# Module Handbook

for the

## Master Programme “Computer Science”

at

## Rheinischen Friedrich-Wilhelms-Universität Bonn

revised version: April 30, 2012

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

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

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

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

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

## Contents

# 1 Algorithmics

| | | | | | |
|---|---|---|---|---|---|
| **Module**<br>MA-INF 1101 | **Pearls of Algorithms** | | | | |
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Norbert Blum | | | | |
| **Lecturer(s)** | Prof. Dr. Norbert Blum, Prof. Dr. Marek Karpinski, Prof. Dr. Rolf Klein, Prof. Dr. Heiko Röglin | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1. | | |
| **Technical skills** | Deeper insights into selected methods and techniques of modern algorithmics | | | | |
| **Soft skills** | Presentation of solutions and methods, critical discussion of applied methods and techniques | | | | |
| **Contents** | 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. | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 4 | 60 T / 105 S | 5.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | Depending on the topics varying from semester to semester, the relevant research literature will be announced before the start of the resp. semester. | | | | |

<table>
<tr><td>Module<br>MA-INF 1102</td><td colspan="5">Combinatorial Optimization</td></tr>
<tr><td>Workload<br>270 h</td><td>Credit points<br>9 CP</td><td>Duration<br>1 semester</td><td colspan="3">Frequency<br>at least every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Jens Vygen</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Jens Vygen, Prof. Dr. Norbert Blum,<br>Prof. Dr. Stefan Hougardy, Prof. Dr. Marek Karpinski,<br>Prof. Dr. Bernhard Korte, Junior-Prof. Dr. Tim Nieberg,<br>Junior-Prof. Dr. Stephan Held</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td colspan="2">Semester<br>1. or 2.</td></tr>
<tr><td>Technical skills</td><td colspan="5">Advanced knowledge of combinatorial optimization. Modelling and development of solution strategies for combinatorial optimization problems</td></tr>
<tr><td>Soft skills</td><td colspan="5">Mathematical modelling of practical problems, abstract thinking, presentation of solutions to exercises</td></tr>
<tr><td>Contents</td><td colspan="5">Matchings, b-matchings and T-joins, optimization over matroids, submodular function minimization, travelling salesman problem, polyhedral combinatorics, NP-hard problems</td></tr>
<tr><td>Prerequisites</td><td colspan="5">none</td></tr>
<tr><td>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lecture</td><td>60</td><td>4</td><td>60 T / 105 S</td><td>5.5</td></tr><tr><td>Exercises</td><td>30</td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Oral exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">• B. Korte, J. Vygen: Combinatorial Optimization: Theory and Algorithms. Springer, 5th edition, 2012<br>• A. Schrijver: Combinatorial Optimization: Polyhedra and Efficiency. Springer 2003<br>• W. Cook, W. Cunningham, W. Pulleyblank, A. Schrijver: Combinatorial Optimization. Wiley 1997</td></tr>
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| | | | | | |
|---|---|---|---|---|---|
| **Module**<br>MA-INF 1103 | **Cryptography** | | | | |
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Joachim von zur Gathen | | | | |
| **Lecturer(s)** | Prof. Dr. Joachim von zur Gathen, Dr. Michael Nüsken | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1. or 2. | | |
| **Technical skills** | Understanding of security concerns and measures, and of the interplay between computing power and security requirements. Mastery of the basic techniques for cryptosystems and cryptanalysis | | | | |
| **Soft skills** | Oral presentation (in tutorial groups), written presentation (of exercise solutions), team collaboration in solving homework problems, critical assessment | | | | |
| **Contents** | Basic private-key and public-key cryptosystems: AES, RSA, group-based. Security reductions. Key exchange, cryptographic hash functions, signatures, identification; factoring integers and discrete logarithms; lower bounds in structured models. | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 4 | 60 T / 105 S | 5.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Written exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | • Stinson, Cryptography: Theory and Practice, 2nd edition<br>• Course notes | | | | |

| **Module**<br>MA-INF 1201 | **Approximation Algorithms for NP-Hard Problems** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>at least every year |
| **Module coordinator** | Prof. Dr. Marek Karpinski | | |
| **Lecturer(s)** | Prof. Dr. Marek Karpinski, Prof. Dr. Norbert Blum, Prof. Dr. Rolf Klein, Prof. Dr. Bernhard Korte, Prof. Dr. Jens Vygen, Prof. Dr. Stefan Hougardy, Junior-Prof. Dr. Stephan Held, Junior-Prof. Dr. Tim Nieberg | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | Introduction to design and analysis of most important approximation algorithms for NP-hard combinatorial optimization problems, and various techniques for proving lower and upper bounds, probabilistic methods and applications | | |
| **Soft skills** | Presentation of solutions and methods, critical discussion of applied methods and techniques | | |
| **Contents** | Approximation Algorithms and Approximation Schemes. Design and Analysis of Approximation algorithms for selected NP-hard problems, like Set-Cover, and Vertex-Cover problems, MAXSAT, TSP, Knapsack, Bin Packing, Network Design, Facility Location. Introduction to various approximation techniques (like Greedy, LP-Rounding, Primal-Dual, Local Search, randomized techniques and Sampling, and MCMC-Methods), and their applications. Analysis of approximation hardness and PCP-Systems. | | |
| **Prerequisites** | **Recommended:**<br>Introductory knowledge of foundations of algorithms and complexity theory is essential. | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Oral exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | | |

**Literature**


- 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 (5th edition), Springer, 2012
- V. V. Vazirani: Approximation Algorithms, Springer, 2001
- D. P. Williamson, D. B. Shmoys: The Design of Approximation Algorithms, Cambridge University Press, 2011

| | | | | | |
|---|---|---|---|---|---|
| **Module**<br>MA-INF 1202 | **Chip Design** | | | | |
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Jens Vygen | | | | |
| **Lecturer(s)** | Prof. Dr. Jens Vygen, Prof. Dr. Stefan Hougardy, Prof. Dr. Bernhard Korte, Junior-Prof. Dr. Tim Nieberg, Junior-Prof. Dr. Stephan Held | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1. or 2. | | |
| **Technical skills** | Knowledge of the central problems and algorithms in chip design. Competence to develop and apply algorithms for solving real-world problems, also with respect to technical constraints. Techniques to develop and implement efficient algorithms for very large instances. | | | | |
| **Soft skills** | Mathematical modelling of problems occurring in chip design, development of efficient algorithms, abstract thinking, presentation of solutions to exercises | | | | |
| **Contents** | Problem formulation and design flow for chip design, logic synthesis, placement, routing, timing analysis and optimization, clocktree design | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 4 | 60 T / 105 S | 5.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | • C.J. Alpert, D.P. Mehta, S.S. Sapatnekar: The Handbook of Algorithms for VLSI Physical Design Automation. CRC Press, New York, 2008.<br>• S. Held, B. Korte, D. Rautenbach, J. Vygen: Combinatorial optimization in VLSI design. In: "Combinatorial Optimization: Methods and Applications" (V. Chvátal, ed.), IOS Press, Amsterdam 2011, pp. 33-96<br>• J. Vygen: Chip Design. Lecture Notes (distributed during the course) | | | | |

<table>
<tr><td>Module<br>MA-INF 1203</td><td colspan="4">Discrete and Computational Geometry</td></tr>
<tr><td>Workload<br>270 h</td><td>Credit points<br>9 CP</td><td>Duration<br>1 semester</td><td colspan="2">Frequency<br>every year</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. Rolf Klein, Prof. Dr. Norbert Blum,<br>Prof. Dr. Marek Karpinski, Dr. Elmar Langetepe</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td>Semester<br>1to4.</td></tr>
<tr><td>Technical skills</td><td colspan="4">To acquire fundamental knowledge on topics and methods in Discrete and Computational Geometry; to gain experience in, and practice, applying this knowledge autonomously in solving new problems, aiming at reliable experience.</td></tr>
<tr><td>Soft skills</td><td colspan="4">Sozialkompetenz (Kommunikationsfähigkeit, Präsentation eigener Lösungsansätze und zielorientierte Diskussion im Gruppenrahmen, Teamfähigkeit), Methodenkompetenz (Analysefähigkeit, Abstraktes Denken, Führen von Beweisen), Individualkompetenz (Leistungs- und Lernbereitschaft, Kreativität, Ausdauer).<br><br>Social competence( communication, presenting one's own solutions, goal-oriented discussions in teams), methodical competence (analysis, abstraction, proofs), individual competence (commitment and willingness to learn,creativity, endurance).</td></tr>
<tr><td>Contents</td><td colspan="4">Geometric distance problems in dimension two and higher, Voronoi diagrams, well-separated pair decomposition, spanner, metric space embedding, dimension reduction, dilation, geometric inequalities, VC-dimension, epsilon-nets, visibility, point location;<br><br>randomized incremental construction, Chan's technique.</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Recommended:<br>BA-INF 114 – Grundlagen der algorithmischen Geometrie</td></tr>
<tr><td>Format</td><td colspan="4"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lecture</td><td>60</td><td>4</td><td>60 T / 105 S</td><td>5.5</td></tr><tr><td>Exercises</td><td>30</td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="4">Oral exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="4">Successful exercise participation (not graded)</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<br>• Narasimhan/Smid, Geometric Spanner Networks<br>• Klein, Concrete and Abstract Voronoi Diagrams</td></tr>
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| **Module**<br>MA-INF 1204 | **Seminar Selected Topics in Information and Learning Theory** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>at least every 2 years | | |
| **Module coordinator** | Prof. Dr. Norbert Blum | | | | |
| **Lecturer(s)** | Prof. Dr. Norbert Blum | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. | | |
| **Technical skills** | Ability to perform individual literature search, critical reading, understanding, and clear didactic presentation | | | | |
| **Soft skills** | Presentation of own and others' solutions and methods, critical discussion of applied methods, techniques and solutions. | | | | |
| **Contents** | Advanced topics in information and learning theory based on modern research literature | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Seminar | 10 | 2 | 30 T / 90 S | 4 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | The relevant literature will be announced towards the end of the previous semester. | | | | |

| **Module**<br>MA-INF 1205 | **Graduate Seminar Discrete Optimization** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Jens Vygen | | |
| **Lecturer(s)** | Prof. Dr. Jens Vygen, Prof. Dr. Stefan Hougardy, Prof. Dr. Bernhard Korte, Junior-Prof. Dr. Tim Nieberg, Junior-Prof. Dr. Stephan Held | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. |
| **Technical skills** | Competence to understand new research results based on original literature, to put such results in a broader context and present such results and relations. | | |
| **Soft skills** | Ability to read and understand research papers, abstract thinking, presentation of mathematical results in a talk | | |
| **Contents** | A current research topic in discrete optimization will be chosen each semester and discussed based on original literature. | | |
| **Prerequisites** | **Required:**<br>MA-INF 1102 – Combinatorial Optimization | | |

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Seminar | 10 | 4 | 60 T / 120 S | 6 |

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

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation, written report | (graded) |
| **Study achievements** | none | (not graded) |
| **Forms of media** | | |
| **Literature** | The topics and the relevant literature will be announced towards the end of the previous semester. | |

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

| | | | | | |
|---|---|---|---|---|---|
| **Module**<br>MA-INF 1207 | **Lab Combinatorial Algorithms** | | | | |
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Jens Vygen | | | | |
| **Lecturer(s)** | Prof. Dr. Jens Vygen, Prof. Dr. Stefan Hougardy, Prof. Dr. Bernhard Korte, Junior-Prof. Dr. Tim Nieberg, Junior-Prof. Dr. Stephan Held | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. | | |
| **Technical skills** | Competence to implement advanced combinatorial algorithms, handling nontrivial data structures, testing, documentation. Advanced software techniques. | | | | |
| **Soft skills** | Efficient implementation of complex algorithms, abstract thinking, documentation of source code | | | | |
| **Contents** | Certain combinatorial algorithms will be chosen each semester. The precise task will be explained in a meeting in the previous semester. | | | | |
| **Prerequisites** | **Required:**<br>MA-INF 1102 – Combinatorial Optimization | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lab | 8 | 4 | 60 T / 210 S | 9 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | The topics and the relevant literature will be announced towards the end of the previous semester | | | | |

<table>
<tr><td>Module<br>MA-INF 1208</td><td colspan="5">Applications of Cryptography</td></tr>
<tr><td>Workload<br>270 h</td><td>Credit points<br>9 CP</td><td>Duration<br>1 semester</td><td colspan="3">Frequency<br>every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Joachim von zur Gathen</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Joachim von zur Gathen, Dr. Michael Nüsken</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td colspan="2">Semester<br>2. or 3.</td></tr>
<tr><td>Technical skills</td><td colspan="5">Understanding, modelling and differentiating the various security requirements in transaction schemes. Overview of cryptographic tools and their potential applications. Learning about success and pitfalls.</td></tr>
<tr><td>Soft skills</td><td colspan="5">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="5">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="5">none</td></tr>
<tr><td>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lecture</td><td>60</td><td>4</td><td>60 T / 105 S</td><td>5.5</td></tr><tr><td>Exercises</td><td>30</td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Written exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">• Course notes<br>• Stinson, Cryptography: Theory and Practice, 2nd edition</td></tr>
</table>

<table>
<tr><td>Module<br>MA-INF 1209</td><td colspan="5">Seminar Advanced Topics in Cryptography</td></tr>
<tr><td>Workload<br>120 h</td><td>Credit points<br>4 CP</td><td>Duration<br>1 semester</td><td colspan="3">Frequency<br>every semester</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Joachim von zur Gathen</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Joachim von zur Gathen, Dr. Michael Nüsken</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td colspan="2">Semester<br>2. or 3.</td></tr>
<tr><td>Technical skills</td><td colspan="5">Understanding research publications, often written tersely. Distilling this into a presentation. Determination of relevant vs. irrelevant material. Developing a presentation that fascinates fellow students.</td></tr>
<tr><td>Soft skills</td><td colspan="5">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="5">A special topic within cryptography, changing from year to year, is studied in depth, based on current research literature</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Required:<br>MA-INF 1103 – Cryptography<br>and one further course in cryptography like The Art of Cryptography or eSecurity.</td></tr>
<tr><td>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Seminar</td><td>10</td><td>2</td><td>30 T / 90 S</td><td>4</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Oral presentation, written report (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">none (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">Current conference publications, to be announced in time</td></tr>
</table>

| **Module**<br>MA-INF 1301 | **Algorithmic Game Theory and the Internet** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every 2 years |
| **Module coordinator** | Prof. Dr. Marek Karpinski | | |
| **Lecturer(s)** | Prof. Dr. Marek Karpinski, Prof. Dr. Norbert Blum | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | The goal is to provide basic techniques and methods related to the Game Theory for analyzing modern Internet-based communication networks and for designing algorithms for the underlying problems of transmission control, resource allocation, mechanism design, market equilibria, combinatorial auctions, and the network cost allocation | | |
| **Soft skills** | Presentation of solutions and methods, critical discussion of applied methods and techniques | | |
| **Contents** | The most defining characteristic of the Internet is that it was not designed by a single central entity, but emerged from the complex interactions of many individual entities or economic agents, such as network operators, service providers, designers, users, etc. We aim at providing basic framework and basic techniques for analyzing and designing algorithms for the following Internet-related problems and contexts: game theoretic problems connected to the Internet and other decentralized networks, resource allocation, mechanism design, Nash and market equilibria, network economics, combinatorial auctions, cost allocations and network design.<br>We will address new broadly applicable and unifying techniques that have emerged recently in the above areas and discuss new fundamental paradigms in design of the relevant algorithms. | | |
| **Prerequisites** | **Recommended:**<br>Introductory knowledge of foundations of algorithms and complexity theory is essential. | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Lecture: 60 / 4 / 60 T / 105 S / 5.5<br>Exercises: 30 / 2 / 30 T / 75 S / 3.5<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Written exam (graded) | | |
| **Study achievements** | Successful exercise participation (not graded) | | |
| **Forms of media** | | | |
| **Literature** | • D. P. Bertsekas, A. Nedic, A. E. Ozdaglar: Convex Analysis and Optimization, Athena, 2003<br>• M. Karpinski, W. Rytter: Fast Parallel Algorithms for Graph Matching Problems, Oxford Univ. Press, 1998<br>• D. M. Kreps: A Course in Microeconomic Theory, Princeton Univ. Press, 1990<br>• N. Nisan, T. Roughgarden, E. Tardos, V.V. Vazirani (ed.): Algorithmic Game Theory, Cambridge Univ. Press, 2007<br>• M. J. Osborne, A. Rubinstein: A Course in Game Theory, MIT Press, 2001 | | |

| | | | |
|---|---|---|---|
| **Module**<br>MA-INF 1302 | **Advanced Topics in Algorithmics** | | |
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>at least every 2 years |
| **Module coordinator** | Prof. Dr. Marek Karpinski | | |
| **Lecturer(s)** | Prof. Dr. Marek Karpinski, Prof. Dr. Norbert Blum, Prof. Dr. Joachim von zur Gathen, Prof. Dr. Rolf Klein, Prof. Dr. Nitin Saxena | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **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 | | |
| **Contents** | The topic will be announced before the start of the relevant semester. | | |
| **Prerequisites** | **Recommended:**<br>Introductory knowledge of foundations of algorithms and complexity theory is essential. | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Written exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | | |
| **Literature** | Depending on the topics varying from semester to semester, the relevant research literature will be announced before the start of the resp. semester. | |

<table>
<tr><td>Module<br>MA-INF 1303</td><td colspan="5">Selected Topics in Algorithmics</td></tr>
<tr><td>Workload<br>180 h</td><td>Credit points<br>6 CP</td><td>Duration<br>1 semester</td><td colspan="3">Frequency<br>at least every 2 years</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Norbert Blum</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Norbert Blum, Prof. Dr. Rolf Klein,<br>Prof. Dr. Marek Karpinski</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td colspan="2">Semester<br>2. or 3.</td></tr>
<tr><td>Technical skills</td><td colspan="5">Introduction to current advanced research topics in algorithmic research</td></tr>
<tr><td>Soft skills</td><td colspan="5">Presentation of own and others' solutions and methods, critical discussion of applied methods, techniques and solutions.</td></tr>
<tr><td>Contents</td><td colspan="5">The topic will be announced before the start of the resp. semester.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">none</td></tr>
<tr><td>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lecture</td><td>60</td><td>2</td><td>30 T / 45 S</td><td>2.5</td></tr><tr><td>Exercises</td><td>30</td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Written exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">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>

| | | | | | |
|---|---|---|---|---|---|
| **Module**<br>MA-INF 1304 | **Seminar Geometric Distance Problems** | | | | |
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Rolf Klein | | | | |
| **Lecturer(s)** | Prof. Dr. Rolf Klein, Dr. Elmar Langetepe | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2to4. | | |
| **Technical skills** | To Independently study problems at research level, based on research publications, to prepare a concise summary, to<br>present the summary in a scientific talk, to lead a critical discussion<br>with other seminar participants. | | | | |
| **Soft skills** | | | | | |
| **Contents** | Current topics in Computational Geometry. | | | | |
| **Prerequisites** | **Recommended:**<br>BA-INF 114 – Grundlagen der algorithmischen Geometrie | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Seminar | 10 | 2 | 30 T / 90 S | 4 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | Multimedia projector, black board. | | | | |
| **Literature** | The relevant literature will be announced. | | | | |

| **Module**<br>MA-INF 1305 | **Graduate Seminar Chip Design** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Jens Vygen | | |
| **Lecturer(s)** | Prof. Dr. Jens Vygen, Prof. Dr. Stefan Hougardy, Prof. Dr. Bernhard Korte, Junior-Prof. Dr. Tim Nieberg, Junior-Prof. Dr. Stephan Held | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. |
| **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 | | |
| **Contents** | Current topics in chip design and related applications | | |
| **Prerequisites** | **Required:** At least 1 of the following:<br>MA-INF 1102 – Combinatorial Optimization<br>MA-INF 1202 – Chip Design | | |

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Seminar | 10 | 4 | 60 T / 120 S | 6 |

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

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation, written report | (graded) |
| **Study achievements** | none | (not graded) |
| **Forms of media** | | |
| **Literature** | The topics and the relevant literature will be announced towards the end of the previous semester | |

| **Module**<br>MA-INF 1306 | **Seminar Combinatorial and Geometric Optimization** | | |
|---|---|---|---|
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Marek Karpinski | | |
| **Lecturer(s)** | Prof. Dr. Marek Karpinski, Prof. Dr. Norbert Blum,<br>Prof. Dr. Rolf Klein | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. |
| **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 latest research literature | | |
| **Prerequisites** | none | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation, written report | (graded) |
| **Study achievements** | none | (not graded) |
| **Forms of media** | | |
| **Literature** | The relevant literature will be announced in time. | |

| **Module**<br>MA-INF 1307 | **Seminar Advanced Algorithms** | | |
|---|---|---|---|
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Marek Karpinski | | |
| **Lecturer(s)** | Prof. Dr. Marek Karpinski, Prof. Dr. Norbert Blum,<br>Prof. Dr. Rolf Klein, Prof. Dr. Heiko Röglin | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. |
| **Technical skills** | Presentation of selected advanced topics in algorithm design and various applications | | |
| **Soft skills** | Ability to perform individual literature search, critical reading, understanding, and clear didactic presentation | | |
| **Contents** | Advanced topics in algorithm design based on newest research literature | | |
| **Prerequisites** | none | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation, written report | (graded) |
| **Study achievements** | none | (not graded) |
| **Forms of media** | | |
| **Literature** | The relevant literature will be announced in time. | |

| **Module**<br>MA-INF 1308 | **Lab Algorithms for Chip Design** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Jens Vygen | | |
| **Lecturer(s)** | Prof. Dr. Jens Vygen, Prof. Dr. Stefan Hougardy,<br>Prof. Dr. Bernhard Korte, Junior-Prof. Dr. Tim Nieberg,<br>Junior-Prof. Dr. Stephan Held | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. |
| **Technical skills** | Competence to implement algorithms for VLSI design, efficient handling of very large instances, testing, documentation. Advanced software techniques. | | |
| **Soft skills** | Efficient implementation of complex algorithms, abstract thinking, modelling of optimization problem in VLSI design, documentation of source code | | |
| **Contents** | A currently challenging problem will be chosen each semester. The precise task will be explained in a meeting in the previous semester. | | |
| **Prerequisites** | **Required:** At least 3 of the following:<br>MA-INF 1102 – Combinatorial Optimization<br>MA-INF 1202 – Chip Design<br>MA-INF 1205 – Graduate Seminar Discrete Optimization<br>MA-INF 1208 – Applications of Cryptography | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Lab / 8 / 4 / 60 T / 210 S / 9<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Oral presentation, written report (graded) | | |
| **Study achievements** | none (not graded) | | |
| **Forms of media** | | | |
| **Literature** | The topics and the relevant literature will be announced towards the end of the previous semester | | |

<table>
<tr><td>Module<br>MA-INF 1309</td><td colspan="5">Lab Efficient Algorithms for Selected Problems: Design, Analysis and Implementation</td></tr>
<tr><td>Workload<br>270 h</td><td>Credit points<br>9 CP</td><td>Duration<br>1 semester</td><td colspan="3">Frequency<br>at least 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. Marek Karpinski, Prof. Dr. Norbert Blum,<br>Prof. Dr. Rolf Klein</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td colspan="2">Semester<br>3.</td></tr>
<tr><td>Technical skills</td><td colspan="5">Ability to design, analyze and implement efficient algorithms for selected computational problems.</td></tr>
<tr><td>Soft skills</td><td colspan="5">ability to work on advanced algorithmic implementation projects, to work in small teams, clear didactic presentation and critical discussion of results</td></tr>
<tr><td>Contents</td><td colspan="5">Design of efficient exact and approximate algorithms and data structures for selected computational problems.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">none</td></tr>
<tr><td>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lab</td><td>8</td><td>4</td><td>60 T / 210 S</td><td>9</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Oral presentation, written report (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">none (not graded)</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>

| **Module**<br>MA-INF 1310 | **Graduate Seminar on Logic** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | | | | | |
| **Lecturer(s)** | | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | | **Mode**<br>Optional | **Semester**<br>3. | |
| **Technical skills** | | | | | |
| **Soft skills** | | | | | |
| **Contents** | | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Seminar | 10 | 4 | 60 T / 120 S | 6 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | | | | | |

<table>
<tr><td>Module<br>MA-INF 1311</td><td colspan="4">Seminar Theoretical Cryptography</td></tr>
<tr><td>Workload<br>120 h</td><td>Credit points<br>4 CP</td><td>Duration<br>1 semester</td><td colspan="2">Frequency<br>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>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td>Semester<br>2. or 3.</td></tr>
<tr><td>Technical skills</td><td colspan="4">Understanding research publications, often written tersely. Distilling this into a presentation. Determination of relevant vs. irrelevant material. Developing a presentation that fascinates fellow students.</td></tr>
<tr><td>Soft skills</td><td colspan="4">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 current research literature</td></tr>
<tr><td>Prerequisites</td><td colspan="4">Recommended:<br>MA-INF 1103 – Cryptography</td></tr>
<tr><td>Format</td><td colspan="4"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Seminar</td><td>10</td><td>2</td><td>30 T / 90 S</td><td>4</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="4">Oral presentation, written report (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="4">none (not graded)</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>

| | | | | | |
|---|---|---|---|---|---|
| **Module**<br>MA-INF 1312 | **The Art of Cryptography** | | | | |
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Joachim von zur Gathen | | | | |
| **Lecturer(s)** | Prof. Dr. Joachim von zur Gathen, Dr. Michael Nüsken | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. | | |
| **Technical skills** | Insights into the theoretical foundations behind security concerns and measures, and of the interplay between computing power, and security requirements. Mastery of advanced techniques for cryptosystems and cryptanalysis. | | | | |
| **Soft skills** | Oral presentation (in tutorial groups), written presentation (of exercise solutions), team collaboration in solving homework problems, critical assessment | | | | |
| **Contents** | Possible topics are<br>• pseudorandomness and zero-knowledge,<br>• security reductions,<br>• lattices. | | | | |
| **Prerequisites** | **Recommended:**<br>MA-INF 1103 – Cryptography | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 4 | 60 T / 105 S | 5.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Written exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | Varying | | | | |

<table>
<tr><td>Module<br>MA-INF 1313</td><td colspan="5">Topics in Theoretical Cryptography</td></tr>
<tr><td>Workload<br>270 h</td><td>Credit points<br>9 CP</td><td>Duration<br>1 semester</td><td colspan="3">Frequency<br>every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Joachim von zur Gathen</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Joachim von zur Gathen, Dr. Michael Nüsken</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td colspan="2">Semester<br>3.</td></tr>
<tr><td>Technical skills</td><td colspan="5">Gain deeper understanding in a special area of cryptography close to current research.</td></tr>
<tr><td>Soft skills</td><td colspan="5">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="5">One varying, advanced topic related to current research in theoretical cryptography, e.g.<br>• elliptic curve cryptography, or<br>• quantum cryptography</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Required:<br>MA-INF 1103 – Cryptography<br>and one further course in cryptography like The Art of Cryptography or eSecurity.</td></tr>
<tr><td>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lecture</td><td>60</td><td>4</td><td>60 T / 105 S</td><td>5.5</td></tr><tr><td>Exercises</td><td>30</td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Written exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">Research articles</td></tr>
</table>

| | | | | | |
|---|---|---|---|---|---|
| **Module**<br>MA-INF 1314 | **Online Motion Planning** | | | | |
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Rolf Klein | | | | |
| **Lecturer(s)** | Prof. Dr. Rolf Klein, Dr. Elmar Langetepe | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1to4. | | |
| **Technical skills** | To acquire fundamental knowledge on topics and methods in online motion planning; | | | | |
| **Soft skills** | | | | | |
| **Contents** | Search and exploration in unknown environments<br>(e.g., graphs, cellular environmwents, polygons, strets), online algorithms, competitive analysis, competitive complexity,functional optimization, shortest watchman route, tethered robots, marker algorithms, spiral search, approximation of optimal search paths. | | | | |
| **Prerequisites** | **Recommended:**<br>BA-INF 114 – Grundlagen der algorithmischen Geometrie | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 4 | 60 T / 105 S | 5.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | Java applets of geometry lab | | | | |
| **Literature** | Scientific research articles will be recommended in the lecture. | | | | |

## 2 Graphics, Vision, Audio

| **Module**<br>MA-INF 2111 | **Foundations of Graphics** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Reinhard Klein | | | | |
| **Lecturer(s)** | Prof. Dr. Reinhard Klein, Prof. Dr. Andreas Weber, Dr. Ingrid Irmer | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1. or 2. | | |
| **Technical skills** | Knowledge of basic mathematical techniques commonly used in Graphics with a strong emphasis on their application to real world problems. | | | | |
| **Soft skills** | Research abilities, information retrieval abilities, collaboration abilities, self management, creativity. | | | | |
| **Contents** | Affine and projective transformations with applications to image formation (rigid body motion, cinematic chains);<br>Parametric curves and surfaces with applications to 3D modelling;<br>Ordinary differential equations with applications to physical based modelling | | | | |
| **Prerequisites** | **Required**: None of the following modules have been passed: MA-INF 2101 – Foundations of Graphics, Vision and Audio | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Written exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | | | | | |

<table>
<tr><td>Module<br>MA-INF 2112</td><td colspan="3">Foundations of Vision and Audio</td></tr>
<tr><td>Workload<br>180 h</td><td>Credit points<br>6 CP</td><td>Duration<br>1 semester</td><td>Frequency<br>every year</td></tr>
<tr><td>Module coordinator</td><td colspan="3">Prof. Dr. Meinard Müller</td></tr>
<tr><td>Lecturer(s)</td><td colspan="3">Prof. Dr. Meinard Müller, PD Dr. Frank Kurth,<br>Prof. Dr. Michael Clausen</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td>Semester<br>1. or 2.</td></tr>
<tr><td>Technical skills</td><td colspan="3"></td></tr>
<tr><td>Soft skills</td><td colspan="3">Theoretical exercises to support in-depth understanding of lecture topics and to stimulate discussions, practical exercises in teamwork to support time management, targeted organisation of practical work and critical discussion of own and others' results.</td></tr>
<tr><td>Contents</td><td colspan="3">In dieser Vorlesung wird eine Einführung in grundlegende Themen der digitalen Signalverarbeitung gegeben. Anhand zahlreicher Beispiele, insbesondere aus der Audiosignalverarbeitung, soll das Verständnis grundlegender Begriffe, Zusammenhänge und Resultate der digitalen Signalverarbeitung vermittelt werden. Weiterhin wird Wert auf eine mathematisch saubere Modellierung und<br>Spezifikation der Konzepte und Probleme gelegt.</td></tr>
<tr><td>Prerequisites</td><td colspan="3">Required: None of the following modules have been passed:<br>MA-INF 2101 – Foundations of Graphics, Vision and Audio</td></tr>
<tr><td>Format</td><td colspan="3"><table>
<tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr>
<tr><td>Lecture</td><td>60</td><td>2</td><td>30 T / 45 S</td><td>2.5</td></tr>
<tr><td>Exercises</td><td>30</td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr>
</table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="3">Written exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="3">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="3"></td></tr>
<tr><td>Literature</td><td colspan="3"></td></tr>
</table>

| **Module**<br>MA-INF 2201 | **Computer Vision** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | NN | | |
| **Lecturer(s)** | NN | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. |
| **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. | | |
| **Contents** | 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. | | |
| **Prerequisites** | **Recommended:**<br>Mathematical background (multidimensional analysis and linear algebra) | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Written exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | | |

**Literature**

- 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

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

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

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|---|---|---|---|
| **Module**<br>MA-INF 2204 | **Rendering Techniques I** | | |
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Reinhard Klein | | |
| **Lecturer(s)** | Prof. Dr. Reinhard Klein | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. |
| **Technical skills** | Analytical formulation of problems related to image synthesis and knowledge of techniques and algorithms for the generation of photorealistic image data. Knowledge of the major algorithms for the simulation of light distributions in 3D-scences and volume data sets. Self-dependent implementation of the basic algorithms. | | |
| **Soft skills** | Analytical problem description, creativity, self-dependent solution of practical problems in the area of rendering, presentation of solution strategies and implementations, self-dependent literature research, collaboration abilities, self-management | | |
| **Contents** | Topics among others will be: models for the description of optical material properties and light sources; transport, volume visualization and rendering equation; algorithms and techniques for the solution of the volume visualization and rendering equation; advanced methods for photorealistic image generation in real-time applications like 3D games. In addition, results from state of the art research will be presented. | | |
| **Prerequisites** | **Recommended:**<br>Algorithms and data structures, basic knowledge on multidimensional analysis und linear algebra, basic knowledge in stochastics and statistics, numerical analysis and numerical linear algebra, C++ | | |

**Format**

| Teaching format | Group size | h/week | Workload[h] | CP |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

| | | |
|---|---|---|
| **Exam achievements** | Oral exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | | |

**Literature**


- L. Szirmay-Kalos: Monte-Carlo Methods in Global Illumination, Institute of Computer Graphics, Vienna University of Technology, Vienna.

  URL: citeseer.ist.psu.edu/szirmay-kalos00montecarlo.html, 1999/
- P. Dutre, K. Bala, P. Bekaert: Advanced Global Illumination, 2nd ed., B&T, 2006
- M. Pharr, G. Humphreys: Physically Based Rendering, Elsevier, 2004
- J. Kautz, J. Lehtinen, P.-P. Sloan: Precomputed Radiance Transfer: Theory and Practice, Siggraph Course Notes, 2005

| | | | | | |
|---|---|---|---|---|---|
| **Module**<br>MA-INF 2205 | **Geometry Processing I** | | | | |
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Reinhard Klein | | | | |
| **Lecturer(s)** | Prof. Dr. Reinhard Klein | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. | | |
| **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 | | | | |
| **Contents** | 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. | | | | |
| **Prerequisites** | **Recommended:**<br>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++ | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | • R. Scopigno, C. Andujar, M. Goesele, H. Lensch: 3D Data Acquistion, Eurographics Tutorial, 2002<br>• E. Grinspun, M. Desbrun (organizers): Discrete Differential Geometry: An Applied Introduction, Siggraph Course Notes, 2006<br>• M. Botsch, M. Pauly: Geometric Modeling Based on Triangle Meshes, Siggraph Course Notes, 2006 | | | | |

| **Module**<br>MA-INF 2206 | **Seminar Vision** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | NN | | | | |
| **Lecturer(s)** | | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. | | |
| **Technical skills** | | | | | |
| **Soft skills** | | | | | |
| **Contents** | | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Seminar | 10 | 2 | 30 T / 90 S | 4 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | | | | | |

| **Module**<br>MA-INF 2207 | **Seminar Graphics** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>every semester | | |
| **Module coordinator** | Prof. Dr. Reinhard Klein | | | | |
| **Lecturer(s)** | Prof. Dr. Reinhard Klein | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. | | |
| **Technical skills** | Ability to understand new research results presented in original scientific papers. | | | | |
| **Soft skills** | Ability to present and to critically discuss these results in the framework of the corresponding area. | | | | |
| **Contents** | Current conference and journal papers. | | | | |
| **Prerequisites** | **Recommended:**<br>Mathematical background (multidimensional analysis and linear algebra, basic numerical methods)<br>Basic knowledge in Computer Graphics | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Seminar | 10 | 2 | 30 T / 90 S | 4 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | | | | | |

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

| | | | |
|---|---|---|---|
| **Module**<br>MA-INF 2209 | **Advanced Topics in Computer Graphics I** | | |
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Reinhard Klein | | |
| **Lecturer(s)** | Prof. Dr. Reinhard Klein | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | Analytical formulation of problems related to geometry processing and rendering. Knowledge of techniques and algorithms to optimize, process, analyze and store geometry and reflectance data as well as knowledge of the major algorithms for the simulation of light distributions in 3D-scences and volume data sets. Self-dependent implementation of the basic algorithms. | | |
| **Soft skills** | Based on the knowledge and skills acquired students should be able to<br>• read and judge current scientific literature in the area of geometry processing and rendering<br>• identify the major literature concerning a given problem in geometry processing or rendering and gain an overview of the current state of the art<br>• discuss problems concerning geometry processing or rendering with researchers from different application fields<br>• present and propose different solutions and work in a team to solve a mesh processing or rendering problem<br>• and should have acquired key-competences like motivation to deliver results, flexibility, scientific integrity, ability to adapt to changes and ability to communicate | | |
| **Contents** | Topics among other will be:<br>• methods for the generation of polygonal meshes from point clouds<br>• efficient mesh data structures and mesh compression<br>• mesh optimization techniques: denoising, smoothing, decimation, refinement<br>• mesh editing techniques<br>• optical material properties and light sources<br>• light transport and rendering equation<br>• algorithms and techniques for the solution of the rendering equation<br>• advanced methods for photorealistic image generation.<br>In addition, results from state of the art research will be presented. | | |
| **Prerequisites** | **Required:**<br>Basic knowledge in computer graphics, data structures, multidimensional analysis und linear algebra, numerical analysis and numerical linear algebra, C++ | | |

| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|---|
| | Lecture | 60 | 4 | 60 T / 105 S | 5.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation, written report | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | | |
| **Literature** | • M. Botsch, L. Kobbelt, M. Pauly, P. Alliez, B. Levy, Polygon Mesh Processing, A K Peters (7. Oktober 2010)<br>• M. Gross, HP. Pfister, Point-Based Graphics, Morgan Kaufmann (21. Juni 2007)<br>• R. Scopigno, C. Andujar, M. Goesele, H. Lensch: 3D Data Acquistion, Eurographics Tutorial, 2002<br>• E. Grinspun, M. Desbrun (organizers): Discrete Differential Geometry: An Applied Introduction, Siggraph Course Notes, 2006<br>• 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/<br>• P. Dutre, K. Bala, P. Bekaert: Advanced Global Illumination, 2nd ed., B&T, 2006<br>• M. Pharr, G. Humphreys: Physically Based Rendering, Elsevier, 2nd revised edition. (26. August 2010) | |

| | | | | | |
|---|---|---|---|---|---|
| **Module**<br>MA-INF 2210 | **Seminar Computer Animation** | | | | |
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>every semester | | |
| **Module coordinator** | Prof. Dr. Andreas Weber | | | | |
| **Lecturer(s)** | Prof. Dr. Andreas Weber | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. | | |
| **Technical skills** | Ability to understand new research results presented in original scientific papers. | | | | |
| **Soft skills** | Ability to present and to critically discuss these results in the framework of the corresponding area. | | | | |
| **Contents** | Current conference and journal papers. | | | | |
| **Prerequisites** | **Recommended:** At least 1 of the following:<br>MA-INF 2202 – Computer Animation<br>MA-INF 2311 – Lab Computer Animation | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Seminar | 10 | 2 | 30 T / 90 S | 4 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Module**<br>MA-INF 2211 | **Music Processing** | | | | |
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Meinard Müller | | | | |
| **Lecturer(s)** | Prof. Dr. Meinard Müller | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1. | | |
| **Technical skills** | Design principles that have been applied to music signals to account for the music-specific aspects. In particular, understandng various musically expressive feature representations that refer to musical dimensions such as harmony, rhythm, timbre, or melody. Assessing the practical and musical relevance of these feature representations in the context of current music analysis and retrieval tasks. | | | | |
| **Soft skills** | Social competences (work in groups), communicative skills (written and oral presentation). | | | | |
| **Contents** | Music Representations;<br>Signals and Fourier Transform;<br>Audio Features (Spectrogram, Pitch, Chroma);<br>Dynamic Time Warping and Music Synchronization;<br>Time Scale Modification;<br>Tempo and Beat Analysis;<br>Audio Fingerprinting and Content-based Music Retrieval;<br>Audio Structure Analysis;<br>Chord Recognition; | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | | | | | |

| **Module**<br>MA-INF 2301 | **Advanced Topics in Computer Vision** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | NN | | | | |
| **Lecturer(s)** | | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | | **Mode**<br>Optional | **Semester**<br>3. | |
| **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. | | | | |
| **Contents** | 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. | | | | |
| **Prerequisites** | **Recommended:**<br>MA-INF 2201 – Computer Vision | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Written exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | Latest topic-related research articles and literature will be announced in advance of the lecture. | | | | |

<table>
<tr><td>Module<br>MA-INF 2302</td><td colspan="5">Physics-based Modelling</td></tr>
<tr><td>Workload<br>180 h</td><td>Credit points<br>6 CP</td><td>Duration<br>1 semester</td><td colspan="3">Frequency<br>at least every 2 years</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Andreas Weber</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Andreas Weber</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td colspan="2">Semester<br>3.</td></tr>
<tr><td>Technical skills</td><td colspan="5">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.</td></tr>
<tr><td>Soft skills</td><td colspan="5">Social competences (work in groups), communicative skills (written and oral presentation)</td></tr>
<tr><td>Contents</td><td colspan="5">Initial value problems; particle simulation; rigid body simulation; multi-body-systems; collision detection; collisions response; cloth modelling; hair modelling; physics-based motion synthesis</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Recommended: all of the following:<br>MA-INF 2111 – Foundations of Graphics<br>– ???</td></tr>
<tr><td>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lecture</td><td>60</td><td>2</td><td>30 T / 45 S</td><td>2.5</td></tr><tr><td>Exercises</td><td>30</td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Oral exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">• Dietmar Jackel, Stephan Neunreither, Friedrich Wagner: Methoden der Computeranimation, Springer 2006<br>• David M. Bourg: Physics for Game Developers, O'Reilly<br>• Advanced course notes on physics-based modelling</td></tr>
</table>

| **Module**<br>MA-INF 2303 | **Selected Topics in Multimedia Retrieval** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Michael Clausen | | |
| **Lecturer(s)** | Prof. Dr. Michael Clausen | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **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. | | |
| **Contents** | 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. | | |
| **Prerequisites** | none | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Lecture: 60 / 4 / 60 T / 105 S / 5.5<br>Exercises: 30 / 2 / 30 T / 75 S / 3.5<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Written exam (graded) | | |
| **Study achievements** | Successful exercise participation (not graded) | | |
| **Forms of media** | | | |
| **Literature** | • Meinard Müller: Methods for Robust and Efficient Multimedia Retrieval. Springer 2007<br>• Lecture script and selected research articles | | |

| | | | | | |
|---|---|---|---|---|---|
| **Module**<br>MA-INF 2304 | **Rendering Techniques II** | | | | |
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Reinhard Klein | | | | |
| **Lecturer(s)** | Prof. Dr. Reinhard Klein | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. | | |
| **Technical skills** | Analytical formulation of problems related to image based rendering and knowledge of advanced techniques in the field of rendering. Knowledge of methods and models for the acquisition and description of light sources and optical material properties for Computer Graphics applications. Knowledge of methods and models for the acquisition and description of image based rendering techniques and digital photography. Self-dependent implementation of the basic algorithms. | | | | |
| **Soft skills** | Analytical problem description, creativity, self-dependent solution of practical problems in the area of image based rendering and digital photography, presentation of solution strategies and implementations, self-dependent literature research, collaboration abilities, self-management | | | | |
| **Contents** | Topics among others will be: advanced material acquisition and modelling techniques; algorithms and techniques of image based rendering; digital photography for image based scene modelling and rendering; computational photography | | | | |
| **Prerequisites** | **Recommended:**<br>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++ | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | • H.P.A. Lensch, M. Goesele (organizers): Realistic Materials in Computer Graphics, Siggraph Course Notes, 2005<br>• P. Debevec, E. Reinhard (organizers): High-Dynamic-Range Imaging: Theory and Applications, Siggraph Course Notes, 2006<br>• N. Hoffman (organizer): Physically Based Reflectance for Games, Siggraph Course Notes, 2006<br>• R. Raskar, J. Tumblin (organizers): Computational Photography, Siggraph Course Notes, 2006 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Module**<br>MA-INF 2305 | **Geometry Processing II** | | | | |
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Reinhard Klein | | | | |
| **Lecturer(s)** | Prof. Dr. Reinhard Klein | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. | | |
| **Technical skills** | Analytical formulation of problems related to geometry processing, shape analysis and shape retrieval as well as knowledge of advanced algorithms and techniques from these fields. Self-dependent implementation of the algorithms. | | | | |
| **Soft skills** | Analytical problem description, creativity, self-dependent solution of practical problems in the area of image based rendering and digital photography, presentation of solution strategies and implementations, self-dependent literature research, collaboration abilities, self-management | | | | |
| **Contents** | This class is focussed on advanced topics in the field of geometry processing. Students will get familiar with recent developments in the area of shape analysis and shape retrieval. Topics among others will be<br>• Parameterization of surfaces<br>• Shape segmentation and shape similarity<br>• Shape classification and content based retrieval<br>• Shape spaces and statistical shape analysis | | | | |
| **Prerequisites** | **Recommended:**<br>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++ | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | • T. Funkhouser, M. Kazhdan, Shape-Based Retrieval and Analysis of 3D-Models, Siggraph Course Notes, 2004<br>• L. Dryden, K.V. Mardia, Statistical Shape Analysis, John Wiley & Sons, 1998<br>• H. Krim, Jr, A. Yezzi (editors): Statistics and Analysis of Shapes (Modeling an Simulation in Science, Engineering and Technology), Birkhäuser Boston, 2006 | | | | |

| **Module**<br>MA-INF 2306 | **Virtual Reality** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Reinhard Klein | | |
| **Lecturer(s)** | Prof. Dr. Reinhard Klein | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. |
| **Technical skills** | Basic knowledge of hard- and software components of current VR-Systems, Broad knowledge of tracking-, collision detection- and real-time rendering algorithms, knowledge of methods to integrate haptic and sound, knowledge of GPU programming with emphasis on special effect generation, ability to implement components of a VR-System | | |
| **Soft skills** | Analytical problem description, creativity, self-dependent solution of practical problems in the area of Virtual Reality, presentation of solution strategies and implementations, self-dependent literature research, collaboration abilities, self-management | | |
| **Contents** | Scene Graphs, Stereo Seeing (HW, SW), Tracking (HW, SW), Acceleration Techniques (LOD; Culling), Collision detection, Haptics, Sound, Special effects (GPU-Programming) | | |
| **Prerequisites** | **Recommended:**<br>Mathematical background (multidimensional analysis and linear algebra, foundations of numerical methods), good knowledge of the foundations of computer graphics | | |

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

| | | |
|---|---|---|
| **Exam achievements** | Oral exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | | |

**Literature**


- K. Stanney (ed.): Handbook of Virtual Environments. Lawrence Erlbaum Associates, 2002
- W. Sherman, A. Craig: Understanding Virtual Reality. Morgan Kaufman, 2002
- D. Pape: Commodity-Based Projection VR, Siggraph Course Notes, 2006
- N. Tatarchuk (organizer): Advanced Real-Time Rendering in ğD Graphics and Games, Siggraph Course Notes, 2006

| **Module**<br>MA-INF 2307 | **Lab Vision** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | NN | | | | |
| **Lecturer(s)** | | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. | | |
| **Technical skills** | | | | | |
| **Soft skills** | | | | | |
| **Contents** | | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lab | 8 | 4 | 60 T / 210 S | 9 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | | | | | |

| **Module**<br>MA-INF 2308 | **Lab Graphics** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every semester | | |
| **Module coordinator** | Prof. Dr. Reinhard Klein | | | | |
| **Lecturer(s)** | Prof. Dr. Reinhard Klein | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. | | |
| **Technical skills** | The students will carry out a practical task (project) in the context of<br>geometry processing, rendering, scientific visualization or human computer interaction, including test and documentation of the implemented software/system. | | | | |
| **Soft skills** | Ability to properly present and defend design decisions, to prepare<br>readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area | | | | |
| **Contents** | Varying selected topics close to current research in the area of geometry processing, rendering, scientific visualization or human computer interaction. | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lab | 8 | 4 | 60 T / 210 S | 9 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | | | | | |

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|---|---|---|---|---|---|
| **Module**<br>MA-INF 2309 | **Lab Audio** | | | | |
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Michael Clausen | | | | |
| **Lecturer(s)** | Prof. Dr. Meinard Müller, Prof. Dr. Michael Clausen,<br>PD Dr. Frank Kurth | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. | | |
| **Technical skills** | The students will carry out a practical task (project) in the context of<br>audio and music processing, including test and documentation of the implemented<br>software/system. | | | | |
| **Soft skills** | Ability to properly present and defend design decisions, to prepare<br>readable documentation of software; skills in constructively collaborating<br>with others in small teams over a longer period of time; ability to<br>classify ones own results into the state-of-the-art of the resp. area. | | | | |
| **Contents** | | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lab | 8 | 4 | 60 T / 210 S | 9 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | | | | | |

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

| **Module**<br>MA-INF 2311 | **Lab Computer Animation** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>at least every year |
| **Module coordinator** | Prof. Dr. Andreas Weber | | |
| **Lecturer(s)** | Prof. Dr. Andreas Weber | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. |
| **Technical skills** | The students will carry out a practical task (project) in the context of<br>computer animation, including test and documentation of the implemented software/system. | | |
| **Soft skills** | Ability to properly present and defend design decisions, to prepare<br>readable documentation of software; skills in constructively collaborating<br>with others in small teams over a longer period of time; ability to<br>classify ones own results into the state-of-the-art of the resp. area | | |
| **Contents** | Varying selected topics close to current research in the area of computer animation. | | |
| **Prerequisites** | **Recommended:** At least 1 of the following:<br>MA-INF 2202 – Computer Animation<br>MA-INF 2302 – Physics-based Modelling | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation, written report | (graded) |
| **Study achievements** | none | (not graded) |
| **Forms of media** | | |
| **Literature** | | |

# 3 Information and Communication Management

| | | | |
|---|---|---|---|
| **Module**<br>MA-INF 3101 | **High Performance Networking** | | |
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Peter Martini | | |
| **Lecturer(s)** | Prof. Dr. Peter Martini, Dr. Nils Aschenbruck, Dr. Matthias Frank | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1., 2. or 3. |
| **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 | | |
| **Contents** | 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 | | |
| **Prerequisites** | **Recommended:**<br>Bachelor-level knowledge of Data Communication and Internet Technology | | |

**Format**

| Teaching format | Group size | h/week | Workload[h] | CP |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

| | |
|---|---|
| **Exam achievements** | Oral exam (graded) |
| **Study achievements** | Successful exercise participation (not graded) |
| **Forms of media** | |
| **Literature** | • M.Hassan, R.Jain, "High Performance TCP/IP Networking", Pearson Prentice Hall 2004;<br>• M.C. Calzarossa, S. Tucci, "Performance Evaluation of Complex Systems: Techniques and Tools", Springer 2002;<br>• R. Jain, "The Art of Computer Systems Performance Analysis", Wiley 1991 |

| **Module**<br>MA-INF 3103 | **Peer-to-Peer Systems** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Björn Scheuermann | | |
| **Lecturer(s)** | Prof. Dr. Björn Scheuermann | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1. |
| **Technical skills** | The students become familiar with key concepts of fully distributed systems and learn to apply them in practice. This includes knowledge about key algorithmic concepts in the area of peer-to-peer systems (self-organization in unstructured and structured overlays, indirection techniques, overlay routing,...), technical aspects (like, e.g., NAT traversal) and theoretical knowledge about fundamental constraints of distributed storage and lookup systems. | | |
| **Soft skills** | • The ability to present and discuss solutions in the exercise course.<br>• Teamwork to support time management, targeted organisation of practical work and critical discussion of own and others' results in the programming project. | | |
| **Contents** | • Unstructured and structured Overlays<br>• Distributed hash tables<br>• Interrelations of routing complexity, node degree, and robustness<br>• Security and fairness in P2P systems<br>• Practical/technical aspects (e.g., NAT traversal)<br>• Applications (e.g., file sharing, P2P telephony, file distribution, media streaming) | | |
| **Prerequisites** | **Recommended:**<br>BA-INF 101 – Kommunikation in Verteilten Systemen | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Lecture: 60 / 2 / 30 T / 45 S / 2.5<br>Exercises: 30 / 2 / 30 T / 75 S / 3.5<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Oral exam (graded) | | |
| **Study achievements** | Successful exercise participation (not graded) | | |
| **Forms of media** | | | |
| **Literature** | • Scientific articles as mentioned on the lecture slides<br>• Steinmetz, Wehrle (Eds.): Peer-to-Peer Systems and Applications, Springer, 2005<br>• Mahlmann, Schindelhauer: Peer-to-Peer-Netzwerke, Springer, 2007 (in German language) | | |

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|---|---|---|---|---|---|
| **Module**<br>MA-INF 3201 | **Network Security** | | | | |
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Peter Martini | | | | |
| **Lecturer(s)** | Prof. Dr. Peter Martini, Dr. Jens Tölle | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. | | |
| **Technical skills** | The students learn fundamental concepts of network security. This includes risks and vulnerabilities of today's computer networks, concepts to increase the level of security in these networks, and a real-life oriented introduction to encryption techniques, their applications and their weaknesses. | | | | |
| **Soft skills** | Theoretical exercises to support in-depth understanding of lecture topics and to stimulate discussions, practical exercises in teamwork to support time management, targeted organisation of practical work and critical discussion of own and others' results | | | | |
| **Contents** | 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. | | | | |
| **Prerequisites** | **Recommended:**<br>MA-INF 3101 – High Performance Networking | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | • Christoph Busch, Stephen D. Wolthusen: Netzwerksicherheit, Spektrum Akademischer Verlag<br>• Matt Bishop: Introduction to Computer Security, Addison Wesley | | | | |

| | | | |
|---|---|---|---|
| **Module**<br>MA-INF 3202 | **Mobile Communication** | | |
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Peter Martini | | |
| **Lecturer(s)** | Prof. Dr. Peter Martini, Dr. Matthias Frank | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | 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 | | |
| **Soft skills** | Theoretical exercises to support in-depth understanding of lecture topics and to stimulate discussions, practical exercises in teamwork to support time management, targeted organisation of practical work and critical discussion of own and others' results | | |
| **Contents** | Mobility Management in the Internet, Wireless Communication Basics, Wireless Networking Technologies, Cellular/Mobile Communication Networks (voice and data communication), Ad-hoc and Sensor Networks. | | |
| **Prerequisites** | **Recommended:**<br>MA-INF 3101 – High Performance Networking | | |

**Format**

| Teaching format | Group size | h/week | Workload[h] | CP |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

| | | |
|---|---|---|
| **Exam achievements** | Oral exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | | |
| **Literature** | • Jochen Schiller: Mobile Communications, Addison-Wesley, 2003<br>• William Stallings: Wireless Communications and Networking, Prentice Hall, 2002<br>• Further up-to-date literature will be announced in due course before the beginning of the lecture | |

| **Module**<br>MA-INF 3203 | **Intelligent Information Systems** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Rainer Manthey | | |
| **Lecturer(s)** | Prof. Dr. Rainer Manthey | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | Students master the principles of management of derived data 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 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) | | |
| **Contents** | Syntax and semantics of deductive rules (views); efficient query processing in deductive DB; rule-based change management; IS design for rule-based applications | | |
| **Prerequisites** | **Recommended:**<br>Good knowledge of the foundations of SQL, predicate logic and set theory | | |

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

| | | |
|---|---|---|
| **Exam achievements** | Written exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | | |
| **Literature** | • C. Zaniolo, S. Ceri et al.: Advanced Database Systems, Morgan Kaufmann, San Francisco/USA, 1997<br>• E. Bertino, G. Zarri, B. Catania: Intelligent Database Systems, Addison Wesley, 2001 | |

| **Module**<br>MA-INF 3207 | **Advanced Logic Programming** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Dr. Günter Kniesel | | |
| **Lecturer(s)** | Dr. Günter Kniesel, Jun.-Prof. Dr. Janis Voigtländer, Dr. Stefan Lüttringhaus-Kappel | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | Ability to master advanced logic programing techniques and to write clean but highly efficient Prolog programs using these techniques; competence in problem solving using the declarative paradigm; competence in using the non-logical features of Prolog; | | |
| **Soft skills** | Skills in written and oral presentation of the solutions to programming assignments, collaboration with other students in small teams | | |
| **Contents** | Quick refresh of logic programming basics and a Prolog development environment, searching, understanding backtracking and the cut, context arguments, difference lists, data structures, constraint programming, meta-programming, meta-interpreters, partial evaluation, partial evaluation of meta-interpreters, efficient Prolog programming, logic program analysis. | | |
| **Prerequisites** | **Recommended:**<br>Good knowledge of the foundations of Logic Programming | | |

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

| | | |
|---|---|---|
| **Exam achievements** | Oral exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | | |
| **Literature** | W. Clocksin, C. Mellish: Programming in Prolog, Springer.<br>• L. Sterling, E. Shapiro (ed.): The Art of Prolog (2nd ed.) MIT Press.<br>• Richard O'Keefe: The Craft of Prolog, MIT Press. | |

<table>
<tr><td>Module<br>MA-INF 3209</td><td colspan="5">Seminar Selected Topics in Communication Management</td></tr>
<tr><td>Workload<br>120 h</td><td>Credit points<br>4 CP</td><td>Duration<br>1 semester</td><td colspan="3">Frequency<br>at least every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Peter Martini</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Peter Martini</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td colspan="2">Semester<br>2. or 3.</td></tr>
<tr><td>Technical skills</td><td colspan="5">Ability to understand new research results presented in original scientific papers.</td></tr>
<tr><td>Soft skills</td><td colspan="5">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">Recommended:<br>MA-INF 3101 – High Performance Networking</td></tr>
<tr><td>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Seminar</td><td>10</td><td>2</td><td>30 T / 90 S</td><td>4</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Oral presentation, written report (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">none (not graded)</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>

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|---|---|---|---|---|---|
| **Module**<br>MA-INF 3210 | **Seminar Selected Topics in Intelligent Information Systems** | | | | |
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>at least every year | | |
| **Module coordinator** | Prof. Dr. Rainer Manthey | | | | |
| **Lecturer(s)** | Prof. Dr. Rainer Manthey | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. | | |
| **Technical 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 | | | | |
| **Soft skills** | | | | | |
| **Contents** | Varying selected topics in intelligent information systems based on modern research literature | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Seminar | 10 | 2 | 30 T / 90 S | 4 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | The relevant literature will be announced towards the end of the previous semester. | | | | |

<table>
<tr><td>Module<br>MA-INF 3212</td><td colspan="5">Advanced Topics in Software Construction</td></tr>
<tr><td>Workload<br>180 h</td><td>Credit points<br>6 CP</td><td>Duration<br>1 semester</td><td colspan="3">Frequency<br>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</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td colspan="2">Semester<br>1., 2. or 3.</td></tr>
<tr><td>Technical skills</td><td colspan="5">• Identification of potential flaws in requirements written in natural language.<br>• Creation of Use Case Models, Domain Object Models and Analysis Object Models,including Use Case Slices.<br>• Identification and handling of conceptual modelling challenges.<br>• Ability to structure models and implementations strategically to address complexity and change.<br>• Definition and use of UML profiles and Meta Models</td></tr>
<tr><td>Soft skills</td><td colspan="5">Teamwork, collaborative problem solving</td></tr>
<tr><td>Contents</td><td colspan="5">• Enhanced approaches to Requirement Elicitation, Requirement Improvement, Requirement Analysis and Domain Modeling.<br>• First introduction into technical approaches to separate concerns: Components, (Web-) Services, Aspect Oriented Programming, Model Driven Architecture.<br>• Recent software process models.<br><br>The content of this module may be adapted to account for new developments in software engineering research and technology.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Recommended:<br>Good knowledge of the foundations of OOP, UML and Software Engineering</td></tr>
<tr><td>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lecture</td><td>60</td><td>2</td><td>30 T / 45 S</td><td>2.5</td></tr><tr><td>Exercises</td><td>30</td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Written exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">• Michael P. Papazoglu: Web Services: Principles and Technology, Pearson Education Limited, 2008<br>• Ivar Jacobson, Pan-Wei Ng: Aspect-Oriented Software Development with Use Cases, Addison-Wesley, 2005<br>• Eric Evans: Domain-Driven Design: Tackling Complexity in the Heart of Software. Addison-Wesley Professional, 2003</td></tr>
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<table>
<tr><td>Module<br>MA-INF 3213</td><td colspan="5">Advanced Topics in Information Systems</td></tr>
<tr><td>Workload<br>180 h</td><td>Credit points<br>6 CP</td><td>Duration<br>1 semester</td><td colspan="3">Frequency<br>every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Jun.-Prof. Dr. Alexander Markowetz</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Jun.-Prof. Dr. Alexander Markowetz</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td colspan="2">Semester<br>1., 2. or 3.</td></tr>
<tr><td>Technical skills</td><td colspan="5"></td></tr>
<tr><td>Soft skills</td><td colspan="5"></td></tr>
<tr><td>Contents</td><td colspan="5"></td></tr>
<tr><td>Prerequisites</td><td colspan="5">none</td></tr>
<tr><td>Format</td><td colspan="5"><table>
<tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr>
<tr><td>Lecture</td><td>60</td><td>2</td><td>30 T / 45 S</td><td>2.5</td></tr>
<tr><td>Exercises</td><td>30</td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr>
</table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Written exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5"></td></tr>
</table>

| **Module**<br>MA-INF 3214 | **Seminar Selected Topics in Information Management** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Armin B. Cremers | | | | |
| **Lecturer(s)** | Prof. Dr. Armin B. Cremers,<br>Jun.-Prof. Dr. Alexander Markowetz | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. | | |
| **Technical skills** | | | | | |
| **Soft skills** | Ability to present and to critically discuss these results in the framework of the corresponding area. | | | | |
| **Contents** | Current conference and journal papers. | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Seminar | 10 | 2 | 30 T / 90 S | 4 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | | | | | |

| **Module**<br>MA-INF 3215 | **Seminar Selected Topics in Malware Analysis and Computer/Network Security** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>at least every year | | |
| **Module coordinator** | Prof. Dr. Peter Martini | | | | |
| **Lecturer(s)** | Prof. Dr. Peter Martini | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. | | |
| **Technical skills** | Ability to understand new research results presented in original scientific papers. | | | | |
| **Soft skills** | Ability to present and to critically discuss these results in the framework of the corresponding area. | | | | |
| **Contents** | Current conference and journal papers, current standardization drafts - with a specific topic focus on Malware Analysis, Computer and Network Security | | | | |
| **Prerequisites** | **Recommended:** all of the following:<br>MA-INF 3101 – High Performance Networking<br>MA-INF 3201 – Network Security | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Seminar | 10 | 2 | 30 T / 90 S | 4 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | | | | | |

| **Module**<br>MA-INF 3216 | **Seminar Sensor Data Fusion** | | |
|---|---|---|---|
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | P.D. Dr. Wolfgang Koch | | |
| **Lecturer(s)** | P.D. Dr. Wolfgang Koch | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. |
| **Technical skills** | Ability to understand new research results presented in original scientific papers. | | |
| **Soft skills** | Ability to present and to critically discuss these results in the framework of the corresponding area. | | |
| **Contents** | Current conference and journal papers | | |
| **Prerequisites** | none | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation, written report | (graded) |
| **Study achievements** | none | (not graded) |
| **Forms of media** | | |
| **Literature** | The relevant literature will be announced towards the end of the previous semester. | |

| **Module**<br>MA-INF 3217 | **User Centered Software Design** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Armin B. Cremers | | |
| **Lecturer(s)** | Prof. Dr. Armin B. Cremers, Dr. Pascal Bihler | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1., 2. or 3. |
| **Technical skills** | The goal of user centered software development is a product that is optimized for its users, rather than a product, for which the users have to adapt their behavior. The student learns how to incorporate a user centered view into software development processes. This enables the student to evaluate a good product usability and a high user satisfaction with the developed software. | | |
| **Soft skills** | Productive working in small groups, critical reflection of competitive solutions, discussion and presentation in groups. | | |
| **Contents** | User centered software design includes a broad spectrum of approaches, techniques and tools from computer science and psychology. In addition to a basic introduction into the methodology of user centered design, the lecture course focuses on a selected topic from the field, e.g. User Interface Engineering, Context Aware Software Development, Software Adaptation, Methods of Software Evaluation or Domain Specific Languages. | | |
| **Prerequisites** | none | | |

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

| | |
|---|---|
| **Exam achievements** | Written exam (graded) |
| **Study achievements** | Successful exercise participation (not graded) |
| **Forms of media** | |
| **Literature** | • Alan Dix, Janet Finlay, Gregory Abowd and Russell Beale: "Human Computer Interaction"<br>• Alan Cooper, Robert Reimann und David Cronin: "About Face: Interface und Interaction Design"<br>• Jonathan Lazar, Jinjuan Heidi Feng, Harry Hochheiser: "Research Methods in Human-Computer Interaction"<br>• Hugh Beyer, Karen Holtzblatt: "Contextual Design. Defining Customer-Centered Systems" |

| **Module**<br>MA-INF 3218 | **Seminar Model-Driven Software Engineering** | | |
|---|---|---|---|
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Dr. Günter Kniesel | | |
| **Lecturer(s)** | Dr. Günter Kniesel | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. |
| **Technical skills** | On successful completion of this module, students should be able to:<br>• Understand the differences between model driven and traditional software development<br>• Describe the common features and peculiarities of different model driven development approaches<br>• Assess the suitability of a model driven approach for a given project<br>• Select appropriate tools for model driven development tasks<br>• Explain the individual scientific topic prepared | | |
| **Soft skills** | On successful completion of this module, students should have refined their scientific writing and presentation skills and should be able to:<br>• Mine for profound knowledge about a given subject<br>• Distill and communicate the summary of a computer science topic orally<br>• Evaluate the scientific integrity of a written summary<br>• Use modern presentation software | | |
| **Contents** | Inhalte<br>Model driven software development concepts, tools and methods.<br>In particular:<br>• Models, meta-models and meta-meta-models (General, MOF, EMOF, ECORE)<br>• Text to model, model to text transformation<br>• Imperative versus declarative model transformation<br>• Model-driven versus other software development approaches<br>• Best practice and research issues in model based development | | |
| **Prerequisites** | **Recommended:** all of the following:<br>MA-INF 3207 – Advanced Logic Programming<br>MA-INF 3212 – Advanced Topics in Software Construction<br>MA 3212 will lays general foundations for model driven development. MA 3207 greatly eases understanding declarative model transformation approaches. | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Seminar / 10 / 2 / 30 T / 90 S / 4<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Oral presentation, written report (graded) | | |
| **Study achievements** | none (not graded) | | |
| **Forms of media** | • Web page: https://sewiki.iai.uni-bonn.de/teaching/seminars/start<br>• Slides (Powerpoint/PDF)<br>• Mailing list for students | | |
| **Literature** | • "Model-Driven Software Development: Technology, Engineering, Management". Thomas Stahl, Markus Voelter, Wiley 2006.<br>• "Model-Driven Software Development". Sami Beydeda , Matthias Book, Volker Gruhn (Eds), ISBN 978-3-540-25613-7, Springer 2005<br>• David S. Frankel: Model Driven Architecture: Applying MDA to Enterprise Computing, John Wiley | | |

| **Module**<br>MA-INF 3219 | **Lab Model-Driven Software Engineering** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Dr. Günter Kniesel | | |
| **Lecturer(s)** | Dr. Günter Kniesel | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. |
| **Technical skills** | On successful completion of this module, students should be able to:<br>• Describe the process of model driven software development (MDSD) and support this description with personal experiences<br>• Connect model driven software development guidelines to concrete practical examples<br>• Be able to use one or several concrete MDSD tools and techniques and explain their use to others | | |
| **Soft skills** | Students should be able to:<br>• Run a software project based on MDSD tools, techniques and methods<br>• Establish and iteratively evolve a project plan<br>• Collaborate in a team<br>• Estimate the required time and other resources for given tasks<br>• Manage a software development project with time constraints | | |
| **Contents** | Model driven software development methods are the key to a new level of<br>automation and tool integration in software development. Students will<br>learn how MDSE concepts, tools an methods boost the development of<br>general purpose and domain specific languages, leverage software quality<br>analysis tools and foster automated software improvement. | | |
| **Prerequisites** | **Required:**<br>MA-INF 3218 – Seminar Model-Driven Software Engineering<br>The seminar lays the conceptual foundations for the work in the lab. | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Lab / 8 / 4 / 60 T / 210 S / 9<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Oral presentation, written report (graded) | | |
| **Study achievements** | none (not graded) | | |
| **Forms of media** | • Web page: https://sewiki.iai.uni-bonn.de/teaching/labs/start<br>• Slides (Powerpoint/PDF)<br>• Wiki as a shared knowledge base<br>• Task Tracking System (Electronical or Physical)<br>• Shared repository for source code and development documents<br>• Mailing list | | |
| **Literature** | • "Model-Driven Software Development: Technology, Engineering, Management". Thomas Stahl, Markus Voelter, Wiley 2006.<br>• "Model-Driven Software Development". Sami Beydeda , Matthias Book, Volker Gruhn (Eds), ISBN 978-3-540-25613-7, Springer 2005<br>• David S. Frankel: Model Driven Architecture: Applying MDA to Enterprise Computing, John Wiley<br>• Modellgetriebene Softwareentwicklung, Techniken, Engineering, Management. dPunkt, 2005 | | |

| | |
|---|---|
| **Module**<br>MA-INF 3220 | **Seminar Agile Software Development** |
| **Workload**<br>120 h | **Credit points**<br>4 CP \| **Duration**<br>1 semester \| **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Armin B. Cremers |
| **Lecturer(s)** | Prof. Dr. Armin B. Cremers |
| **Classification** | **Programme**<br>M. Sc. Computer Science \| **Mode**<br>Optional \| **Semester**<br>2. |
| **Technical skills** | On successful completion of this module, students should be able to:<br>• Describe the common features and variations of different agile development approaches<br>• Understand the differences between agile and traditional software development<br>• Recall how agile software development evolved<br>• Explain the individual scientific topic prepared. |
| **Soft skills** | On successful completion of this module, students should be able to:<br>• Balance the pros and cons of an agile development method<br>• Mine for profound knowledge about a given subject<br>• Use up-to-date presentation software to support group presentations<br>• Further refine their scientific writing and presentation skills<br>Based on the knowledge and skills acquired they should be able to:<br>• Compare and select agile software development methods to fit for a concrete project<br>• Select appropriate tools for an agile software development<br>• Communicate the summary of a computer science topic orally<br>• Evaluate the scientific integrity of a written summary |
| **Contents** | Agile software development, teamwork and efficiency, as known from eXtreme Programming (XP), are the focus of this seminar. Topics the seminar focuses on are:<br>• History of agile software development, software development methods in comparison.<br>• Testing (Unit Testing, Functional Testing, Integration Testing, Acceptance Testing, Code Coverage)<br>• Software configuration management (SCM)<br>• Specific topics relevant for the semester's Agile Software Development Lab project. (These specific topics will make up 50% of the overall topics of the lab.) |
| **Prerequisites** | none |
| **Format** | **Teaching format** \| **Group size** \| **h/week** \| **Workload[h]** \| **CP**<br>Seminar \| 10 \| 2 \| 30 T / 90 S \| 4<br>T = face-to-face teaching; S = independent study |
| **Exam achievements** | Oral presentation, written report (graded) |
| **Study achievements** | none (not graded) |
| **Forms of media** | • Web page: https://sewiki.iai.uni-bonn.de/teaching/seminars/start<br>• Slides (Powerpoint/PDF)<br>• Software-Examples<br>• Mailing list for students |
| **Literature** | • Kent Beck, Cynthia Andres: Extreme Programming Explained: Embrace Change. 2nd Edt., Addison-Wesley Professional; 2004<br>• Alistair Cockburn: Agile Software Development: The Cooperative Game, 2nd Edt., Addison-Wesley Professional, 2006<br>• Kent Beck: Test Driven Development: By Example, Addison-Wesley Professional, 2002<br>• Erich Gamma, Richard Helm, Ralph Johnson, and John Vlissides: Design Patterns: Elements of Reusable Object-Oriented Software. Addison-Wesley Professional, 1994<br>• Martin Fowler et al., Refactoring: Improving the Design of Existing Code. Addison-Wesley Professional, 1999<br>• Ken Schwaber, Mike Beedle: Agile Software Development with Scrum. Prentice Hall, 2001<br>• Marry Poppendieck, Tom Poppendieck: Lean Software Development: An Agile Toolkit, Addison-Wesley Professional, 2003<br>• David Anderson: Kanban: Successful Evolutionary Change for Your Technology Business, Blue Hole Press, 2010 |

| | |
|---|---|
| **Module**<br>MA-INF 3221 | **Lab Agile Software Development** |
| **Workload**<br>270 h | **Credit points**: 9 CP \| **Duration**: 1 semester \| **Frequency**: every year |
| **Module coordinator** | Prof. Dr. Armin B. Cremers |
| **Lecturer(s)** | Prof. Dr. Armin B. Cremers |
| **Classification** | **Programme**: M. Sc. Computer Science \| **Mode**: Optional \| **Semester**: 2. |
| **Technical skills** | On successful completion of this module, students should be able to:<br>• Describe the process of an agile software development and support this description with personal experiences<br>• Connect agile software development guidelines to concrete practical examples<br>• Define the terms Agile Software Development, Interaction with an On-site Customer, Project Planning with User Stories, Task-Breakdown, Story- and Task-Estimation, Test-First Development, Unit-Tests, Acceptance Tests, Small Releases, Short Development Cycles, Cycle and Release Planning/Steering, Stand-Up Meeting, Retrospective, Simple Design, Code Quality Checking, Refactoring, Continuous Integration, Pair Programming, and Collective Code Ownership. |
| **Soft skills** | On successful completion of this module, students should be able to:<br>• Use up-to-date tools for agile software development in teams<br>• Decompose work items into tractable smaller ones<br>• Visualize the progress of the development<br>• Iterate over the continuous development of an evolving product<br>• Establish an infrastructure for high quality code development<br>• Commit themselves for a given development task<br>Based on the knowledge and skills acquired they should be able to:<br>• Run a software project with the help of agile methods<br>• Adapt development plans to evolving specifications<br>• Estimate the required time and other resources for a given software project<br>• Manage a software development project with time constraints<br>• Work in a professional, industry-like team setting |
| **Contents** | Agile software development methods like Extreme Programming, Scrum or Kanban let blow a new wind in the context of traditional Software Development. Short development cycles, flexible planning, holistic values and the focus on the developer as human being have already radiated into the development processes of many professionals. |
| **Prerequisites** | **Recommended:**<br>MA-INF 3220 – Seminar Agile Software Development |
| **Format** | **Teaching format** \| **Group size** \| **h/week** \| **Workload[h]** \| **CP**<br>Lab \| 8 \| 4 \| 60 T / 210 S \| 9<br>T = face-to-face teaching; S = independent study |
| **Exam achievements** | Oral presentation, written report (graded) |
| **Study achievements** | none (not graded) |
| **Forms of media** | • Web page: https://sewiki.iai.uni-bonn.de/teaching/labs/start<br>• Wiki as a shared knowledge base<br>• Shared repository for examples and source code<br>• Slides (Powerpoint/PDF)<br>• Task Tracking System (Electronical or Physical)<br>• Mailing list for students |
| **Literature** | • Kent Beck, Cynthia Andres: Extreme Programming Explained: Embrace Change. 2nd Edt., Addison-Wesley Professional; 2004<br>• Alistair Cockburn: Agile Software Development: The Cooperative Game, 2nd Edt., Addison-Wesley Professional, 2006<br>• Kent Beck: Test Driven Development: By Example, Addison-Wesley Professional, 2002<br>• Erich Gamma, Richard Helm, Ralph Johnson, and John Vlissides: Design Patterns: Elements of Reusable Object-Oriented Software. Addison-Wesley Professional, 1994<br>• Martin Fowler et al., Refactoring: Improving the Design of Existing Code. Addison-Wesley Professional, 1999<br>• Ken Schwaber, Mike Beedle: Agile Software Development with Scrum. Prentice Hall, 2001<br>• Marry Poppendieck, Tom Poppendieck: Lean Software Development: An Agile Toolkit, Addison-Wesley Professional, 2003<br>• David Anderson: Kanban: Successful Evolutionary Change for Your Technology Business, Blue Hole Press, 2010 |

| **Module**<br>MA-INF 3222 | **eSecurity** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Joachim von zur Gathen | | |
| **Lecturer(s)** | Prof. Dr. Joachim von zur Gathen, Dr. Michael Nüsken | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. |
| **Technical skills** | Understanding of security concerns and measures, and of the interplay between computing power and security requirements in the realm of real-world applications, in particular internet-based ones. Mastery of advanced techniques for the design of cryptosystems and practical cryptanalysis. | | |
| **Soft skills** | Oral presentation (in tutorial groups), written presentation (of exercise solutions), team collaboration in solving homework problems, critical assessment. | | |
| **Contents** | First focus: security on the internet and secure protocols. Furthermore: at least one real world application, for example<br>• electronic health cards,<br>• electronic elections, or<br>• electronic passports. | | |
| **Prerequisites** | **Required:**<br>MA-INF 1103 – Cryptography | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Written exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | | |
| **Literature** | Varying according to the selected topic | |

| **Module**<br>MA-INF 3223 | **Seminar Applied Cryptography** | | |
|---|---|---|---|
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Joachim von zur Gathen | | |
| **Lecturer(s)** | Prof. Dr. Joachim von zur Gathen | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | Understanding research publications, often written tersely. Distilling this into a presentation. Determination of relevant vs. irrelevant material. Developing a presentation that fascinates fellow students. | | |
| **Soft skills** | Understanding and presenting material both orally and in visual media. Motivating other students to participate. Critical assessment of research results. | | |
| **Contents** | A special topic within cryptography, changing from year to year, is studied in depth, based on current research literature | | |
| **Prerequisites** | **Recommended:**<br>MA-INF 1103 – Cryptography | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation, written report | (graded) |
| **Study achievements** | none | (not graded) |
| **Forms of media** | | |
| **Literature** | Current conference publications, to be announced in time | |

| **Module**<br>MA-INF 3224 | **Selected Aspects of Sensor Data Fusion – Methods and Applications** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | PD Dr. Wolfgang Koch | | |
| **Lecturer(s)** | PD Dr. Wolfgang Koch | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. |
| **Technical skills** | All participants shall get known to the advanced theory in selected topics of sensor data fusion. Based on the Introduction lecture from the winter term, both real world applications and theoretical results from an analysis on specific challenges will be presented.<br>All algorithms will be motivated by examples from ongoing research projects, industrial cooperations, and impressions of current demonstration hardware. | | |
| **Soft skills** | In many applications with multiple sensors, full communication is not available. In particular, scenarios using wireless channels such as HF radio, WLAN, or 3G networks suffer from link breakdowns and small bandwidths. Furthermore, if sensors with high update rates (e.g.~sonar or lidar) or many false measurements (e.g.~radar) are involved, nowadays network technologies are not sufficient to cover all needs with respect to a constant transfer of measurements. In the lecture, students shall gain expertise in coping with the challenges of outdated measurements, decorrelated track-to-track fusion, recognition of endangered situations, signal processing and more. | | |
| **Contents** | • Distributed Kalman Filter<br>• Out-of-Sequence Processing<br>• Signal Processing<br>• Track-before-Detect<br>• Recognition of endangered situation | | |
| **Prerequisites** | **Recommended:**<br>MA-INF 3310 – Introduction to Sensor Data Fusion | | |

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

| | | |
|---|---|---|
| **Exam achievements** | Oral exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | | |
| **Literature** | | |

| **Module**<br>MA-INF 3225 | **Lab Building a Hardware Router** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Björn Scheuermann | | |
| **Lecturer(s)** | Prof. Dr. Björn Scheuermann | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. |
| **Technical skills** | The students will carry out a practical task (project) in the context of hardware routers, including test and documentation of the implemented software/system. | | |
| **Soft skills** | Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area. | | |
| **Contents** | | | |
| **Prerequisites** | none | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation, written report | (graded) |
| **Study achievements** | none | (not graded) |
| **Forms of media** | | |
| **Literature** | | |

| **Module**<br>MA-INF 3226 | **Lab Distributed Systems** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Björn Scheuermann | | | | |
| **Lecturer(s)** | Prof. Dr. Björn Scheuermann | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. | | |
| **Technical skills** | The students will carry out a practical task (project) in the context of distributed systems, including test and documentation of the implemented software/system. | | | | |
| **Soft skills** | Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area. | | | | |
| **Contents** | | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lab | 8 | 4 | 60 T / 210 S | 9 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | | | | | |

| **Module**<br>MA-INF 3227 | **Seminar Anonymity and Privacy on the Internet** | | |
|---|---|---|---|
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Björn Scheuermann | | |
| **Lecturer(s)** | Prof. Dr. Björn Scheuermann | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. |
| **Technical skills** | Ability to understand new research results presented in original scientific papers. | | |
| **Soft skills** | Ability to present and to critically discuss these results in the framework of the corresponding area. | | |
| **Contents** | Current conference and journal papers. | | |
| **Prerequisites** | none | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation, written report | (graded) |
| **Study achievements** | none | (not graded) |
| **Forms of media** | | |
| **Literature** | | |

| **Module**<br>MA-INF 3302 | **Temporal Information Systems** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Rainer Manthey | | |
| **Lecturer(s)** | Prof. Dr. Rainer Manthey | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | | | |
| **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) | | |
| **Contents** | | | |
| **Prerequisites** | none | | |

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

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

| **Module**<br>MA-INF 3304 | **Lab Communication and Communicating Devices** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every semester |
| **Module coordinator** | Prof. Dr. Peter Martini | | |
| **Lecturer(s)** | Prof. Dr. Peter Martini | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | The students will carry out a practical task (project) in the context of communication systems, including test and documentation of the implemented software/system. | | |
| **Soft skills** | Work in small teams and cooperate with other teams in a group; ability to make design decisions in a practical task; present and discuss (interim and final) results in the team/group and to other students; prepare written documentation of the work carried out | | |
| **Contents** | Selected topics close to current research in the area of communication systems, network security, mobile communication and communicating devices. | | |
| **Prerequisites** | **Recommended:** At least 2 of the following:<br>MA-INF 3101 – High Performance Networking<br>MA-INF 3201 – Network Security<br>MA-INF 3202 – Mobile Communication | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation, written report | (graded) |
| **Study achievements** | none | (not graded) |
| **Forms of media** | | |
| **Literature** | The relevant literature will be announced towards the end of the previous semester. | |

<table>
<tr><td>Module<br>MA-INF 3305</td><td colspan="5">Lab Information Systems</td></tr>
<tr><td>Workload<br>270 h</td><td>Credit points<br>9 CP</td><td>Duration<br>1 semester</td><td colspan="3">Frequency<br>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, Prof. Dr. Rainer Manthey,<br>Dr. Stefan Lüttringhaus-Kappel, Dr. Thomas Bode</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td colspan="2">Semester<br>2. or 3.</td></tr>
<tr><td>Technical skills</td><td colspan="5">The students will carry out a practical task (project) in the context of information systems, including test and documentation of the implemented software/system.</td></tr>
<tr><td>Soft skills</td><td colspan="5">Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify 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>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lab</td><td>8</td><td>4</td><td>60 T / 210 S</td><td>9</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Oral presentation, written report (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">none (not graded)</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>

| | | | | | |
|---|---|---|---|---|---|
| **Module**<br>MA-INF 3307 | **Sensor Networks** | | | | |
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>at least every 2 years | | |
| **Module coordinator** | Prof. Dr. Peter Martini | | | | |
| **Lecturer(s)** | Dr. Nils Aschenbruck, Dr. Matthias Frank | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. | | |
| **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) | | | | |
| **Contents** | Sensor network architectures, single node architecture, hardware platforms, operating systems, MAC protocols for sensor networks, link layer, transport layer, localization, middleware, data management. | | | | |
| **Prerequisites** | **Recommended:**<br>MA-INF 3101 – High Performance Networking | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | • Holger Karl and Andreas Willig, “Protocols and Architectures for Wireless Sensor Networks”, Wiley, 2005.<br>• Feng Zhao and Leo Guibas, “Wireless Sensor Networks: An Information Processing Approach”, Morgan Kaufmann, 2004 | | | | |

| **Module**<br>MA-INF 3309 | **Lab Malware Analysis** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every semester | | |
| **Module coordinator** | Prof. Dr. Peter Martini | | | | |
| **Lecturer(s)** | Prof. Dr. Peter Martini | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. | | |
| **Technical skills** | The students will carry out a practical task (project) in the context of communication systems with a specific topic focus on Malware Analysis and Computer/Network Security, including test and documentation of the implemented software/system. | | | | |
| **Soft skills** | Work in small teams and cooperate with other teams in a group; ability to make design decisions in a practical task; present and discuss (interim and final) results in the team/group and to other students; prepare written documentation of the work carried out | | | | |
| **Contents** | Selected topics close to current research in the area of communication systems, malware analysis, computer and network security. | | | | |
| **Prerequisites** | **Recommended:** all of the following:<br>MA-INF 3101 – High Performance Networking<br>MA-INF 3201 – Network Security | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lab | 8 | 4 | 60 T / 210 S | 9 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | | | | | |

| **Module**<br>MA-INF 3310 | **Introduction to Sensor Data Fusion** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | P.D. Dr. Wolfgang Koch | | |
| **Lecturer(s)** | P.D. Dr. Wolfgang Koch | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. |
| **Technical skills** | All participants shall get known to the basic theory of sensor data fusion. The lecture starts with preliminaries on how to handle uncertain data and knowledge within analytical calculus. Then, the fundamental and well-known Kalman filter is derived. Based on this tracking scheme, further approaches to a wide spectrum of applications will be shown. All algorithms will be motivated by examples from ongoing research projects, industrial cooperations, and impressions of current demonstration hardware. | | |
| **Soft skills** | Because of inherent practical issues, every sensor measures certain properties up to an error. This lecture shows how to model and overcome this error by an application of theoretical tools such as Bayes' rule and further derivations. Moreover, solutions to possible false-alarms, miss-detections, maneuvering phases, and much more will be presented. | | |
| **Contents** | • Gaussian probability density functions<br>• Kalman filter<br>• Multi Hypothesis Filter<br>• Interacting Multiple Model Filter<br>• Retrodiction / Smoothing<br>• Maneuver Modeling | | |
| **Prerequisites** | none | | |

| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|---|
| | Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |

| | | |
|---|---|---|
| **Exam achievements** | Oral exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | | |
| **Literature** | • Y. Bar-Shalom, "Estimation with Applications to Tracking and Navigation", Wiley-Interscience, 2001. | |

<table>
<tr><td>Module<br>MA-INF 3311</td><td colspan="5">Topics in Applied Cryptography</td></tr>
<tr><td>Workload<br>270 h</td><td>Credit points<br>9 CP</td><td>Duration<br>1 semester</td><td colspan="3">Frequency<br>every year</td></tr>
<tr><td>Module coordinator</td><td colspan="5">Prof. Dr. Joachim von zur Gathen</td></tr>
<tr><td>Lecturer(s)</td><td colspan="5">Prof. Dr. Joachim von zur Gathen, Dr. Michael Nüsken</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td colspan="2">Semester<br>3.</td></tr>
<tr><td>Technical skills</td><td colspan="5">Gain deeper understanding in a special area of cryptography close to current research.</td></tr>
<tr><td>Soft skills</td><td colspan="5">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="5">One varying, advanced topic related to current research in applied cryptography, e.g.<br>• mobile security, or<br>• design and analysis of hash functions.</td></tr>
<tr><td>Prerequisites</td><td colspan="5">Required:<br>MA-INF 1103 – Cryptography<br>and one further course in cryptography like The Art of Cryptography or eSecurity.</td></tr>
<tr><td>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lecture</td><td>60</td><td>4</td><td>60 T / 105 S</td><td>5.5</td></tr><tr><td>Exercises</td><td>30</td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Written exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5"></td></tr>
</table>

| **Module**<br>MA-INF 3312 | **Lab Sensor Data Fusion** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | P.D. Dr. Wolfgang Koch | | |
| **Lecturer(s)** | P.D. Dr. Wolfgang Koch | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. |
| **Technical skills** | The students will work together on a data fusion project using various sensor hardware. Latest algorithms for fusing information from several nodes will be implemented. | | |
| **Soft skills** | The students shall work together in a team. Every one is responsible for a specific part in the context of a main goal. Results will be exchanged and integrated via software interfaces. | | |
| **Contents** | Varying selected topics on sensor data fusion. | | |
| **Prerequisites** | none | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Lab / 8 / 4 / 60 T / 210 S / 9<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Oral presentation, written report (graded) | | |
| **Study achievements** | none (not graded) | | |
| **Forms of media** | | | |
| **Literature** | The relevant literature will be announced towards the end of the previous semester. | | |

| **Module**<br>MA-INF 3313 | **Lab Intelligent Information Systems** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Rainer Manthey | | | | |
| **Lecturer(s)** | Prof. Dr. Rainer Manthey | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. | | |
| **Technical skills** | | | | | |
| **Soft skills** | | | | | |
| **Contents** | | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lab | 8 | 4 | 60 T / 210 S | 9 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | | | | | |

# 4 Intelligent Systems

| **Module**<br>MA-INF 4111 | **Intelligent Learning and Analysis Systems: Machine Learning** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Stefan Wrobel | | |
| **Lecturer(s)** | Prof. Dr. Stefan Wrobel | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1. or 2. |
| **Technical skills** | This module is one of two complementary modules in which students gain an understanding of the most important paradigms and methods of intelligent learning systems as they are used in data analysis and/or for implementing adaptive behaviour (machine learning, data mining, knowledge discovery in databases). This module concentrates on the core task of predictive learning from examples and on agent learning, and teaches the main classes of algorithms for these tasks. At the end of the module, students will be capable of choosing appropriate methods and systems for particular predictive learning applications and use them to arrive at convincing results, and will know where to start whenever adaptation or further development of algorithms and systems is necessary. This module complements MA-INF 4112 and can be taken before or after that module. | | |
| **Soft skills** | Communicative skills (oral and written presentation of solutions, discussions in small teams), self competences (ability to accept and formulate criticism, ability to analyze problems) | | |
| **Contents** | Types of learning and analysis tasks, most important non-parametric and parametric methods for supervised learning (e.g., decision trees, rules, linear methods, neural networks, neighbourhood methods, kernel methods, probabilistic approaches), reinforcement learning, evaluation and learning theory. | | |
| **Prerequisites** | **Recommended:**<br>Prior knowledge of probability theory, linear algebra, artificial intelligence, information systems and data bases<br>**Required**: None of the following modules have been passed:<br>MA-INF 4102 – Intelligent Learning and Analysis Systems | | |

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

| | | |
|---|---|---|
| **Exam achievements** | Written exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | Lectures, exercises, software packages | |
| **Literature** | - Tom Mitchell, Machine Learning, McGraw-Hill, 1997<br>- Ian Witten, Eibe Frank, Data Mining, Morgan Kauffmann, 2000 | |

| **Module**<br>MA-INF 4112 | **Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Stefan Wrobel | | |
| **Lecturer(s)** | Prof. Dr. Wrobel | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1. or 2. |
| **Technical skills** | This module is one of two complementary modules in which students gain an understanding of the most important paradigms and methods of intelligent learning systems as they are used in data analysis and/or for implementing adaptive behaviour (machine learning, data mining, knowledge discovery in databases). This module concentrates on the core tasks of pattern discovery in databases and teaches the main classes of algorithms for this task (subgroups discovery. At the end of the module, students will be capable of choosing appropriate methods and systems for particular pattern discovery applications and use them to arrive at convincing results, and will know where to start whenever adaptation or further development of algorithms and systems is necessary. This module complements MA-INF 4111 and can be taken before or after that module. | | |
| **Soft skills** | Communicative skills (oral and written presentation of solutions, discussions in small teams), self competences (ability to accept and formulate criticism, ability to analyze problems) | | |
| **Contents** | Types of learning and analysis tasks, scalability techniques, descriptive data mining methods, association rules, subgroups, clustering, pre- and postprocessing, data storage (data warehouses, OLAP), special data types (spatial, network, text, multimedia data), interactive and visual systems. | | |
| **Prerequisites** | **Recommended:**<br>Prior knowledge of probability theory, linear algebra, artificial intelligence, information systems and data bases<br>**Required**: None of the following modules have been passed:<br>MA-INF 4102 – Intelligent Learning and Analysis Systems | | |

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

| | | |
|---|---|---|
| **Exam achievements** | Written exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | Lectures, exercises, software packages | |
| **Literature** | - Ian Witten, Eibe Frank, Data Mining, Morgan Kauffmann, 2000<br>- Jiawei Han, Micheline Kamber, Data Mining: Concepts and Techniques, Morgan Kaufmann, 2000 | |

| **Module**<br>MA-INF 4113 | **Cognitive Robotics** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Sven Behnke | | |
| **Lecturer(s)** | Prof. Dr. Sven Behnke | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1. or 2. |
| **Technical skills** | This lecture is one of two introductory lectures of the intelligent systems track. The lecture covers cognitive capabilities of robots, like self-localization, mapping, object perception, and action-planning in complex environments.<br>This module complements MA-INF 4114 and can be taken before or after that module. | | |
| **Soft skills** | Communicative skills (oral and written presentation of solutions, discussions in small teams), self competences (ability to accept and formulate criticism, ability to analyze problems) | | |
| **Contents** | Probabilistic approaches to state estimation (Bayes Filters, Kalman Filter, Particle Filter), motion models, sensor models, self-localization, mapping with known poses, simultaneous mapping and localization (SLAM), iterated closest-point matching, path planning, place- and person recognition, object recognition. | | |
| **Prerequisites** | **Required**: None of the following modules have been passed:<br>MA-INF 4101 – Theory of Sensorimotor Systems | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Lecture: 60 / 2 / 30 T / 45 S / 2.5<br>Exercises: 30 / 2 / 30 T / 75 S / 3.5<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Written exam (graded) | | |
| **Study achievements** | Successful exercise participation (not graded) | | |
| **Forms of media** | | | |
| **Literature** | • S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.<br>• B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008.<br>• R. Szeliski: Computer Vision: Algorithms and Applications, Springer 2010. | | |

| **Module**<br>MA-INF 4114 | **Robot Learning** | | | |
|---|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year | |
| **Module coordinator** | Prof. Dr. Sven Behnke | | | |
| **Lecturer(s)** | Prof. Dr. Sven Behnke, Dr. Nils Goerke | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1. or 2. | |
| **Technical skills** | This lecture is one of two introductory lectures of the intelligent systems track. Creating autonomous robots that can learn to assist humans in situations of daily life is a fascinating challenge for machine learning.<br>The lecture covers key ingredients for a general robot learning approach to get closer towards human-like performance in robotics, such as reinforcement learning, learning models for control, learning motor primitives, learning from demonstrations and imitation learning, and interactive learning.<br>This module complements MA-INF 4113 and can be taken before or after that module. | | | |
| **Soft skills** | Communicative skills (oral and written presentation of solutions, discussions in small teams), self competences (ability to accept and formulate criticism, ability to analyze problems) | | | |
| **Contents** | Reinforcement learning, Markov decision processes, dynamic programming, Monte Carlo methods, temporal-difference methods, function approximation, liear quadratic regulation, differential dynamic programming, partially observable MDPs, policy gradient methods, inverse reinforcement learning, imitation learning, learning kinematic models, perceiving and handling of objects. | | | |
| **Prerequisites** | none | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** / **CP** |
| | Lecture | 60 | 2 | 30 T / 45 S / 2.5 |
| | Exercises | 30 | 2 | 30 T / 75 S / 3.5 |
| | T = face-to-face teaching; S = independent study | | | |
| **Exam achievements** | Oral exam (graded) | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | |
| **Forms of media** | | | | |
| **Literature** | • R. Sutton and A. Barto: Reinforcement Learning, MIT-Press, 1998.<br>• O. Sigaud and J. Peters (Eds.): From Motor Learning to Interaction Learning in Robots. Springer, 2010. | | | |

| **Module**<br>MA-INF 4201 | **Artificial Life** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Sven Behnke | | |
| **Lecturer(s)** | Prof. Dr. Sven Behnke, Dr. Nils Goerke | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1., 2. or 3. |
| **Technical skills** | Detailed understanding of the most important approaches and principles of artificial life. Knowledge and understanding of the current state of research in the field of artificial life | | |
| **Soft skills** | Capability to identify the state of the art in artificial life, and to present and defend the found solutions within the exercises in front of a group of students. Critical discussion of the results of the homework. | | |
| **Contents** | Foundations of artificial life, cellular automata, Conway's "Game of Life"; mechanisms for structural development; foundations of nonlinear dynamical systems, Lindenmeyer-systems, evolutionary methods and genetic algorithms, reinforcement learning, artificial immune systems, adaptive behaviour, self-organising criticality, multi-agent systems, and swarm intelligence, particle swarm optimization. | | |
| **Prerequisites** | none | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Lecture: 60 / 2 / 30 T / 45 S / 2.5<br>Exercises: 30 / 2 / 30 T / 75 S / 3.5<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Written exam (graded) | | |
| **Study achievements** | Successful exercise participation (not graded) | | |
| **Forms of media** | Pencil and paper work, explain solutions in front of athe exercise group, implementation of small programs, use of simple simulation tools. | | |
| **Literature** | • Christoph Adami: Introduction to Artificial Life, The Electronic Library of Science, TELOS, Springer-Verlag<br>• 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.<br>• Andrzej Osyczka: Evolutionary Algorithms for Single and Multicriteria Design Optimization, Studies in Fuzzyness and Soft Computing, Physica-Verlag, A Springer-Verlag Company, Heidelberg | | |

| **Module**<br>MA-INF 4202 | **Computational Neuroscience and Neural Computation** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Rolf Eckmiller | | | | |
| **Lecturer(s)** | Prof. Dr. Rolf Eckmiller, Dr. Nils Goerke | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. | | |
| **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, biocybernetics...). | | | | |
| **Contents** | Structure and function of neural modules and elements. Information processing and learning in specific regions of the central nervous system, including: 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. | | | | |
| **Prerequisites** | none | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Written exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | • J.M. Bower: Computational Neuroscience: Trends in Research, Cal Tech Pasadena, Plenum Press, New York,1997<br>• Simon Haykin: Neural Networks, A Comprehensive Foundation, Prentice Hall International Editions<br>• Christopher M. Bishop: Neural Networks for Pattern Recognition, Oxford University Press<br>• E.R. Kandel, J.H. Schwartz, T.H. Jessel: Principles of Neural Science, McGraw-Hill, New York | | | | |

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

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

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

| **Module**<br>MA-INF 4204 | **Technical Neural Nets** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Joachim K. Anlauf | | |
| **Lecturer(s)** | Prof. Dr. Joachim K. Anlauf, Dr. Nils Goerke | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>1., 2. or 3. |
| **Technical skills** | Detailed knowledge of the most important neural network approaches and learning algorithms and its fields of application. Knowledge and understanding of technical neural networks as Non-Von Neumann computer architectures similar to concepts of brain functions at different stages of development | | |
| **Soft skills** | The students will be capable to propose several paradigms from neural networks that are capable to solve a given task. They can discuss the pro and cons with respect to efficency and risk. The will be capable to plan and implement a small project with state of the art neural network solutions. | | |
| **Contents** | Multi-layer perceptron, radial-basis function nets, Hopfield nets, self organizing maps (Kohonen), adaptive resonance theory, learning vector quantization, recurrent networks, back-propagation of error, reinforcement learning, Q-learning, support vector machines, pulse processing neural networks. Exemplary applications of neural nets: function approximation, prediction, quality control, image processing, speech processing, action planning, control of technical processes and robots. Implementation of neural networks in hardware and software: tools, simulators, analog and digital neural hardware. | | |
| **Prerequisites** | none | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| | Exercises | 30 | 2 | 30 T / 75 S | 3.5 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Written exam (graded) | | | | |
| **Study achievements** | Successful exercise participation (not graded) | | | | |
| **Forms of media** | | | | | |
| **Literature** | • Christopher M. Bishop: Neural Networks for Pattern Recognition, Oxford University Press, ISBN-10: 0198538642, ISBN-13: 978-0198538646<br>• Ian T. Nabney: NETLAB. Algoriths for Pattern Recognition, Springer, ISBN-10: 1852334401, ISBN-13: 978-1852334406 | | | | |

| **Module**<br>MA-INF 4205 | **Probabilistic Graphical Models** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Armin B. Cremers | | |
| **Lecturer(s)** | Prof. Dr. Armin B. Cremers | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | 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. | | |
| **Soft skills** | Students should acquire the following skills:<br>• Ability to derive a solution oriented problem formulation of a given task.<br>• Ability to cooparate in small groups on solving a given task.<br>• Ability to put a conceptual solution and its implemention down on paper.<br>• 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.<br>Inference: (loopy) belief propagation, junction trees, MC and MCMC methods, and variational methods.<br>Learning: Bayesian learning and model selection techniques. | | |
| **Prerequisites** | **Recommended:** all of the following:<br>MA-INF 4101 – Theory of Sensorimotor Systems<br>MA-INF 4102 – Intelligent Learning and Analysis Systems | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Lecture / 60 / 2 / 30 T / 45 S / 2.5<br>Exercises / 30 / 2 / 30 T / 75 S / 3.5<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Written exam (graded) | | |
| **Study achievements** | Successful exercise participation (not graded) | | |
| **Forms of media** | | | |
| **Literature** | • M. I. Jordan: An Introduction to Probabilistic Graphical Models, in preparation<br>• Daphne Koller, Nir Friedman: Bayesian Networks and Beyond, in preparation<br>• F. V. Jensen: Bayesian Networks and Decision Graphs, Springer 2001<br>• M.I. Jordan (editor): Learning in Graphical Models, MIT-Press 1998<br>• additional papers | | |

| **Module**<br>MA-INF 4206 | **Knowledge-based Image Understanding** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | PD Dr. Volker Steinhage | | |
| **Lecturer(s)** | PD Dr. Volker Steinhage | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. |
| **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<br>• Ability to derive a solution oriented problem formulation of a given task<br>• Ability to cooparate in small groups on solving a given task.<br>• Ability to put a conceptual solution and its implemention down on paper<br>• Ability to present and discuss a conceptual solution and its implemention in an oral presentation | | |
| **Contents** | Knowledge representation and inference about scenes and objects to detect object in image data: model-driven segmentation, feature spaces, feature-based classification, optimization, geometric and solid modeling (object-centered vs. appearance-based modeling), interpretation strategies, component-based representation and recognition. | | |
| **Prerequisites** | **Required:** all of the following:<br>MA-INF 2112 – Foundations of Vision and Audio<br>BA-INF 131 – Intelligente Sehsysteme<br>"Knowledge-based Image Understanding" requires knowledge and skills in the foundations of compuer vision like given in the Bachelor module BA-INF 131 "Intelligente Sehsysteme" or partially in Master module MA-INF 2112 "Foundations of Vision and Audio" or comparable lectures. A standard reference is D. Forsyth, J. Ponce: Computer Vision – A Modern Approach. Pearson Education Int., 2003. | | |

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

| | | |
|---|---|---|
| **Exam achievements** | Written exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | | |
| **Literature** | • David A. Forsyth, Jean Ponce: Computer Vision: A Modern Approach. 2nd. Ed., Prentice Hall, 2011.<br>• Journal Computer Vision and Image Understanding, Editor-in-Chief: A.C. Kak. Elsevier. *Individual references given in the lecture. | |

| **Module**<br>MA-INF 4207 | **Dynamically Reconfigurable Systems** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>at least every 2 years |
| **Module coordinator** | Prof. Dr. Joachim K. Anlauf | | |
| **Lecturer(s)** | Prof. Dr. Joachim K. Anlauf | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. |
| **Technical skills** | Knowledge of the most important FPGA architectures, ability to select appropriate FPGAs for a given application, overview of programming tools | | |
| **Soft skills** | Communicative skills (oral and written presentation of solutions), social skills (ability to solve problems in small teams, discussions of solution concepts) self competences (ability to accept and formulate criticism, ability to analyze problems) | | |
| **Contents** | Architecture of FPGAs, Configurable Logic Blocks, Wiring Ressources, Special Blocks, Hardware Description Languages, Synthesis, Technology Mapping, Place and Route, FPGA Computing, Partial Reconfigurability | | |
| **Prerequisites** | none | | |

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

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

| **Module**<br>MA-INF 4208 | **Seminar Vision Systems** | | |
|---|---|---|---|
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>every semester |
| **Module coordinator** | Prof. Dr. Sven Behnke | | |
| **Lecturer(s)** | Prof. Dr. Sven Behnke, Prof. Dr. Joachim K. Anlauf, Dr. Nils Goerke | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | Knowledge in advanced topics in the area of technical vision systems, such as image segmentation, feature extraction, and object recognition.<br>Ability to understand new research results presented in original scientific papers and to present them in a research talk as well as in a seminar report. | | |
| **Soft skills** | Self-competences (time management, literature search, self-study),<br>communication skills (preparation and clear didactic presentation of research talk, scientific discussion, structured writing of seminar report),<br>social skills (ability to formulate and accept criticism, critical examination of research results). | | |
| **Contents** | Current research papers from conferences and journals in the field of vision systems covering fundamental techniques and applications. | | |
| **Prerequisites** | **Recommended:** At least 1 of the following:<br>MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning<br>MA-INF 4204 – Technical Neural Nets | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Seminar / 10 / 2 / 30 T / 90 S / 4<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Oral presentation, written report (graded) | | |
| **Study achievements** | none (not graded) | | |
| **Forms of media** | | | |
| **Literature** | • R. Szeliski: Computer Vision: Algorithms and Applications, Springer 2010.<br>• C. M. Bishop: Pattern Recognition and Machine Learning, Springer 2006.<br>• D. A. Forsyth and J. Ponce: Computer Vision: A Modern Approach, Prentice Hall, 2003. | | |

<table>
<tr><td>Module<br>MA-INF 4209</td><td colspan="4">Seminar Principles of Data Mining and Learning Algorithms</td></tr>
<tr><td>Workload<br>120 h</td><td>Credit points<br>4 CP</td><td>Duration<br>1 semester</td><td colspan="2">Frequency<br>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>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td>Semester<br>2. or 3.</td></tr>
<tr><td>Technical skills</td><td colspan="4">Enhanced and in-depth knowledge in specialized topics in the area of machine learning and data mining, acquiring the competence to independently study scientific literature, present it to others and discuss it with a knowledgeable scientific auditorium. Learn how to scientifically present prior work by others, in writing and in presentations.</td></tr>
<tr><td>Soft skills</td><td colspan="4">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">Recommended: At least 1 of the following:<br>MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning<br>MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery</td></tr>
<tr><td>Format</td><td colspan="4"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Seminar</td><td>10</td><td>2</td><td>30 T / 90 S</td><td>4</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="4">Oral presentation, written report (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="4">none (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="4">Scientific papers and websites, interactive presentations.</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>

| **Module**<br>MA-INF 4210 | **Seminar Advanced Topics in Technical Informatics** | | |
|---|---|---|---|
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>at least every 2 years |
| **Module coordinator** | Prof. Dr. Joachim K. Anlauf | | |
| **Lecturer(s)** | Prof. Dr. Joachim K. Anlauf | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | Current Topics in Technical Informatics | | |
| **Soft skills** | Communicative skills (preparing and presenting talks, preparing a structured written document), social skills (ability to accept and formulate criticism, discussions of current content) self competences (time management with long-ranging deadlines, understanding of research topics from original literature) | | |
| **Contents** | Current topics such as: new architectures of computers or FPGAs (field programmable gate arrays) or new applications of dynamically reconfigurable systems | | |
| **Prerequisites** | none | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation, written report | (graded) |
| **Study achievements** | none | (not graded) |
| **Forms of media** | | |
| **Literature** | Current research papers | |

| **Module**<br>MA-INF 4211 | **Seminar Cognitive Robotics** | | |
|---|---|---|---|
| **Workload**<br>120 h | **Credit points**<br>4 CP | **Duration**<br>1 semester | **Frequency**<br>every semester |
| **Module coordinator** | Prof. Dr. Sven Behnke | | |
| **Lecturer(s)** | Prof. Dr. Sven Behnke, Dr. Nils Goerke | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | Knowledge in advanced topics in the area of cognitive robotics, such as robot perception, action planning, and robot learning.<br>Ability to understand new research results presented in original scientific papers and to present them in a research talk as well as in a seminar report. | | |
| **Soft skills** | Self-competences (time management, literature search, self-study),<br>communication skills (preparation and clear didactic presentation of research talk, scientific discussion, structured writing of seminar report),<br>social skills (ability to formulate and accept criticism, critical examination of research results). | | |
| **Contents** | Current research papers from conferences and journals in the field of cognitive robotics covering fundamental techniques and applications. | | |
| **Prerequisites** | **Recommended:** At least 1 of the following:<br>MA-INF 4113 – Cognitive Robotics<br>MA-INF 4114 – Robot Learning | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Seminar / 10 / 2 / 30 T / 90 S / 4<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Oral presentation, written report (graded) | | |
| **Study achievements** | none (not graded) | | |
| **Forms of media** | | | |
| **Literature** | • S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.<br>• B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008.<br>• Selected papers. | | |

<table>
<tr><td>Module<br>MA-INF 4301</td><td colspan="5">Advanced Topics in Artificial Intelligence</td></tr>
<tr><td>Workload<br>180 h</td><td>Credit points<br>6 CP</td><td>Duration<br>1 semester</td><td colspan="3">Frequency<br>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</td></tr>
<tr><td>Classification</td><td colspan="2">Programme<br>M. Sc. Computer Science</td><td>Mode<br>Optional</td><td colspan="2">Semester<br>3.</td></tr>
<tr><td>Technical skills</td><td colspan="5">Introduction of advanced Artificial Intelligence (AI) techniques. This course aims at familiarising students with the latest trends in AI research.</td></tr>
<tr><td>Soft skills</td><td colspan="5">Students should acquire the following skills:<br>• Ability to derive a solution oriented problem formulation of a given task.<br>• Ability to cooparate in small groups on solving a given task.<br>• Ability to put a conceptual solution and its implemention down on paper.<br>• Ability to present and discuss a conceptual solution and its implemention in an oral presentation.</td></tr>
<tr><td>Contents</td><td colspan="5">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="5">Recommended: all of the following:<br>MA-INF 4101 – Theory of Sensorimotor Systems<br>MA-INF 4102 – Intelligent Learning and Analysis Systems</td></tr>
<tr><td>Format</td><td colspan="5"><table><tr><th>Teaching format</th><th>Group size</th><th>h/week</th><th>Workload[h]</th><th>CP</th></tr><tr><td>Lecture</td><td>60</td><td>2</td><td>30 T / 45 S</td><td>2.5</td></tr><tr><td>Exercises</td><td>30</td><td>2</td><td>30 T / 75 S</td><td>3.5</td></tr></table>T = face-to-face teaching; S = independent study</td></tr>
<tr><td>Exam achievements</td><td colspan="5">Written exam (graded)</td></tr>
<tr><td>Study achievements</td><td colspan="5">Successful exercise participation (not graded)</td></tr>
<tr><td>Forms of media</td><td colspan="5"></td></tr>
<tr><td>Literature</td><td colspan="5">• G. F. Luger: Artificial Intelligence, 5th edition, Addison Wesley 2005<br>• M. Ghallab, D. Nau, P. Traverso: Automated Planning, Elsevier, 2004<br>• additional papers</td></tr>
</table>

| **Module**<br>MA-INF 4302 | **Advanced Learning Systems** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Stefan Wrobel | | |
| **Lecturer(s)** | Prof. Dr. Stefan Wrobel, Dr. Thomas Gärtner | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | Participants specialize and require in-depth knowledge of one particular class of learning algorithms, they acquire the necessary knowledge to improve existing algorithms and construct their own within the given class, all the way up to the research frontier on the topic. | | |
| **Soft skills** | In group work, students acquire the necessary social and communication skills for effective team work and project planning, and learn how to present software projects to others. | | |
| **Contents** | The module is offered every year, each time concentrating on one or more specific algorithm classes, e.g.<br>• kernel machines<br>• neural networks<br>• probabilistic and statistical learning approaches<br>• logic-based learning approaches<br>• reinforcement learning | | |
| **Prerequisites** | **Recommended:** all of the following:<br>MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning<br>MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery | | |

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

| | | |
|---|---|---|
| **Exam achievements** | Written exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | lectures, exercises, software systems | |
| **Literature** | • B. Schoelkopf, A.J. Smola, Learning with Kernels, The MIT Press, 2002, Cambridge, MA<br>• John Shawe-Taylor, Nello Christianini, Kernel Methods for Pattern Analysis, CUP, 2004<br>• Christopher Bishop, Pattern Recognition and Machine Learning, The University of Edinburgh, 2006<br>• David MacKay, Information Theory, Inference, and Learning Algorithms, 2003<br>• Richard Duda, Peter Hart, David Stork, Pattern Classification, John Wiley and Sons, 2001 | |

| **Module**<br>MA-INF 4303 | **Learning from Non-Standard Data** | | |
|---|---|---|---|
| **Workload**<br>180 h | **Credit points**<br>6 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Stefan Wrobel | | |
| **Lecturer(s)** | Prof. Dr. Stefan Wrobel, Dr. Tamas Horvath | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | Participants deepen their knowledge of learning systems with respect to one particular non-standard data type, i.e., non-tabular data, as they are becoming increasingly important in many applications. Each type of data not only requires specialized algorithms but also knowledge of the surrounding pre- and postprocessing operations which is acquired by the participants in the module. In group work, students acquire the necessary social and communication skills for effective team work and project planning, and learn how to present software projects to others. | | |
| **Soft skills** | Communicative skills (oral and written presentation of solutions, discussions in teams), self-competences (ability to accept and formulate criticism, ability to analyse, creativity in the context of an "open end" task) | | |
| **Contents** | The module will offered every year, concentrating on one particular non-standard data type each time, including: Text Mining, Multimedia Mining, Graph Mining. Learning from structured data, Spatial Data Mining | | |
| **Prerequisites** | **Recommended:** all of the following:<br>MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning<br>MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery | | |

**Format**

| Teaching format | Group size | h/week | Workload[h] | CP |
|---|---|---|---|---|
| Lecture | 60 | 2 | 30 T / 45 S | 2.5 |
| Exercises | 30 | 2 | 30 T / 75 S | 3.5 |

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

| | | |
|---|---|---|
| **Exam achievements** | Written exam | (graded) |
| **Study achievements** | Successful exercise participation | (not graded) |
| **Forms of media** | lectures, exercises, software systems. | |

**Literature**


- Gennady Andrienko, Natalia Andrienko, Exploratory Analysis of Spatial and Temporal Data, Springer, 2006
- Diane J. Cook, Lawrence B. Holder, Mining Graph Data, Wiley & Sons, 2006
- Saso Dzeroski, Nada Lavrac, Relational Data Mining, Springer, 2001
- Sholom M. Weiss, Nitin Indurkhya, Tong Zhang, Fred J. Damerau, Text Mining. Predictive Methods for Analyzing Unstructured Information, Springer, 2004

| **Module**<br>MA-INF 4304 | **Lab Cognitive Robotics** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every semester |
| **Module coordinator** | Prof. Dr. Sven Behnke | | |
| **Lecturer(s)** | Prof. Dr. Sven Behnke | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | Participants acquire practical experience and in-depth knowledge in the design and implementation of perception and control algorithms for complex robotic systems.<br>In a small group, they analyze a problem, realize a state-of-the-art solution, and evaluate its performance. | | |
| **Soft skills** | Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions),<br>communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of implementations) | | |
| **Contents** | Robot middleware (ROS), simultaneous localization and mapping (SLAM), 3D representations of objects and environments, object detection and recognition, person detection and tracking, action recognition, action planning and control, mobile manipulation, human-robot interaction. | | |
| **Prerequisites** | **Recommended:** At least 1 of the following:<br>MA-INF 4113 – Cognitive Robotics<br>MA-INF 4114 – Robot Learning | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Lab / 8 / 4 / 60 T / 210 S / 9<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Oral presentation, written report (graded) | | |
| **Study achievements** | none (not graded) | | |
| **Forms of media** | | | |
| **Literature** | • S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.<br>• B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008.<br>• Selected research papers. | | |

| **Module**<br>MA-INF 4305 | **Lab Autonomous Robots** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year |
| **Module coordinator** | Prof. Dr. Armin B. Cremers | | |
| **Lecturer(s)** | Prof. Dr. Armin B. Cremers | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **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:<br>• Ability to derive a solution oriented problem formulation of a given task.<br>• Ability to cooparate in small groups on solving a given task.<br>• Ability to put a conceptual solution and its implemention down on paper.<br>• Ability to present and discuss a conceptual solution and its implemention in an oral presentation. | | |
| **Contents** | 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. | | |
| **Prerequisites** | **Recommended:** all of the following:<br>MA-INF 4101 – Theory of Sensorimotor Systems<br>MA-INF 4203 – Autonomous Mobile Systems | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation, written report | (graded) |
| **Study achievements** | none | (not graded) |
| **Forms of media** | | |
| **Literature** | • Sebastian Thrun, Wolfram Burgard, Dieter Fox: Probabilistic Robotics, MIT Press, 2005<br>• Howie Choset et al.: Principles of Robot Motion, MIT-Press, 2005<br>• additional papers | |

| **Module**<br>MA-INF 4306 | **Lab Development and Application of Data Mining and Learning Systems** | | | | |
|---|---|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every year | | |
| **Module coordinator** | Prof. Dr. Stefan Wrobel | | | | |
| **Lecturer(s)** | Prof. Dr. Stefan Wrobel | | | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. | | |
| **Technical skills** | Students will acquire in-depth knowledge in the construction and development of intelligent learning systems for machine learning and data mining. They learn how to work with existing state-of-the-art systems and apply them to application problems, usually extending them for the requirements of their particular task. | | | | |
| **Soft skills** | Communicative skills (appropriate oral presentation and written documentation of project results), social skills (ability to work in teams), self-competences (time management, aiming at long-range goals under limited ressources, ability to work under pressure, ability to accept/formulate ciriticsm) | | | | |
| **Contents** | Data storage and process models of data analysis. Common open source frameworks for the construction of data analysis systems, specialized statistical packages. Pre-processing tools. Mathematical libraries for numerical computation. Search and optimization methods. User interfaces and visualization for analysis systems. Data analysis algorithms for embedded and distributed systems. Ubiquitous discovery systems. | | | | |
| **Prerequisites** | **Recommended:** At least 1 of the following:<br>MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning<br>MA-INF 4112 – Intelligent Learning and Analysis Systems: Data Mining and Knowledge Discovery | | | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lab | 8 | 4 | 60 T / 210 S | 9 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | Computer Software, Documentation, Research Papers. | | | | |
| **Literature** | The relevant literature will be announced towards the end of the previous semester. | | | | |

| **Module**<br>MA-INF 4307 | **Lab Field Programmable Gate Arrays** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>at least every 2 years |
| **Module coordinator** | Prof. Dr. Joachim K. Anlauf | | |
| **Lecturer(s)** | Prof. Dr. Joachim K. Anlauf | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | Development and simulation of digital circuits in VHDL and SystemC, experience with synthesizable subsets, knowledge of the design path from the idea to a realized circuit implemented in an FPGA (field programmable gate array) | | |
| **Soft skills** | Communicative skills (oral and written presentation of results), social skills (ability to cooperate in small teams, discussions of solution concepts) self competences (ability to accept and formulate criticism, ability to analyze and find practical solutions to problems) | | |
| **Contents** | VHDL for Hardware Description, Simulation, and Synthesis, SystemC for Hardware Description, Simulation, and Synthesis, Synthesizable Subsets, Test of Implementations on FPGA Evaluation Boards | | |
| **Prerequisites** | **Recommended:**<br>MA-INF 4207 – Dynamically Reconfigurable Systems | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Lab / 8 / 4 / 60 T / 210 S / 9<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Oral presentation, written report (graded) | | |
| **Study achievements** | none (not graded) | | |
| **Forms of media** | | | |
| **Literature** | Technical documentation | | |

| **Module**<br>MA-INF 4308 | **Lab Vision Systems** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>every semester |
| **Module coordinator** | Prof. Dr. Sven Behnke | | |
| **Lecturer(s)** | Dr. Nils Goerke | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>3. |
| **Technical skills** | Students will acquire knowledge of the design and implementation of parallel algorithms on GPUs. They will apply these techniques to accelerate standard machine learning algorithms for data-intensive computer vision tasks. | | |
| **Soft skills** | Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions), communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of implementations) | | |
| **Contents** | Basic matrix and vector computations with GPUs (CUDA). Classification algorithms, such as multi-layer perceptrons, support-vector machines, k-nearest neighbors, linear-discriminant analysis. Image preprocessing and data handling. Quantitative performance evaluation of learning algorithms for segmentation and categorization. | | |
| **Prerequisites** | **Recommended:** At least 1 of the following:<br>MA-INF 4111 – Intelligent Learning and Analysis Systems: Machine Learning<br>MA-INF 4204 – Technical Neural Nets | | |
| **Format** | **Teaching format** / **Group size** / **h/week** / **Workload[h]** / **CP**<br>Lab / 8 / 4 / 60 T / 210 S / 9<br>T = face-to-face teaching; S = independent study | | |
| **Exam achievements** | Oral presentation, written report (graded) | | |
| **Study achievements** | none (not graded) | | |
| **Forms of media** | | | |
| **Literature** | • R. Szeliski: Computer Vision: Algorithms and Applications, Springer 2010.<br>• C. M. Bishop: Pattern Recognition and Machine Learning, Springer 2006.<br>• NVidia CUDA Programming Guide, Version 4.0, 2011. | | |

| **Module**<br>MA-INF 4309 | **Lab Knowledge-Based Image Understanding** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>at least every 2 years |
| **Module coordinator** | PD. Dr. Volker Steinhage | | |
| **Lecturer(s)** | PD. Dr. Volker Steinhage | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | Competence to implement algorithms for kwoledge-based image understanding, efficient handling and testing, documentation. | | |
| **Soft skills** | Efficient implementation of complex algorithms, abstract thinking, documentation of source code. | | |
| **Contents** | Varying selected up-to-date topics on image understanding | | |
| **Prerequisites** | **Required:** all of the following:<br>MA-INF 2112 – Foundations of Vision and Audio<br>MA-INF 4206 – Knowledge-based Image Understanding | | |

**Format**

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

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

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation, written report | (graded) |
| **Study achievements** | none | (not graded) |
| **Forms of media** | | |
| **Literature** | Relevant literature will be anounced at start of the lab. | |

| **Module**<br>MA-INF 4310 | **Lab Mobile Robots** | | |
|---|---|---|---|
| **Workload**<br>270 h | **Credit points**<br>9 CP | **Duration**<br>1 semester | **Frequency**<br>at least every year |
| **Module coordinator** | Prof. Dr. Sven Behnke | | |
| **Lecturer(s)** | Prof. Dr. Sven Behnke, Dr. Nils Goerke | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Optional | **Semester**<br>2. or 3. |
| **Technical skills** | Participants acquire basic knowledge and practical experience in the design and implementation of control algorithms for simple structured robotic systems using real mobile robots. Fundamental paradigms for mobile robots will be identified and implemented in 2 person groups. | | |
| **Soft skills** | Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions),<br>communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of implementations) | | |
| **Contents** | Robot middleware (e.g. ROS), robot simulation tools, basic capabilities for mobile robots: reactive control, SMPA architecture, navigation, path planning, localisation, simultaneous localization and mapping (SLAM), visual based object detection, learning robot control. | | |
| **Prerequisites** | **Recommended:** At least 1 of the following:<br>BA-INF 132 – Grundlagen der Robotik<br>BA-INF 131 – Intelligente Sehsysteme<br>MA-INF 1314 – Online Motion Planning<br>MA-INF 2201 – Computer Vision<br>MA-INF 4113 – Cognitive Robotics<br>MA-INF 4114 – Robot Learning<br>MA-INF 4203 – Autonomous Mobile Systems | | |
| **Format** | **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
| | Lab | 8 | 4 | 60 T / 210 S | 9 |
| | T = face-to-face teaching; S = independent study | | | | |
| **Exam achievements** | Oral presentation, written report (graded) | | | | |
| **Study achievements** | none (not graded) | | | | |
| **Forms of media** | Robots simulation environments, robot control middleware, computer vision libraries, programming, demonstration of robot capabilities (real robotic systems), presentation and written report of approach and results. | | | | |
| **Literature** | • S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.<br>• J. Buchli: Mobile Robots: Moving Intelligence, Published by Advanced Robotic Systems and Pro Literatur Verlag<br>• B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008.<br>• Additional State-of-the-art publications. | | | | |

# 5 Master Thesis

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

| **Module**<br>MA-INF 0402 | **Master Seminar** | | |
|---|---|---|---|
| **Workload**<br>60 h | **Credit points**<br>2 CP | **Duration**<br>1 semester | **Frequency**<br>every semester |
| **Module coordinator** | | | |
| **Lecturer(s)** | All lecturers of computer science | | |
| **Classification** | **Programme**<br>M. Sc. Computer Science | **Mode**<br>Compulsory | **Semester**<br>4. |
| **Technical skills** | Ability to document and defend the results of the thesis work in a scientifically appropriate style, taking into consideration the state-of-the-art in research in the resp. area | | |
| **Soft skills** | | | |
| **Contents** | Topic, scientific context, and results of the master thesis | | |
| **Prerequisites** | none | | |

**Format**

| **Teaching format** | **Group size** | **h/week** | **Workload[h]** | **CP** |
|---|---|---|---|---|
| Seminar | | 2 | 30 T / 30 S | 2 |

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

| | | |
|---|---|---|
| **Exam achievements** | Oral presentation of final results | (graded) |
| **Study achievements** | none | (not graded) |
| **Forms of media** | | |
| **Literature** | Individual bibliographic research required for identifying relevant literature (depending on the topic of the thesis) | |