
<tr><td colspan="4">Module name:
Selected Topics in Signal Processing</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 2203</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Michael Clausen</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Michael Clausen</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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.</td></tr>
<tr><td>Contents</td><td colspan="4">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.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercise
(Theoretical consolidation of methods presented. Practical realisation of basic algorithms, partially in small groups supported by tutors in our multimedia lab)</td><td>60
30</td><td>4
2</td><td>60 T/90 S
30 T/60 S</td><td>5
3</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• 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</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Rendering: Global Illumination and Real-Time Photorealism</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 2204</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Reinhard Klein</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Reinhard Klein</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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</td></tr>
<tr><td>Contents</td><td colspan="4">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.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Foundations of Graphics, Vision, and Audio (MA-INF 2101)
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="3">Format/workload/ credits</td><td colspan="2">Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td colspan="2">Lecture
Exercise</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 T/45 S</td><td>2
2</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td></td><td colspan="4">Oral exam
(This 4LP-module can be combined with the 4LP-module „Digital Geometric Models: Representation, Creation and Editing“ to a 8LP-module „Advanced Computer Graphics I“ with one exam only, provided that both modules are done within the same semester.)</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Literature</td><td colspan="4">• 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</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Digital Geometric Models: Representation, Creation and Editing</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 2205</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Reinhard Klein</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Reinhard Klein</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
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.
soft skills:
Analytical problem description, creativity, self-dependent solution of practical problems in the area of mesh processing, presentation of solution strategies and implementations, self-dependent literature research, collaboration abilities, self-management</td></tr>
<tr><td>Contents</td><td colspan="4">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="4">Required:
Foundations of Graphics, Vision, and Audio (MA-INF 2101)
Recommended:
Algorithms and data structures or knowledge of basic discrete differential geometry, knowledge on multidimensional analysis und linear algebra as well as numerical analysis and numerical linear algebra, C++</td></tr>
<tr><td rowspan="3">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercise</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 T/45 S</td><td>2
2</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam
(This 4LP-module can be combined with the 4LP-module „Rendering Techniques I“ to a 8LP-module „Advanced Computer Graphics I“ with one exam only, provided that both modules are done within the same semester.)</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Literature</td><td colspan="4">• 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>

T = Face-to-face teaching; S = Independent study

Module name: **Seminar Graphics, Vision, Audio**			universitätbonn
Module No. MA-INF 2206	Workload 120 h	Credit points 4	Frequency Every semester
Module coordinator	Prof. Dr. Reinhard Klein		
Lecturer(s)	Prof. Dr. Michael Clausen, Prof. Dr. Daniel Cremers, Prof. Dr. Reinhard Klein, Prof. Dr. Andreas Weber		

Classification	Programme	Compulsory/ Optional	Semester
	M.Sc. Computer Science	Optional	2nd and 3rd sem.

Targeted learning outcomes	<u>technical skills</u>: Ability to read, understand and present selected topics on current research in Graphics, Vision and Audio. <u>soft skills</u>: Ability to perform literature research, critical evaluation and comparison of algorithms and methods, structured presentation of results at research level.
Contents	Current topics in Graphics, Vision, and Audio.
Prerequisites	<u>Recommended</u>: Mathematical background (multidimensional analysis and linear algebra, basic numerical methods) Foundations of Graphics, Vision, and Audio (MA-INF 2101) are strongly recommended.

Format/workload/ credits	Teaching format	Group size	Hours/ week	Workload [h]	Credits
	Seminar	10	2	30 T/90 S	4

Exam achievements (graded)	Exam(s)
	Oral presentation
Study achievements (not graded)	Regular participation, written report
Forms of media	
Literature	Selected articles on latest topics of Computer Graphics

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Advanced Topics in Computer Vision</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 2301</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Daniel Cremers</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Daniel Cremers</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
Advanced computer vision methods
soft skills:
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="4">The class focuses on advanced topics in the fields of computer vision and image processing. In particular, it will make students familiar with recent developments in computer vision research.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Foundations of Graphics, Vision, and Audio (MA-INF 2101)
Recommended:
Computer Vision (MA-INF 2201)</td></tr>
<tr><td rowspan="3">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises</td><td>60
30</td><td>2
1</td><td>30 T/30 S
30 T/30 S</td><td>2
2</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">Latest topic-related research articles and literature will be announced in advance of the lecture.</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Physics-based Modelling</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 2302</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Andreas Weber</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Andreas Weber</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4"><u>technical skills</u>:
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.
<u>soft skills</u>:
Social competences (work in groups), communicative skills (written and oral presentation)</td></tr>
<tr><td>Contents</td><td colspan="4">Particle simulation; rigid bodies; multi-body-systems; collision detection; collisions response; cloth modelling; hair modelling; fluid animation; physics-based motion editing</td></tr>
<tr><td>Prerequisites</td><td colspan="4"><u>Required</u>:
Foundations of Graphics, Vision, and Audio (MA-INF 2101)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Discussions of theoretical concepts in groups; realizations of small software projects in small groups.)</td><td>60
30</td><td>4
2</td><td>60 T/90 S
30 T/60 S</td><td>5
3</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• 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</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="5">Module name:
Selected Topics in Multimedia Retrieval</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 2303</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="3">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Michael Clausen</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Michael Clausen</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td colspan="2">Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td colspan="2">1st or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="5">technical skills:
Learning advanced topics as well as efficient algorithms for content-based search in multimedia documents (audio, motion capture data, 3D data, etc). Develop skills in designing suitable data structures and indexing techniques for efficient retrieval. 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.</td></tr>
<tr><td>Contents</td><td colspan="5">Group theoretic concepts for multimedia retrieval, robust retrieval techniques for deformations, concepts from invariant theory. Techniques for hierarchical indexing. Advanced problem-specific retrieval models. Similarity measures for selected problems and application domains. Statistical concepts for modelling data variability.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td colspan="2">Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td colspan="2">Lecture
Exercises
(Theoretical consolidation of methods presented. Practical realisaton of basic algorithms, partially in small groups supported by tutors in our multimedia lab)</td><td>60
30</td><td>4
2</td><td>60 T/90 S
30 T/60 S</td><td>5
3</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="5">Exam(s)</td></tr>
<tr><td colspan="5">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="5">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">• Meinard Müller: Methods for Robust and Efficient Multimedia Retrieval. Springer 2007
• Lecture script and selected research articles</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Rendering: Materials and Images</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 2304</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Reinhard Klein</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Reinhard Klein</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>1st or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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</td></tr>
<tr><td>Contents</td><td colspan="4">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</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Foundations of Graphics, Vision, and Audio (MA-INF 2101)
Recommended:
Algorithms and data structures, basic knowledge on multidimensional analysis und linear algebra, basic knowledge in stochastic and statistics, numerical analysis and numerical linear algebra, C++</td></tr>
<tr><td rowspan="3">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 T/45 S</td><td>2
2</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam
(This 4LP-Modul can be combined with the 4LP-Modul „Geometry Processing II“ to a 8LP-Modul „Shape Analysis: Classification, Matching and Retrieval“ with one exam only, provided that both modules are done within the same semester.)</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• 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</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Shape Analysis: Classification, Matching and Retrieval</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 2305</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Reinhard Klein</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Reinhard Klein</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>1st or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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</td></tr>
<tr><td>Contents</td><td colspan="4">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</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Foundations of Graphics, Vision, and Audio (MA-INF 2101)
Recommended:
Algorithms and data structures, basic knowledge on multidimensional analysis und linear algebra, basic knowledge in stochastic and statistics, numerical analysis and numerical linear algebra, C++</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 T/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam
(This 4LP-module can be combined with the 4LP-module „Rendering: Materials and Images“ to a 8LP-module „Advanced Computer Graphics II“ with one exam only, provided that both modules are done within the same semester.)</td></tr>
<tr><td>Study achievments (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• 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</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Virtual Reality</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 2306</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Reinhard Klein</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Reinhard Klein</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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</td></tr>
<tr><td>Contents</td><td colspan="4">Scene Graphs, Stereo Seeing (HW, SW), Tracking (HW, SW), Acceleration Techniques (LOD; Culling), Collision detection, Haptics, Sound, Special effects (GPU-Programming)</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Recommended:
Mathematical background (multidimensional analysis and linear algebra, foundations of numerical methods), good knowledge of the foundations of computer graphics</td></tr>
<tr><td rowspan="3">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 T/45 S</td><td>2
2</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• 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 §D Graphics and Games, Siggraph Course Notes, 2006</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

Module name: **Lab Graphics, Vision, and Audio**			universitätbonn
Module No. MA-INF 2307	Workload 240 h	Credit points 8	Frequency Every year
Module coordinator	Prof. Dr. Reinhard Klein		
Lecturer(s)	Prof. Dr. Michael Clausen, Prof. Dr. Daniel Cremers, Prof. Dr. Reinhard Klein, Prof. Dr. Andreas Weber		

Classification	Programme	Compulsory/ Optional	Semester
	M.Sc. Computer Science	Optional	3rd sem.

Targeted learning outcomes	technical skills: Ability to design, analyze and implement efficient algorithms for selected problems in Graphics, Vision and Audio. soft skills: Research abilities, creativity, ability for individual implementation, documentation and presentation of research results.
Contents	Selected algorithms and techniques from Graphics, Vision and Audio
Prerequisites	Recommended: Mathematical background (multidimensional analysis and linear algebra, basic numerical methods) Foundations of Graphics, Vision, and Audio (MA-INF 2101) are strongly recommended

Format/workload/ credits	Teaching format	Group size	Hours/ week	Workload [h]	Credits
	Lab	8	4	60 T/180 S	8

Exam achievements (graded)	Exam(s)
	Oral presentation
Study achievements (not graded)	Regular participation, written documentation
Forms of media	
Literature	Selected articles on latest topics of Computer Graphics

T = Face-to-face teaching; S = Independent study

Module Handbook

Master Programme "Computer Science"

Area of Competence

Information and Communication Management

MA-INF 3101	L4E2	8 CP	**High Performance Networking**	PM
MA-INF 3102	L4E2	8 CP	**Information Systems Engineering**	ABC
MA-INF 3201	L2E1	4 CP	**Network Security**	PM
MA-INF 3202	L2E1	4 CP	**Mobile Communication**	PM
MA-INF 3203	L4E2	8 CP	**Intelligent Information Systems**	RM
MA-INF 3204	L2E1	4 CP	**Distributed and Mobile Information Systems**	TB
MA-INF 3205	L2E1	4 CP	**Internet Information Systems**	SLK
MA-INF 3206	L2E1	4 CP	**Aspect-oriented Software Development**	GK
MA-INF 3207	L2E1	4 CP	**Advanced Logic Programming**	ABC
MA-INF 3208	L2E1	4 CP	**Model-Driven Engineering**	ABC
MA-INF 3209	Sem	4 CP	**Seminar Selected Topics in Communication Management**	PM
MA-INF 3210	Sem	4 CP	**Seminar Advanced Topics in Information Management**	ABC
MA-INF 3211	Sem	4 CP	**Seminar Selected Topics in Sensor Networks Research**	PJM
MA-INF 3301	L2E1	4 CP	**Spatial Information Systems**	VS
MA-INF 3302	L2E1	4 CP	**Database Techniques for Event Monitoring Systems**	RM
MA-INF 3303	Sem	4 CP	**Seminar Enterprise Software Engineering**	ABC
MA-INF 3304	Lab	8 CP	**Lab Communication and Communicating Devices**	PM
MA-INF 3305	Lab	8 CP	**Lab Information Systems**	ABC
MA-INF 3306	Lab	8 CP	**Lab Enterprise Software Engineering**	ABC
MA-INF 3307	L2E1	4 CP	**Lecture Sensor Networks**	PJM
MA-INF 3308	Sem	4 CP	**Seminar Selected Topics in Ubiquitous Computing**	PJM

(L: Lecture, E: Exercise, Sem: Seminar)

Module coordinators:
Armin B. Cremers (ABC), Rainer Manthey (RM), Pedro José Marrón (PJM), Peter Martini (PM), Thomas Bode (TB), Günter Kniesel (GK), Stefan Lüttringhaus-Kappel (SLK), Volker Steinhage (VS)

<table>
<tr><td colspan="4">Module name:
High Performance Networking</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3101</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Peter Martini</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Peter Martini, Prof. Dr. Pedro José Marrón</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>1st or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
The students come to know fundamental concepts of modeling, evaluation and efficiency optimization of communication systems and communicating devices. They reach the ability to work on real-life issues in the areas of dynamic behavior of networks and interconnected devices with measurements, simulation and/or mathematical analysis.
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</td></tr>
<tr><td>Contents</td><td colspan="4">Networking fundamentals, performance measurements in TCP/IP based networks, modeling of networks and networked devices, TCP/IP performance over wireless and/or mobile networks, traffic engineering, performance management, active queue management, Quality of Service</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Recommended:
Bachelor-level knowledge of Data Communication and Internet Technology</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Practical exercises with state-of-the-art network simulation software)</td><td>60
30</td><td>4
2</td><td>60 T/60 S
30 P/90 S</td><td>4
4</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Written exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• M.Hassan, R.Jain, “High Performance TCP/IP Networking”, Pearson Prentice Hall 2004;
• M.C. Calzarossa, S. Tucci, “Performance Evaluation of Complex Systems: Techniques and Tools”, Springer 2002;
• R. Jain, “The Art of Computer Systems Performance Analysis”, Wiley 1991</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="5">Module name:
Information Systems Engineering</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3102</td><td>Workload
240 h</td><td colspan="2">Credit points
8</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Armin B. Cremers</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Armin B. Cremers, Prof. Dr. Rainer Manthey</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td colspan="2">Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td colspan="2">1st or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="5">technical skills:
Understanding the most important paradigms and methods of modeling and engineering large-scale software including advanced aspects of very large data bases and distributed information systems.
soft skills:
Communicative skills (oral/written presentation, „defending“ solutions), self-competence (time management, self-organisation, creativity), social skills (constructive discussion, sharing work in small teams)</td></tr>
<tr><td>Contents</td><td colspan="5">Software Architecture, patterns and styles, elements of service-oriented architecture; advanced aspects of object-oriented modeling, abstract data types, polymorphism, behavioral refinement; object-oriented application frameworks, business process redesign, web applications; architectural layers of database servers; transactional information systems</td></tr>
<tr><td>Prerequisites</td><td colspan="5">None</td></tr>
<tr><td rowspan="3">Format/workload/ credits</td><td colspan="2">Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td colspan="2">Lecture
Exercises</td><td>60
30</td><td>4
2</td><td>60 T/60 S
30 P/90 S</td><td>5
3</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="6">Exam(s)</td></tr>
<tr><td colspan="6">Written exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="6">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="6"></td></tr>
<tr><td>Literature</td><td colspan="6">• Eliens: Object-oriented Software Development, 2nd edition, Addison Wesley, 2000
• additional papers</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Network Security</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3201</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Peter Martini</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Peter Martini</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4"><u>technical skills</u>:
The students learn fundamental concepts of network security. This includes risks and vulnerabilities of today’s computer networks, concepts to increase the level of security in these networks, and a real-life oriented introduction to encryption techniques, their applications and their weaknesses.
<u>soft skills</u>:
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="4">Threats and attack scenarios, organizational aspects, technical aspects: securing networks using different firewall concepts, IDS and IPS (intrusion detection systems and intrusion prevention systems), security protocols for different protocol layers, integrity protection: hash functions and their weaknesses, certificates, privacy protection, encryption.</td></tr>
<tr><td>Prerequisites</td><td colspan="4"><u>Required (exceptionally not for students of 1st semester):</u>
High Performance Networking (MA-INF 3101)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Extensive practical exercises in the Network Security Lab)</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 P/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• Christoph Busch, Stephen D. Wolthusen: Netzwerksicherheit, Spektrum Akademischer Verlag
• Matt Bishop: Introduction to Computer Security, Addison Wesley</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Mobile Communication</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3202</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Peter Martini</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Dr. Matthias Frank, Prof. Dr. Peter Martini</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4"><u>technical skills</u>:
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
<u>soft skills</u>:
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="4">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="4"><u>Required (exceptionally not for students of 1st semester):</u>
High Performance Networking (MA-INF 3101)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 P/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• 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>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="5">Module name:
Intelligent Information Systems</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3203</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="3">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Rainer Manthey</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Rainer Manthey</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td colspan="2">Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td colspan="2">2nd or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="5">technical skills:
Students master the principles of view, constraint and trigger management both theoretically and in practical systems development and application modeling; they are able to understand and classify the state-of-the-art in research in active and deductive databases.
soft skills:
Communicative skills (oral/written presentation, „defending“ solutions), self-competence (time management, self-organisation, creativity), social skills (constructive discussion, sharing work in small teams)</td></tr>
<tr><td>Contents</td><td colspan="5">Syntax and semantics of triggers, constraints and views; efficient query processing in deductive DB; rule-based change management; trigger processing; soft and strong consistency checking; rule-based analysis of temporal data; IS design for rule-based applications</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Recommended:
Good knowledge of the foundations of SQL</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises</td><td>60
30</td><td>4
2</td><td>60 T/90 S
30 P/60 S</td><td>5
3</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="5">Exam(s)</td></tr>
<tr><td colspan="5">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="5">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">• C. Zaniolo, S. Ceri et al.: Advanced Database Systems, Morgan Kaufmann, San Francisco/USA, 1997
• E. Bertino, G. Zarri, B. Catania: Intelligent Database Systems, Addison Wesley, 2001</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="5">Module name:
Distributed and Mobile Information Systems</td><td colspan="2">universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3204</td><td>Workload
120 h</td><td colspan="2">Credit points
4</td><td colspan="2">Frequency
Every 2 years</td></tr>
<tr><td>Module coordinator</td><td colspan="6">Dr. Thomas Bode</td></tr>
<tr><td>Lecturer(s)</td><td colspan="6">Dr. Thomas Bode</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="3">Programme</td><td>Compulsory/ Optional</td><td colspan="2">Semester</td></tr>
<tr><td colspan="3">M.Sc. Computer Science</td><td>Optional</td><td colspan="2">2nd or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="6"><u>technical skills</u>:
Solid understanding of modern architecture concepts and problem solving techniques for distributed and mobile information systems.
<u>soft skills</u>:
Communicative skills (written and oral presentations, decision making), personal skills (time-management, self-reflection).</td></tr>
<tr><td>Contents</td><td colspan="6">System architectures (distributed and mobile data base systems, peer-to-peer information systems, data-grids, data management in sensor nets), transaction management, query evaluation techniques, system managed redundancy (semantic caching, hoarding, replication- and synchronization of data), spatial information handling in mobile information systems.</td></tr>
<tr><td>Prerequisites</td><td colspan="6"><u>Recommended</u>:
Profound knowledge in databases and information systems</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td colspan="2">Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td colspan="2">Lecture
Exercises
(Theoretical and practical exercises in small groups)</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 P/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="6">Exam(s)</td></tr>
<tr><td colspan="6">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="6">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="6"></td></tr>
<tr><td>Literature</td><td colspan="6">G. Coulouris, J. Dollimore, T. Kindberg, Distributed Systems. Concepts and Design. Addison Wesley, June 2005</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="5">Module name:
Internet Information Systems</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3205</td><td>Workload
120 h</td><td colspan="2">Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Dr. Stefan Lüttringhaus-Kappel</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Dr. Stefan Lüttringhaus-Kappel</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td colspan="2">Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td colspan="2">2nd or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="5">technical skills:
Profound knowledge of content management systems; ability to select and apply appropriate technologies and tools for web applications
soft skills:
Ability to present, evaluate, and discuss solutions with fellow students; analytical and creative skills</td></tr>
<tr><td>Contents</td><td colspan="5">Relevant technologies: client/server architecture, HTTP; document formats and markup: XML, XHTML 2, CSS, SVG; style sheets: CSS and XSL, etc.; server-side technologies: CGI, template mechanisms, Java Servlet and JSP, application servers, middleware, database mapping, content management systems (CMS): technical foundations, common systems, extensions, XML-technologies in CMS; client-side programming, JavaScript, "Web 2.0"; selected additional topics; practical exercises related to the essential topics and tools</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Recommended:
Basic knowledge of XML and Java</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(To deepen and extend insight, including programming assignments in Java and selected open source tools)</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 P/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="5">Exam(s)</td></tr>
<tr><td colspan="5">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="5">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">• Jeffrey Jackson: Web Technologies: A Computer Science Perspective. Prentice Hall 2007
• Heiko Wöhr: Web-Technologien. dpunkt.verlag, 2004
• Selected chapters from other books, various system documentations</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Aspect-oriented Software Development</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3206</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Dr. Günter Kniesel</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Dr. Günter Kniesel</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
Ability to identify cross-cutting concerns (CCC), understand their impact on software development, the essence of the various aspect-oriented (AO) solution approaches, asses the adequacy of a particular AO-technique for a given CCC and modularize CCCs using the most suitable AO technique.
soft skills:
Teamwork, collaborative problem solving</td></tr>
<tr><td>Contents</td><td colspan="4">Cross-cutting concerns, join points, aspect effects, effect specifications (introduction and advice), aspects, a widely-used aspect language, sample aspect application areas, generic aspect languages, cross-language aspects, symmetric aspects, domain-specific aspects, fine-grained aspects, dynamic aspects, aspect weaving technologies, concern mining, refactoring to aspects, refactoring of aspects, aspect-aware refactoring, aspect interference analysis, aspects and modular reasoning, early aspects, aspect-oriented design, empirical validation.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Practical work in goups of 2-4 students using state-of-the-art MDE tools, languages, and methodologies)</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 P/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral or written (depending on number of candidates)</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• Robert E. Filman, Tzilla Elrad, Siobhán Clarke, Mehmet Aksit: Aspect-Oriented Software Development, Addison-Wesley, 2005
• Communications of the ACM, Volume 44, Issue 10, October 2001
• Ramnivas Laddad: AspectJ in Action, Manning Publications, 2003</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Advanced Logic Programming</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3207</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Armin B. Cremers</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Armin B. Cremers, Dr. Günter Kniesel,
Dr. Stefan Lüttringhaus-Kappel</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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
soft skills:
Skills in written and oral presentation of the solutions to programming assignments, collaboration with other students in small teams</td></tr>
<tr><td>Contents</td><td colspan="4">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.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Recommended:
Good knowledge of the foundations of Logic Programming</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Weekly programming assignments in Prolog, both individually and in small teams)</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 P/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• L. Sterling, E. Shapiro (ed.): The Art of Prolog (2nd ed.) MIT Press.
• Richard O'Keefe: The Craft of Prolog, MIT Press.</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Model Driven Engineering</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3208</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Armin B. Cremers</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Dr. Günter Kniesel, Prof. Dr. A. B. Cremers</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
Ability to understand and use MDA tools and techniques. Ability to assess the applicability of a particular MDA technique or tool to a given problem. Ability to understand advanced MDA literature.
soft skills:
Teamwork, collaborative problem solving</td></tr>
<tr><td>Contents</td><td colspan="4">Structural and behavioural reflection, models and meta-models, UML and the meta-object facility (MOF), model driven architecture (MDA), model transformations, declarative and imperative model transformation systems, model transformation analysis, composition and reuse of model transformations, compilation and optimization of model transformations, model-based testing, model driven methodologies, MDA applications and success stories, evaluation.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Practical work in groups of 2-4 students using state-of-the-art MDE tools, languages, and methodologies)</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 P/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• David S. Frankel: Model Driven Architecture: Applying MDA to Enterprise Computing, John Wiley
• Modellgetriebene Softwareentwicklung, Techniken, Engineering, Management. dPunkt, 2005
• additional papers and articles reflecting the rapid development of this new field</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

#

<table>
<tr><td colspan="4">Module name:
Seminar Selected Topics in Communication Management</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3209</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every semester</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Peter Martini</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Peter Martini</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd and 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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.</td></tr>
<tr><td>Contents</td><td colspan="4">Current conference and journal papers, current standardization drafts</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
High Performance Networking (MA-INF 3101)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td colspan="2">Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td colspan="2">Seminar</td><td>10</td><td>2</td><td>30 T/90 S</td><td>4</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Regular participation, written report</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">The relevant literature will be announced towards the end of the previous semester</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Seminar Advanced Topics in Information Management</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3210</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
At least every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Armin B. Cremers</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Armin B. Cremers, Dr. Thomas Bode,
Dr. Stefan Lüttringhaus-Kappel, Prof. Dr. Rainer Manthey</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd and/or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">Ability to acquire and evaluate advanced scientific literature; skills in didactic preparation as well as oral presentation of complex matters and latest research results; ability to evaluate and discuss presentations of fellow students, and to constructively deal with critical feedback of others</td></tr>
<tr><td>Contents</td><td colspan="4">Varying selected topics in information systems based on modern research literature</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Information Systems Engineering (MA-INF 3102)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Seminar</td><td>10</td><td>2</td><td>30 T/90 S</td><td>4</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Regular participation, written report</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">The relevant literature will be announced towards the end of the previous semester.</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Seminar Selected Topics in Sensor Network Research</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3211</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency of availability
Every semester</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Pedro José Marrón</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Pedro José Marrón</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>optional</td><td>2nd or 3rd Sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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</td></tr>
<tr><td>Contents</td><td colspan="4">Current conference and journal papers, current standardization drafts</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
High Performance Networking (MA-INF 3101)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Seminar</td><td>10</td><td>2</td><td>30 T / 90 S</td><td>4</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="5">Exam(s)</td></tr>
<tr><td colspan="5">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="5">Regular participation, written report</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5"></td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Spatial Information Systems</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3301</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">PD Dr. Volker Steinhage</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">PD Dr. Volker Steinhage</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4"><u>technical skills</u>:
Understanding the most important paradigms and methods of spatial information systems: spatial data types, geometric representation schemes, geometric algorithms, spatial access methods, and processing of spatial queries
<u>soft skills</u>:
• Ability to rate different approaches on conceptual, logical and physical concepts of spatial information design
• Ability to derive a solution oriented problem formulation of a given task
• Ability to cooparate in small groups on solving a given task.
• Ability to put a conceptual solution and its implemention down on paper
• Ability to present and discuss a conceptual solution and its implemention in an oral presentation</td></tr>
<tr><td>Contents</td><td colspan="4">Vocabulary of spatial information systems, representation of spatial objects, logical models and query languages, basic geometric algorithms, spatial access methods, processing of spatial queries, and review of prototypical commercial systems</td></tr>
<tr><td>Prerequisites</td><td colspan="4">None</td></tr>
<tr><td rowspan="3">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture</td><td>60</td><td>2</td><td>30 T/30 S</td><td>2</td></tr>
<tr><td>Exercises</td><td>30</td><td>1</td><td>15 P/45 S</td><td>2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Written exam (oral exam in exceptional cases)</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">Philippe Rigaux, Michel Scholl, Agnés Voisard:
Spatial Databases with Applications to GIS. Morgan Kaufmann – The Morgan Kaufmann Series in Data Management Systems, 2001.</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Database Techniques for Event Monitoring Systems</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3302</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Rainer Manthey</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Rainer Manthey</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4"><u>technical skills</u>:
Students will get acquainted with basic issues in and methods of database support for event monitoring systems. Apart from methods for representation and storage of events in a database, various algorithmic approaches to analysis and processing of data streams are introduced. In particular, techniques from the areas of active, deductive, and temporal and real-time data bases are introduced and discussed in relation with stream processing and event monitoring issues.
<u>soft skills</u>:
Communicative skills (oral/written presentation, „defending“ solutions), self-competence (time management, self-organisation, creativity), social skills (constructive discussion, sharing work in small teams)</td></tr>
<tr><td>Contents</td><td colspan="4">Architecture of an event-driven DBMS; types of events and event logs; representation and storage of data streams, index structures and query processing for data streams (in particular, continuous queries); views over data streams; active and deductive rules for processing and analyzing events; one-pass-algorithms, window functions and methods of update propagation; foundations of active, deductive, and temporal data base systems; prototypical stream management systems</td></tr>
<tr><td>Prerequisites</td><td colspan="4">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 P/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• C. Aggarwal (ed.): Data Streams: Models and Algorithms, Springer, New York/USA, 2007
• A. Gupta, I.S. Mumick: Materialized Views: Techniques, Implementation, and Applications, NetLibrary Inc., 1998
• N. Paton (ed.): Active Rules in Database Systems, Springer, New York/USA, 1999</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Seminar Enterprise Software Engineering</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3303</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Armin B. Cremers</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Armin B. Cremers, Dr. Günter Kniesel</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
Familiarity with an advanced domain of current software engineering research. This might include either a broad overview of a specific field or in depth exploration of new, breakthrough results.
soft skills:
Ability to acquire and evaluate advanced scientific literature; skills in didactic preparation as well as oral presentation of complex matters and latest research results; ability to evaluate and discuss presentations of fellow students, and to constructively deal with critical feedback of others.</td></tr>
<tr><td>Contents</td><td colspan="4">Selected topics in software engineering based on modern research results. The topics will either deepen one of the areas of the software engineering related lectures of the master program or introduce students to new, emerging topics of software engineering.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Information Systems Engineering (MA-INF 3102) and at least one of the following lectures:
Model-Driven Software Engineering (MA-INF 3208),
Aspect-Oriented Software Engineering (MA-INF 3206)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Seminar</td><td>10</td><td>2</td><td>30 T/90 S</td><td>4</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Regular participation, written report</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">Articles representing established and new work in the respective area of each course instance</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

Module name: **Lab Communication and Communicating Devices**						universitätbonn
Module No. MA-INF 3304	Workload 240 h	Credit points 8				Frequency Every semester
Module coordinator	Prof. Dr. Peter Martini					
Lecturer(s)	Prof. Dr. Peter Martini					
Classification	Programme		Compulsory/ Optional		Semester	
	M.Sc. Computer Science		Optional		2nd and/or 3rd sem.	
Targeted learning outcomes	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:					
Contents	Selected topics close to current research in the area of communication systems, network security, mobile communication and communicating devices.					
Prerequisites	Required: High Performance Networking (MA-INF 3101), Network Security (MA-INF 3201) and/or Mobile Communication (MA-INF 3202)					
Format/workload/ credits	Teaching format		Group size	Hours /week	Workload [h]	Credits
	Lab (The majority of tasks is embedded in co-operation projects with external partners such as local industry and research organisations)		8	4	60 T/180 S	8
Exam achievements (graded)	Exam(s)					
	Oral presentation					
Study achievements (not graded)	Regular participation, written documentation					
Forms of media						
Literature	The relevant literature will be announced towards the end of the previous semester.					

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="3">Module name:
Lab Information Systems</td><td colspan="3">  </td></tr>
<tr><td>Module No.
MA-INF 3305</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="3">Frequency
At least every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Armin B. Cremers</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Armin B. Cremers, Dr. Thomas Bode,
Dr. Stefan Lüttringhaus-Kappel, Prof. Dr. Rainer Manthey</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td colspan="2">Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td colspan="2">2nd and/or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="5">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</td></tr>
<tr><td>Contents</td><td colspan="5">Varying selected topics close to current research in the area of database- and information systems.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td colspan="2">Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td colspan="2">Lab</td><td>8</td><td>4</td><td>60 T/180 S</td><td>8</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="5">Exam(s)</td></tr>
<tr><td colspan="5">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="5">Regular participation, written documentation</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">The relevant literature will be announced towards the end of the previous semester.</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Lab Enterprise Software Engineering</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3306</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Armin B. Cremers</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. A. B. Cremers, Dr. Günter Kniesel</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
Ability to participate in and run a software project, communicate with customers, identify and analyse requirements, identify risks, estimate the workload, plan iterations, keep the team involved, control the progress and adapt the process if necessary, choose and use state of the art tools for software development, issue management, configuration management, testing and integration.
soft skills
Effective collaboration in a small team including the ability to jointly reach design and management decisions.</td></tr>
<tr><td>Contents</td><td colspan="4">The course participants will work as a team on a joint project, applying advanced software engineering concepts (e.g. SOA, MDE, AOSD) and related modern software development tools in the framework of an agile software development process (XP, Scrum, etc.).</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Seminar Enterprise Software Engineering (MA-INF 3303),
Information Systems Engineering (MA-INF 3102) and at least one of
Model-Driven Software Engineering (MA-INF 3208) or
Aspect-Oriented Software Engineering (MA-INF 3206)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lab
(Team of 10-12 students practicing “extreme programming” techniques – pair programming, planning game, refactoring, test-first, etc.)</td><td>8</td><td>6</td><td>90 T/150 S</td><td>8</td></tr>
<tr><td>Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td></td><td colspan="4">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Regular participation, written documentation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">„Extreme programming explained”, Kent Beck, Addison Wesley, and literature pertaining to the specific topic of the respective course instance. See also the prerequisite courses (MA-INF 3102, MA-INF 3206, MA-INF-3208, MA-INF 3303).</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Sensor Networks</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3307</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency of availability
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Pedro José Marrón</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Pedro José Marrón</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>optional</td><td>3rd Sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
The students learn the fundamental concepts of sensor networks and how they differ from traditional networked systems that do not take energy and resource constraints into account. During the experiments, the students will deal with real-world deployments of sensor networks and use real sensor nodes to understand better the effects of real-world phenomena in aspects like link quality, localization, etc.
soft skills:
Communicative skills (oral/written presentation, defending solutions), self-competence (time management, self-organisation, creativity), social skills (constructive discussion, sharing work in small teams)</td></tr>
<tr><td>Contents</td><td colspan="4">Sensor network architectures, single node architecture, hardware platforms, operating systems, MAC protocols for sensor networks, link layer, transport layer, localization, middleware, data management.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
High Performance Networking (MA-INF 3101)</td></tr>
<tr><td rowspan="3">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises</td><td>60
30</td><td>2
1</td><td>30 T / 30 S
15 T / 45 S</td><td>2
2</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• Holger Karl and Andreas Willig, “Protocols and Architectures for Wireless Sensor Networks”, Wiley, 2005.
• Feng Zhao and Leo Guibas, “Wireless Sensor Networks: An Information Processing Approach”, Morgan Kaufmann, 2004</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="5">Module name:
Seminar Selected Topics in Ubiquitous Computing</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 3308</td><td>Workload
120 h</td><td colspan="2">Credit points
4</td><td colspan="2">Frequency of availability
Every semester</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Pedro José Marrón</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Pedro José Marrón</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ optional</td><td colspan="2">Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>optional</td><td colspan="2">2nd or 3rd Sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="5">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</td></tr>
<tr><td>Contents</td><td colspan="5">Current conference and journal papers, current standardization drafts.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Required:
High Performance Networking (MA-INF 3101)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Seminar</td><td>10</td><td>2</td><td>30 T / 90 S</td><td>4</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="5">Exam(s)</td></tr>
<tr><td colspan="5">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="5">Regular participation, written report</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5"></td></tr>
</table>

T = Face-to-face teaching; S = Independent study

Module Handbook

Master Programme "Computer Science"

Area of Competence

Intelligent Systems

MA-INF 4101	L4E2	8 CP	**Theory of Sensorimotor Systems**	RE
MA-INF 4102	L4E2	8 CP	**Intelligent Learning and Analysis Systems**	SW
MA-INF 4201	L2E1	4 CP	**Artificial Life**	RE
MA-INF 4202	L2E1	4 CP	**Computational Neuroscience and Neural Computation**	RE
MA-INF 4203	L2E1	4 CP	**Autonomous Mobile Systems**	RE
MA-INF 4204	L2E1	4 CP	**Technical Neural Nets**	JA
MA-INF 4205	L2E1	4 CP	**Probabilistic Graphical Models**	ABC
MA-INF 4206	L2E1	4 CP	**Knowledge-based Image Understanding**	VS
MA-INF 4207	L2E1	4 CP	**Dynamically Reconfigurable Systems**	JA
MA-INF 4208	Sem	4 CP	**Seminar Biological and Technical Neural Computation**	RE
MA-INF 4209	Sem	4 CP	**Seminar Principles of Data Mining and Learning Algorithms**	SW
MA-INF 4210	Sem	4 CP	**Seminar Advanced Topics in Technical Informatics**	JA
MA-INF 4301	L2E1	4 CP	**Advanced Topics in Artificial Intelligence**	ABC
MA-INF 4302	L2E1	4 CP	**Advanced Learning Systems**	SW
MA-INF 4303	L2E1	4 CP	**Learning from Non-Standard Data**	SW
MA-INF 4304	Lab	8 CP	**Lab Development and Physical Realisation of Sensory and Motor Modules**	RE
MA-INF 4305	Lab	8 CP	**Lab Autonomous Robots**	ABC
MA-INF 4306	Lab	8 CP	**Lab Development and Application of Data Mining and Learning Systems**	SW
MA-INF 4307	Lab	8 CP	**Lab Field Programmable Gate Arrays**	JA

(L: Lecture, E: Exercise, Sem: Seminar)

Module coordinators:
Joachim K. Anlauf (JA), Armin B. Cremers (ABC), Rolf Eckmiller (RE), Stefan Wrobel (SW), Volker Steinhage (VS)

<table>
<tr><td colspan="4">Module name:
Theory of Sensorimotor Systems</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 4101</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Armin B. Cremers</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Rolf Eckmiller, Dr. Nils Goerke</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>1st or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
The students will be capable to assess real world problems and applications by means of sensorimotor approaches. They will be capable to identify what part of a sensorimotor application 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.
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)</td></tr>
<tr><td>Contents</td><td colspan="4">Basic principles of learning sensorimotor systems with biological examples (e.g.: visually guided eye movements, auditory guided speech generation) and technical examples (e.g.: sensory guided processes, manipulators, or vehicles); theories of decision making and task planning; foundations of autonomous systems. Configuration, control, and functional principles of sensory systems, planning, decision, and motor systems as well as process control systems. Processing of sensory data; motor control; basic control architectures</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Recommended:
Good knowledge of the foundations of artificial intelligence, technical computer science and probability calculus</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Paper-and-pencil exercises, tasks with standard software and simulation systems like Matlab, Simulink or Labview. Work in 2- person groups)</td><td>60
30</td><td>4
2</td><td>60 T / 90 S
30 P / 60 S</td><td>5
3</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Written exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• B. Widrow, S.D. Stearns: Adaptive Signal Processing, Prentice Hall, Englewood
• E.R. Kandel, J.H. Schwartz, T.H. Jessel: Principles of Neural Science, McGraw-Hill, New York
• D.A. White, D.A. Sofge: Handbook of Intelligent Control: Neural, Fuzzy and Adaptive Approaches, Van Nostrand Reinhold, New York</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Intelligent Learning and Analysis Systems</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 4102</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Stefan Wrobel</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Armin B. Cremers, PD Dr. Volker Steinhage,
Prof. Dr. Stefan Wrobel</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>1st or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
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). At the end of the module, students will be capable of choosing appropriate methods and systems for particular 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.
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)</td></tr>
<tr><td>Contents</td><td colspan="4">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), clustering, reinforcement learning, evaluation and learning theory, descriptive data mining methods (association rules, subgroups), pre- and postprocessing, data storage (data warehouses, OLAP), special data types (spatial, network, text, multimedia data), interactive and visual systems</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Recommended:
Prior knowledge of probability theory, linear algebra, artificial intelligence, information systems and data bases</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Paper-and-pencil exercises, hands-on-work on data analysis tasks with popular software systems like Yale, R; group work on competition projects)</td><td>60
30</td><td>4
2</td><td>60 T/90 S
30 P/60 S</td><td>5
3</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Written exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• Tom Mitchell, Machine Learning, McGraw-Hill, 1997
• Ian Witten, Eibe Frank, Data Mining, Morgan Kauffmann, 2000
• Jiawei Han, Micheline Kamber, Data Mining: Concepts and Techniques, Morgan Kaufmann, 2000</td></tr>
</table>

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<table>
<tr><td colspan="4">Module name:
Artificial Life</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 4201</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every 2 years</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Rolf Eckmiller</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Rolf Eckmiller, Dr. Nils Goerke</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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.</td></tr>
<tr><td>Contents</td><td colspan="4">Foundations of artificial life, cellular automata, Conway’s “Game of Life”; mechanisms for structure 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</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Theory of Sensorimotor Systems (MA-INF 4101)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Paper-and-pencil exercises in two person groups. Presentation and discussion of the results during the exercises. Small tasks to be completed using state of the art simulation tools, and programms implemented individually (C++, JAVA, ...))</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 P/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• 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</td></tr>
</table>

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<table>
<tr><td colspan="4">Module name:
Computational Neuroscience and Neural Computation</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 4202</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Rolf Eckmiller</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Rolf Eckmiller, Dr. Nils Goerke</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
Knowledge of structure and function of biological neural systems and its elements; knowledge of biomimetic systems and modules, which simulate sensorimotor systems with neural control. Foundations of bi-directional man-machine interaction between a learning technical sensorimotor system and a human user.
soft skills:
The students will be capable to classify real world tasks by means of biological information processing paradigms. They will learn and practise the interdisciplinary communication by scientific discussions with other subjects (e.g. neuroscience, neuroanatomy, biocybernet-ics...).</td></tr>
<tr><td>Contents</td><td colspan="4">Structure and function of neural modules and elements. Information proc-essing and learning in specific regions of the central nervous system, includ-ing: retina, sensory cortex, cerebellum, and motor cortex. Systems theory, control theory, vector analysis, tensor calculus, and Fourier transformation for information processing of sensory and motor brain functions. Simulation of function and learning properties of neural systems. Relationship between the definitions of information versus entropy.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Paper-and-pencil exercises, 3-5 exer-cises per week. Presentation of the results during the exercises in front of the group.)</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 P/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="5">Exam(s)</td></tr>
<tr><td colspan="5">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="5">Successful exercise participation</td></tr>
<tr><td>Literature</td><td colspan="5">• J.M. Bower: Computational Neuroscience: Trends in Research, Cal Tech Pasadena, Plenum Press, New York,1997
• Simon Haykin: Neural Networks, A Comprehensive Foundation, Prentice Hall International Editions
• Christopher M. Bishop: Neural Networks for Pattern Recognition, Oxford University Press
• E.R. Kandel, J.H. Schwartz, T.H. Jessel: Principles of Neural Science, McGraw-Hill, New York</td></tr>
</table>

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<table>
<tr><td colspan="4">Module name:
Autonomous Mobile Systems</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 4203</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Rolf Eckmiller</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Armin B. Cremers, Prof. Dr. Rolf Eckmiller, Dr. Nils Goerke</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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.</td></tr>
<tr><td>Contents</td><td colspan="4">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.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Theory of Sensorimotor Systems (MA-INF 4101)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Paper-and-pencil exercises, work in two person groups. Presentation, defending and discussion of the results during the exercises. Tasks with standard software, simulation systems for autonomous mobile systems e.g. Labview, Stage & Gazebo and own programms (C++, JAVA))</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 P/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• J.-C. Latombe: Robot Motion Planning, Klwer Academic
• J. Buchli: Mobile Robots: Moving Intelligence, Published by Advanced Robotic Systems and Pro Literatur Verlag</td></tr>
</table>

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<table>
<tr><td colspan="4">Module name:
Technical Neural Nets</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 4204</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Joachim K. Anlauf</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Joachim K. Anlauf, Prof. Dr. Rolf Eckmiller, Dr. Nils Goerke</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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.</td></tr>
<tr><td>Contents</td><td colspan="4">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.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Intelligent Learning and Analysis Systems (MA-INF 4102)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Paper-and-pencil exercises in 2-person groups. Presentation and discussion of the results during the exercises. Small tasks to be completed using state of the art neural network systems and programming libraries.)</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 P/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Literature</td><td colspan="4">• 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</td></tr>
</table>

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Module name: **Probabilistic Graphical Models**			universitätbonn
Module No. MA-INF 4205	Workload 120 h	Credit points 4	Frequency Every year
Module coordinator	Prof. Dr. Armin B. Cremers		
Lecturer(s)	Prof. Dr. Armin B. Cremers		

Classification	Programme	Compulsory/ Optional	Semester
	M.Sc. Computer Science	Optional	2nd or 3rd sem.

Targeted learning outcomes

<u>technical skills</u>:
Participants acquire in-depth knowledge of the representation of uncertain information using probabilistic graphical models. They learn how to design and apply different types of models to estimation and inference task in the context of sensorimotor systems.
<u>soft skills</u>:
Students should acquire the following skills:
- Ability to derive a solution oriented problem formulation of a given task.
- Ability to cooparate in small groups on solving a given task.
- Ability to put a conceptual solution and its implemention down on paper.
- Ability to present and discuss a conceptual solution and its implemention in an oral presentation.

Contents

This module introduces a selection of graphical models, their associated inference and learning algorithms as well as application in the domain of sensorimotor systems. Topics include: *Models:* Bayes nets, Bayes filters, Hidden Markov Models, dynamic models, and undirected models.
Inference: (loopy) belief propagation, junction trees, MC and MCMC methods, and variational methods.
Learning: Bayesian learning and model selection techniques.

Prerequisites

<u>Recommended</u>:
Intelligent Learning and Analysis Systems (MA-INF 4101) and/or Theory of Sensorimotor Systems (MA-INF 4102)

Format/workload/ credits	Teaching format	Group size	Hours /week	Workload [h]	Credits
	Lecture	60	2	30 T/30 S	2
	Exercises	30	1	15 P/45 S	2

Exam achievements (graded)	Exam(s)
	Oral exam
Study achievements (not graded)	Successful exercise participation
Forms of media	

Literature

- M. I. Jordan: An Introduction to Probabilistic Graphical Models, in preparation
- Daphne Koller, Nir Friedman: Bayesian Networks and Beyond, in preparation
- F. V. Jensen: Bayesian Networks and Decision Graphs, Springer 2001
- M.I. Jordan (editor): Learning in Graphical Models, MIT-Press 1998
- additional papers

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<table>
<tr><td colspan="4">Module name:
Knowledge-based Image Understanding</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 4206</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">PD Dr. Volker Steinhage</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">PD Dr. Volker Steinhage</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
Understanding the most important paradigms and methods of knowledge-based image understanding systems
soft skills:
• Ability to rate different approaches on conceptual, logical and physical concepts of spatial information design
• Ability to derive a solution oriented problem formulation of a given task
• Ability to cooparate in small groups on solving a given task.
• Ability to put a conceptual solution and its implemention down on paper
• Ability to present and discuss a conceptual solution and its implemention in an oral presentation</td></tr>
<tr><td>Contents</td><td colspan="4">Knowledge representation and inference about scenes and objects: feature spaces, semantic networks, frames, scripts, fuzzy logic, graphical models. Spatial and image-based object models: CSG, B-Rep, Multi-View, Invariants. Interpretation strategies: bottom-up, top-down, feedback, heterarchical. Component-based representation and recognition. Active vision: salience, attention, tracking.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 P/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• Larry S. Davis (Ed.): Foundations of Image Understanding. Series: The Springer International Series in Engineering and Computer Science, Vol. 628, Springer, 2001
• David A. Forsyth, Jean Ponce: Computer Vision: A Modern Approach. Prentice Hall, 2003
• Journal Computer Vision and Image Understanding, Editor-in-Chief: A.C. Kak. Elsevier</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

Module name: **Dynamically Reconfigurable Systems**			universitätbonn
Module No. MA-INF 4207	Workload 120 h	Credit points 4	Frequency At least every 2 years
Module coordinator	Prof. Dr. Joachim K. Anlauf		
Lecturer(s)	Prof. Dr. Joachim K. Anlauf		

Classification	Programme	Compulsory/ Optional	Semester
	M.Sc. Computer Science	Optional	2nd sem.

Targeted learning outcomes	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, Partial Reconfigurability
Prerequisites	None

Format/workload/ credits	Teaching format	Group size	Hours /week	Workload [h]	Credits
	Lecture	60	2	30 T/30 S	2
	Exercises (Paper-and-pencil exercises, programming tasks with hardware description languages such as VHDL and SystemC)	30	1	15 P/45 S	2

Exam achievements (graded)	Exam(s)
	Oral exam
Study achievements (not graded)	Successful exercise participation
Forms of media	
Literature	Current research papers and technical documentation

T = Face-to-face teaching; S = Independent study

Module name: **Seminar Biological and Technical Neural Computation**					
Module No. MA-INF 4208	Workload 120 h	Credit points 4		Frequency Every year	
Module coordinator	Prof. Dr. Rolf Eckmiller				
Lecturer(s)	Prof. Dr. Joachim K. Anlauf, Prof. Dr. Rolf Eckmiller, Dr. Nils Goerke				
Classification	Programme		Compulsory/ Optional	Semester	
	M.Sc. Computer Science		Optional	2nd sem.	
Targeted learning outcomes	<u>technical skills</u>: Detailed understanding of the essential principles of neural computation. Independent study of the fundamental principles based on current literature <u>soft skills</u>: The students will have learned to prepare and give a talk on the given subject. They will know how to find state of the art literature and publications for the given subject, to comprehend the found items, and to content filter the found literature. They will be capable to prepare the slides for a 45-60 minutes talk. The give the presentation and can lead the subsequent discussion.				
Contents	Principles of biological and biomimetic elements and systems. Structure and function of selected neural systems (especially: retina, visual cortex, motor cortex, cerebellum). Principles of the most important technical neural net paradigms and learning algorithms and corresponding application areas. Selected approaches and typical applications that represent the state-of-the-art.				
Prerequisites	<u>Required</u>: Theory of Sensorimotor Systems (MA-INF 4101) or Intelligent Learning and Analysis Systems (MA-INF 4102)				
Format/workload/ credits	Teaching format	Group size	Hours /week	Workload [h]	Credits
	Seminar	10	2	30 T/90 S	4
Exam achievements (graded)	Exam(s)				
	Oral presentation				
Study achievements (not graded)	Regular participation, written report				
Forms of media					
Literature	• R.J. Baron: The Cerebral Computer: An Introduction to the Computational Structure of the Human Brain, Lawrence Erlbaum, Associates, Publisher, London • E.R. Kandel, J.H. Schwartz, T.H. Jessel: Principles of Neural Science, McGraw-Hill, New York • P.S. Churchland, T.S. Sejnowski: The Computational Brain, MIT Press				

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Seminar Principles of Data Mining and Learning Algorithms</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 4209</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Stefan Wrobel</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Stefan Wrobel</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>2nd or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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
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)</td></tr>
<tr><td>Contents</td><td colspan="4">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.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Seminar</td><td>10</td><td>2</td><td>30 T/90 S</td><td>4</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Regular participation, written report</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">The relevant literature will be announced towards the end of the previous semester.</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

Module name: **Seminar Advanced Topics in Technical Informatics**						universitätbonn
Module No. MA-INF 4210	Workload 120 h	Credit points 4				Frequency At least every 2 years
Module coordinator	Prof. Dr. Joachim K. Anlauf					
Lecturer(s)	Prof. Dr. Joachim K. Anlauf					
Classification	Programme		Compulsory/ Optional		Semester	
	M.Sc. Computer Science		Optional		2nd or 3rd sem.	
Targeted learning outcomes	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/workload/ credits	Teaching format		Group size	Hours /week	Workload [h]	Credits
	Seminar		10	2	30 T/90 S	4
Exam achievements (graded)	Exam(s)					
	Oral presentation					
Study achievements (not graded)	Regular participation, written report					
Forms of media						
Literature	Current research papers					

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Advanced Topics in Artificial Intelligence</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 4301</td><td>Workload
120 h</td><td>Credit points
4</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Armin B. Cremers</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Armin B. Cremers</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">technical skills:
Introduction of advanced Artificial Intelligence (AI) techniques. This course aims at familiarising students with the latest trends in AI research.
soft skills:
Students should acquire the following skills:
• Ability to derive a solution oriented problem formulation of a given task.
• Ability to cooparate in small groups on solving a given task.
• Ability to put a conceptual solution and its implemention down on paper.
• Ability to present and discuss a conceptual solution and its implemention in an oral presentation.</td></tr>
<tr><td>Contents</td><td colspan="4">This class focuses on teaching modern AI methods which capture the current state of the art in their respective area, e.g. perception, reasoning, planning, learning, and decision making.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Intelligent Learning and Analysis Systems (MA-INF 4102) and/or Theory of Sensorimotor Systems" (MA-INF 4101)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 T/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Successful exercise participation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• G. F. Luger: Artificial Intelligence, 5th edition, Addison Wesley 2005
• M. Ghallab, D. Nau, P. Traverso: Automated Planning, Elsevier, 2004
• additional papers</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

Module name: **Advanced Learning Systems**			universitätbonn
Module No. MA-INF 4302	Workload 120 h	Credit points 4	Frequency Every year
Module coordinator	Prof. Dr. Stefan Wrobel		
Lecturer(s)	Prof. Dr. Stefan Wrobel		

Classification	Programme	Compulsory/ Optional	Semester
	M.Sc. Computer Science	Optional	2nd or 3rd sem.

Targeted learning outcomes	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 consists of alternating lectures on different algorithm classes, including • neural networks • kernel machines • probabilistic and statistical learning approaches • logic-based learning approaches • reinforcement learning
Prerequisites	Required: Intelligent Learning and Analysis Systems (MA-INF 4102) and/or Theory of Sensorimotor Systems" (MA-INF 4101) (Exceptions for students starting in the summer semester can be arranged after prior consultation only.)

Format/workload/ credits	Teaching format	Group size	Hours /week	Workload [h]	Credits
	Lecture	60	2	30 T/30 S	2
	Exercises (Written exercises and software-oriented work with state-of-the-art Learning Systems)	30	1	15 T/45 S	2

Exam achievements (graded)	Exam(s)
	Oral exam
Study achievements (not graded)	Successful exercise participation
Forms of media	
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

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="5">Module name:
Learning from Non-Standard Data</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 4303</td><td>Workload
120 h</td><td>Credit points
4</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 rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td colspan="2">Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td colspan="2">2nd or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="5"><u>technical skills</u>:
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.
<u>soft skills</u>:
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)</td></tr>
<tr><td>Contents</td><td colspan="5">The module will be filled with varying lectures on different non-standard data types, including: Text Mining, Multimedia Mining, Graph Mining. Learning from structured data, Spatial Data Mining</td></tr>
<tr><td>Prerequisites</td><td colspan="5"><u>Required</u>:
Intelligent Learning and Analysis Systems (MA-INF 4102) and/or
Theory of Sensorimotor Systems" (MA-INF 4101)
(Exceptions for students starting in the summer semester can be arranged after prior consultation only.)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lecture
Exercises
(Written exercises and software-oriented work with state-of-the-art Learning Systems)</td><td>60
30</td><td>2
1</td><td>30 T/30 S
15 T/45 S</td><td>2
2</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="5">Exam(s)</td></tr>
<tr><td colspan="5">Oral exam</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="5">Successful exercise participation</td></tr>
<tr><td>Literature</td><td colspan="5">• 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</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="3">Module name:
Lab Development and Physical Realisation of Sensory and Motor Modules</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 4304</td><td>Workload
240 h</td><td>Credit points
8</td><td>Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="3">Prof. Dr. Rolf Eckmiller</td></tr>
<tr><td>Lecturer(s)</td><td colspan="3">Prof. Dr. Joachim K. Anlauf, Prof. Dr. Rolf Eckmiller,
Dr. Nils Goerke</td></tr>
<tr><td rowspan="2">Classification</td><td>Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td>M.Sc. Computer Science</td><td>Optional</td><td>3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="3">technical skills:
Practical experience in design and implementation of adaptive and learning modules for the control of sensorimotor systems. Implementation of functional elements for measurement and control with analog and digital electronic hardware
soft skills:
The students will learn how to design and conduct scientific experiments in 2-person groups. They will alternate in leading the small working group, analyze the results and evaluate the underlying assumptions in a scientific manner. They will learn to discuss the results and write documents that describe the experiments and report the found results. They will learn how to interpret the experiments and to draw conclusions.</td></tr>
<tr><td>Contents</td><td colspan="3">Principles of systems theory and the function of feedback control systems. Implementation of selected feedback control modules (e.g.: as mechanical or mechatronic hardware), application of the implemented modules for several test beds, e.g.: autonomous robot, manipulator, inverted pendulum, selected sensory and motor capabilities of humans. Principles of adaptive and learning control</td></tr>
<tr><td>Prerequisites</td><td colspan="3">Required:
Theory of Sensorimotor Systems (MA-INF 4101),
Computational Neuroscience and Neural Computation (MA-INF 4202) and/or
Technical Neural Nets (MA-INF 4204)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lab</td><td>8</td><td>4</td><td>60 T/180 S</td><td>8</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Regular participation, written documentation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">• D.A. White, D.A. Sofge: Handbook of Intelligent Control: Neural, Fuzzy and Adaptive Approaches, Van Nostrand Reinhold, New York
• M.M. Gupta, N.K. Sinha: Intelligent Control Systems, Theory and Applications, IEEE Press, New York</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Lab Autonomous Robots</td><td colspan="3">universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 4305</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="4">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="6">Prof. Dr. Armin B. Cremers</td></tr>
<tr><td>Lecturer(s)</td><td colspan="6">Prof. Dr. Armin B. Cremers</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td colspan="3">Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td colspan="3">2nd or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="6">technical skills:
Students will gain experience in the design and implementation of different aspects of control software for autonomous robots. They will familiarize with the algorithms involved and learn to solve problems which are specific to the deployment of complex software systems on mobile robots.
soft skills:
Students should acquire the following skills:
• Ability to derive a solution oriented problem formulation of a given task.
• Ability to cooparate in small groups on solving a given task.
• Ability to put a conceptual solution and its implemention down on paper.
• Ability to present and discuss a conceptual solution and its implemention in an oral presentation.</td></tr>
<tr><td>Contents</td><td colspan="6">In this course students will design, implement, and evaluate parts of robot control systems which enable robots to autonomously fulfil specific tasks. Typical tasks in this respect are: autonomous navigation, map-building and exploration, multi-robot coordination and motion planning.</td></tr>
<tr><td>Prerequisites</td><td colspan="6">Required:
Theory of Sensorimotor Systems (MA-INF 4101)
Autonomous Mobile Systems (MA-INF 4203)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td colspan="2">Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td colspan="2">Lab</td><td>8</td><td>4</td><td>60 T/180 S</td><td>8</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="6">Exam(s)</td></tr>
<tr><td colspan="6">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="6">Regular participation, written documentation</td></tr>
<tr><td>Forms of media</td><td colspan="6"></td></tr>
<tr><td>Literature</td><td colspan="6">• Sebastian Thrun, Wolfram Burgard, Dieter Fox: Probabilistic Robotics, MIT Press, 2005
• Howie Choset et al.: Principles of Robot Motion, MIT-Press, 2005
• additional papers</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Lab Development and Application of Data Mining and Learning Systems</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 4306</td><td>Workload
240 h</td><td>Credit points
8</td><td colspan="2">Frequency
Every year</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Stefan Wrobel</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">Prof. Dr. Stefan Wrobel</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Optional</td><td>3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="4">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)</td></tr>
<tr><td>Contents</td><td colspan="4">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.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Required:
Theory of Sensorimotor Systems (MA-INF 4101) or
Intelligent Learning and Analysis Systems (MA-INF 4102)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Lab
(Working in small teams)</td><td>8</td><td>2</td><td>30 P/210 S</td><td>8</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">Regular participation, written documentation</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">The relevant literature will be announced towards the end of the previous semester.</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Lab Field-Programmable Gate Arrays</td><td colspan="3">universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 4307</td><td>Workload
240 h</td><td colspan="2">Credit points
8</td><td colspan="3">Frequency
At least every 2 years</td></tr>
<tr><td>Module coordinator</td><td colspan="6">Prof. Dr. Joachim K. Anlauf</td></tr>
<tr><td>Lecturer(s)</td><td colspan="6">Prof. Dr. Joachim K. Anlauf</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="3">Programme</td><td>Compulsory/ Optional</td><td colspan="2">Semester</td></tr>
<tr><td colspan="3">M.Sc. Computer Science</td><td>Optional</td><td colspan="2">2nd or 3rd sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="6"><u>technical skills</u>:
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)
<u>soft skills</u>:
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)</td></tr>
<tr><td>Contents</td><td colspan="6">VHDL for Hardware Description, Simulation, and Synthesis, SystemC for Hardware Description, Simulation, and Synthesis, Synthesizable Subsets, Test of Implementations on FPGA Evaluation Boards</td></tr>
<tr><td>Prerequisites</td><td colspan="6"><u>Required</u>:
Dynamically Reconfigurable Systems (MA-INF 4207)</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td colspan="2">Teaching format</td><td>Group size</td><td>Hours /week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td colspan="2">Lab</td><td>8</td><td>4</td><td>60 P/180 S</td><td>8</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="6">Exam(s)</td></tr>
<tr><td colspan="6">Oral presentation</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="6">Regular participation, written documentation</td></tr>
<tr><td>Forms of media</td><td colspan="6"></td></tr>
<tr><td>Literature</td><td colspan="6">Technical documentation</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

<table>
<tr><td colspan="4">Module name:
Master Thesis</td><td>universitätbonn</td></tr>
<tr><td>Module No.
MA-INF 0401</td><td>Workload
900 h</td><td>Credit points
30</td><td colspan="2">Frequency
Every semester</td></tr>
<tr><td>Module coordinator</td><td colspan="4">Prof. Dr. Rainer Manthey</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">All lecturers of computer science</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">Programme</td><td>Compulsory/ Optional</td><td>Semester</td></tr>
<tr><td colspan="2">M.Sc. Computer Science</td><td>Compulsory</td><td>4th sem.</td></tr>
<tr><td>Targeted learning outcomes</td><td colspan="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</td></tr>
<tr><td>Contents</td><td colspan="4">Topics of the thesis may be chosen from any of the areas of computer science represented in the curriculum</td></tr>
<tr><td>Prerequisites</td><td colspan="4">None</td></tr>
<tr><td rowspan="2">Format/workload/ credits</td><td>Teaching format</td><td>Group size</td><td>Hours/ week</td><td>Workload [h]</td><td>Credits</td></tr>
<tr><td>Independent preparation of a scientific thesis with individual coaching</td><td></td><td></td><td>900 S</td><td>30</td></tr>
<tr><td rowspan="2">Exam achievements (graded)</td><td colspan="4">Exam(s)</td></tr>
<tr><td colspan="4">Master Thesis</td></tr>
<tr><td>Study achievements (not graded)</td><td colspan="4">None</td></tr>
<tr><td>Forms of media</td><td colspan="4"></td></tr>
<tr><td>Literature</td><td colspan="4">Individual bibliographic research required for identifying relevant literature (depending on the topic of the thesis)</td></tr>
</table>

T = Face-to-face teaching; S = Independent study

Module name: **Master Seminar**			universitätbonn
Module No. MA-INF 0402	Workload 60 h	Credit points 2	Frequency Every semester
Module coordinator	Prof. Dr. Rainer Manthey		
Lecturer(s)	All lecturers of computer science		
Classification	Programme	Compulsory/ Optional	Semester
	M.Sc. Computer Science	Compulsory	4th sem.
Targeted learning outcomes	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		
Contents	Topic, scientific context and results of the master thesis		
Prerequisites	None		

Format/workload/ credits	Teaching format	Group size	Hours/ week	Workload [h]	Credits
	Seminar	10	2	30 T/30 S	2

Exam achievements (graded)	Exam(s)
	Oral presentation of final results
Study achievements (not graded)	Regular participation, oral presentation of intermediate results
Forms of media	
Literature	Individual bibliographic research required for identifying relevant literature (depending on the topic of the thesis)

T = Face-to-face teaching; S = Independent study