JACOBS UNIVERSITY

School of Engineering and Science

Smart Systems

Graduate Program

Contents

Disclaimer

The Engineering and Science programs are offered in substantially the form presented here, nonetheless Jacobs University Bremen reserves the right to make changes and/or substitutions as appropriate in scheduling and course titles.

This document conforms to the *Procedures for Administering Graduate Programs* approved on December 5 2005 by the Academic Council and the Faculty Council.

1 Introduction to Smart Systems

The "Smart Systems" graduate program provides graduate level education in Computer Science and is offered by the School of Engineering and Science at the Jacobs University Bremen. This section describes the overall philosophy, the degrees offered, the career options and the target audience.

1.1 Philosophy

As humans we can sense, act, speak, listen, decide and sometimes understand. The 21st century will witness technologies that can do the same. We will see cars that negotiate with each other in order to optimize traffic flow. Our T-shirts may have their own Internet addresses and tell the manufacturer if they are only rarely worn. In addition to their well-established role as programmable machine-tools, robots are also more and more used in domains where some autonomy and intelligence is necessary. They work under conditions where the robot is not constantly supervised by a human operator and where it has to be adaptive as its developer can not fully predict which situations it will encounter in its application environment. We all know future descriptions of this kind, we also know that they are no longer science fiction, although real future may still look quite differently. But whatever course the future takes, it will be scientists and engineers who help in shaping it. They will develop systems (yet unthinkable) that could likewise be described as robots, user interfaces, web agents, enhanced reality or personal assistants. The hallmark of such smart systems is their integration of technologies from communication networks, Internet services, artificial intelligence, machine learning, robotics, and many more. Smart systems may even imitate social systems for achieving some benefit. These systems will be exceedingly complex. Scientists and engineers who take an active role in creating such systems will have to master a highly diverse repertoire of professional techniques as a matter of course. In addition, they will need to cope with complexity itself: making heterogeneous system components communicate with each other, integrating diverse knowledge representations, blending hardware with software with sensors with users, and overall understanding the dynamical properties of complex dynamical systems.

Jacobs University takes part in this rapidly growing, boldly interdisciplinary endeavor. Coordinated by the Computer Science group, a highly future-oriented graduate program in Smart Systems is offered. It integrates a rigorous training in several important disciplines of computer science, especially networks, artificial intelligence, robotics and the mathematics of complex systems. A student acquires in this graduate program the knowledge to work at the forefront of technological developments.

1.2 Degrees

The Smart Systems graduate program in Computer Science offers the following two degrees in two separate tracks:

1.2.1 Master of Science (M.Sc.) in Computer Science

The M.Sc. program at Jacobs University Bremen takes two years or four semesters. The first three semesters (1.5 years of study) of the Master's degree include regular course work, i.e., lectures and seminars, and the opportunity to engage in scientific work. Provided a sufficiently high level of achievement in first three semesters, the student is permitted to complete a Master's thesis during semester four.

Upon graduation, Jacobs University Bremen awards the "*Master of Science in Computer Science*".

Students on the M.Sc. track who excel in their first three semesters may, subject to the discretion of the Dean, enter the Ph.D. track.

1.2.2 Doctor of Philosophy (Ph.D.) in Computer Science

Students with an excellent record of achievement in their Bachelor's or Master's studies may apply to pursue a Ph.D. degree at Jacobs University.

Students joining the program's Ph.D. track with a B.Sc degree are required to complete successfully three semesters of taught courses before progressing to the Ph.D. dissertation.

Students who have already achieved a Master's degree and have demonstrated an aptitude to research may, subject to the discretion of the Dean, progress immediately after matriculation to the completion of a Ph.D. dissertation. In total, the completion of a Ph.D. degree will typically take three years in this case.

Upon graduation, Jacobs University Bremen awards the "*Doctor of Philosophy in Computer Science*". Upon request to the city state of Bremen, this Ph.D. can be transformed into a German doctorate degree.

1.3 Prospects and Career Options for Graduates

The prime goal of this program is to prepare students for a scientific career (Ph.D. or postdoctoral research) or leading positions in industry, where the skills of *data analysis*, *modeling and simulation*, and the *development of complex algorithms and systems* form the basis for professional excellence. In addition to the training of these fundamental skills, the program provides training that covers the knowledge from the industrial fields of *Robotics*, *Automation*, *Network and Distributed Systems*, *Man Machine Interaction*, *Artificial Intelligence*, *Control Engineering*, *Data Mining*, *Databases and Web Information Technology*, *Machine Vision*, and *Computer Graphics and Visualization*.

1.4 Target Audience

The target audience of the CS Graduate Program "Smart Systems" are

- students who have completed their B.Sc. in CS or related disciplines and who want to deepen their knowledge and proceed to research oriented work towards a Master or Ph.D. degree,
- graduate students who have completed their Master's degree and would like to continue their graduate education.

The two-year Master program's goal is to *qualify* students to carry out independent research, while in the three-year Ph.D. program highly qualified students *do* research. Consequently, the Master program offers a highly structured educational program, whereas the Ph.D. program can be seen as a stage on which the student defines, and executes, his/her own research in a professional collaboration with a chosen supervisor.

2 The M.Sc. Program

The M.Sc. program is a two year program aiming at qualifying students for independent research.

2.1 Program Structure

The structure of the Master program is highly research oriented. In addition to the regular course work within the Master track, the students have to engage in seminars and projects. As part of the seminars, the students fulfill reading assignments and present recent work of the field. The projects serve as platform to learn about research-oriented methodologies. The students are furthermore guided via the projects towards conference participation and publications for which credits can be earned.

Sem.	Description	Credits	Sem. Total	Running Total
1	3 Graduate Lectures	$3 \cdot 5 = 15$	15	15
1	3 Graduate Labs	$3 \cdot 5 = 15$	30	30
2	2 Graduate Seminars	$2 \cdot 5 = 10$	10	40
2	2 Graduate Projects	$2 \cdot 10 = 20$	30	60
3	1 Graduate Lecture	$1 \cdot 5 = 5$	5	65
3	1 Graduate Lab	$1 \cdot 5 = 5$	10	70
3	Master Thesis Proposal	20	30	90
4	Master Thesis	30	30	120

Figure 1: The structure of the M.Sc. program

Figure 1 gives an overview over the structure; all credits involved are ECTS credits. For a detailed account of course contents, see Section 4. Generally, Fall semesters (usually semesters 1 and 3) have advanced lectures and labs in all research areas of the graduate program. They introduce the topics and cover pertinent results and methods of the respective field. These lectures and labs come in pairs which alternate over a 4-semester interval, so that all Master students can participate in both versions during their 2-year studies without creating redundancy. Typically, lecture and lab of one field are co-requisites of each other.

The Spring semesters (usually semesters 2 and 4) are dedicated to research seminars and projects. These seminars drill down on particular topics of interest in the research areas and introduce the students to the state of the art. In the projects, each student will work out and present an assigned topic from research papers or from original research on the topic.

In their first semester, Masters students will need to acquire 30 credits from three core Smart Systems lectures and labs. In some cases, Jacobs University undergraduate courses or courses from other Jacobs University graduate programs can be admitted by the Smart Systems faculty into this category.

In the second semester, Master students will take part in two of the research seminars and projects. This yields the required 30 credits.

In the third semester, the student takes one additional lecture and lab from the Smart Systems core curriculum to supplement the knowledge gained in the first two semesters. The student must reach 10 credits from these courses. In parallel, he/she works on a 20-page (target length) thesis proposal guided by an academic supervisor chosen at the beginning of the semester. The purpose of this document is to introduce the student to academic writing and focus the research interest and efforts towards the eventual thesis topic. A research proposal with a passing grade gives 20 credits.

In the fourth and last semester, the student researches and writes the Master's thesis guided and supported by the chosen academic supervisor. The resulting document (target size 60 pages) presents the research of the student. The thesis will be jointly judged by a thesis committee which consists of the thesis supervisor and at least one other member. The other member(s) can be Jacobs University faculty members or external members. The thesis will be graded using the Jacobs University grading system ranging from 1 (excellent) to 5 (fail). A thesis with a passing grade gives 30 credits.

Number	Credits	Type	Title
320501	20	Thesis	Master/Doctorate Thesis Proposal

Figure 2: The Structural Components of the Smart Systems Program

2.2 Graduation Requirements and Regulations

The following list summarizes the formerly announced guidelines. All specified credits are minimum requirements.

- 120 ECTS credits are needed to graduate. These credits have to be earned as follows:
  - 20 credits from Smart Systems lectures. Undergraduate courses or courses from other graduate programs can be taken upon approval of the program coordinator.
  - 20 credits from Smart Systems labs. Undergraduate courses or courses from other graduate programs can be taken upon approval of the program coordinator.
  - 10 credits from Smart Systems seminars.
  - 20 credits from Smart Systems projects.
  - 20 credits from the master thesis proposal.
  - 30 credits from the master thesis.
- Master's thesis credits are awarded only if the grade is better than 4.0. In case the thesis does not fulfill this requirement, the examination committee may grant the right to resubmit it within three months.
- Failed examinations may be retaken once, at most one semester later.
- At least 20 ECTS credits must be earned in every semester, with an average grade of at least 3.0 or better, otherwise the student will be placed on academic probation by the

registrar. Any graduate student whose GPA in any given semester is worse than 4.33 will be automatically suspended.

- Students intending to take undergraduate courses or courses outside the Smart Systems curriculum need the approval of the program coordinator. Credits will be counted according to the program from which the courses are taken.
- Language courses and university study courses are generally not admissible here, and credits possibly acquired while taking them will not be counted towards the amount of 120 credits needed to obtain the M.Sc. degree.

2.3 Graduate Course Overview

In the following we will introduce the contents of the lectures, labs, seminars, and projects in the Master's track of the CS graduate program Smart Systems.

Research is considered to be an essential part of the education at Jacobs University. Therefore master students will already be involved in research projects during their first semesters (in conjunction with and supported by the Spring semester seminars and projects). The purpose of the courses offered in Fall is to introduce topics and to cover pertinent results and methods of the research areas.

Figure 3 lists the lecture and lab modules that are offered on a regular basis in the program.

These courses come in pairs, which are organized by the core faculty indicated. The courses and course modules will be held in Fall semesters and will alternate over a 4-semester time frame, so that all Master students can participate in all courses and course modules during their 2-year studies without creating redundancy.

The courses above will be complemented by a set of seminars and projects, which varies over time (see Figure 4). In addition, there are graduate courses in mathematics, physics, and possibly other disciplines of relevance for CS master students, depending on their chosen specialization area.

Number	Credits	Type	Title	Responsible
320411	5	Lecture	Information Architectures	P. Baumann
320622	5	Lab	Information Architectures Lab	P. Baumann
320421	5	Lecture	Advanced Robotics	A. Birk
320601	5	Lab	Advanced Robotics Lab	A. Birk
320541	5	Lecture	Computational Semantics of Natural Language	M. Kohlhase
320591	5	Lab	Computational Semantics of Natural Language Lab	M. Kohlhase
320451	5	Lecture	Advanced Machine Learning	H. Jaeger
320641	5	Lab	Advanced Machine Learning Lab	H. Jaeger
320471	5	Lecture	Advanced Networking	J. Schönwälder
320401	5	Lab	Advanced Networking Lab	J. Schönwälder
320491	5	Lecture	Advanced Graphics	L. Linsen
320632	5	Lab	Advanced Graphics Lab	L. Linsen
320651	5	Lecture	Advanced Automation and Control	A. Nüchter
320661	5	Lab	Advanced Automation and Control Lab	A. Nüchter
320511	5	Lecture	Semantic Web Engineering	P. Baumann
320631	5	Lab	Semantic Web Engineering Lab	P. Baumann
320521	5	Lecture	Autonomous Systems	A. Birk
320611	5	Lab	Autonomous Systems Lab	A. Birk
320441	5	Lecture	Computational Logic	M. Kohlhase
320612	5	Lab	Computational Logic Lab	M. Kohlhase
320551	5	Lecture	Algorithmical and Statistical Modelling	H. Jaeger
320572	5	Lab	Algorithmical and Statistical Modelling Lab	H. Jaeger
320571	5	Lecture	Advanced Distributed Systems	J. Schönwälder
320602	5	Lab	Advanced Distributed Systems Lab	J. Schönwälder
320581	5	Lecture	Advanced Visualization	L. Linsen
320621	5	Lab	Advanced Visualization Lab	L. Linsen
320671	5	Lecture	Machine Vision	A. Nüchter
320681	5	Lab	Machine Vision Lab	A. Nüchter

Figure 3: The lectures and labs offered regularly in the M.Sc. program

3 The Ph.D. Program

The three-year Ph.D. track is devoted to focused research within the research group of an academic supervisor. Students who enter the Ph.D. program from the Smart Systems Master's track typically choose their supervisor after the third Master semester, whereas students who enter the program by a direct application typically choose the supervisor during the application/acceptance process.

Figure 5 shows an overview of a typical Ph.D. project. In the first semester, the student works out a thesis proposal in collaboration with the academic supervisor. This proposal (target size 15–20 pages) must

- demonstrate that the student masters the professional terminology in the research domain and has the requisite background knowledge,
- identify and motivate a relevant and feasible research question,

Number	Credits	Type	Title	Responsible
320422	5	Seminar	Networks and Distributed Systems A	J. Schönwälder
320424	10	Project	Networks and Distributed Systems Project A	J. Schönwälder
320432	5	Seminar	Semantic Web and Knowledge Representation A	M. Kohlhase
320434	10	Project	Semantic Web and Knowledge Representation Project A	M. Kohlhase
320442	5	Seminar	Machine Learning A	H. Jaeger
320444	10	Project	Machine Learning Project A	H. Jaeger
320452	5	Seminar	Web Information Systems A	P. Baumann
320454	10	Project	Web Information Systems Project A	P. Baumann
320482	5	Seminar	Topics in Robotics A	A. Birk
320484	10	Project	Topics in Robotics Project A	A. Birk
320492	5	Seminar	Topics in Graphics	L. Linsen
320494	10	Project	Topics in Graphics Project	L. Linsen
320592	5	Seminar	Topics in Automation	A. Nüchter
320594	10	Project	Topics in Automation Project	A. Nüchter
320522	5	Seminar	Networks and Distributed Systems B	J. Schönwälder
320524	10	Project	Networks and Distributed Systems Project B	J. Schönwälder
320532	5	Seminar	Semantic Web and Knowledge Representation B	M. Kohlhase
320534	10	Project	Semantic Web and Knowledge Representation Project B	M. Kohlhase
320542	5	Seminar	Machine Learning B	H. Jaeger
320544	10	Project	Machine Learning Project B	H. Jaeger
320552	5	Seminar	Web Information Systems B	P. Baumann
320554	10	Project	Web Information Systems Project B	P. Baumann
320582	5	Seminar	Topics in Robotics B	A. Birk
320584	10	Project	Topics in Robotics Project B	A. Birk
320562	5	Seminar	Topics in Visualization	L. Linsen
320564	10	Project	Topics in Visualization Project	L. Linsen
320672	5	Seminar	Topics in Machine Vision	A. Nüchter
320674	10	Project	Topics in Machine Vision Project	A. Nüchter

Figure 4: The seminars and projects offered regularly in the M.Sc. program

- connect the question to the state of the art by a focused and illustrative literature overview,
- lay out a design for planned experiments, theoretical investigations or implementations, including a schedule,
- and describe criteria for evaluating the eventual success of the project.

At the end of the first semester, a doctoral thesis committee is constituted and the proposal is defended in a public presentation.

After (and if) the thesis proposal is successfully defended, in the remaining time the proposed research is carried out. It is only natural that the originally stated objectives are refined or even re-defined in this process. Progress is monitored by presentations within the graduate program, and of course on a day-by-day basis in close interaction with the supervisor.

At the end of semester 4, the thesis committee gives a written progress assessment report based

Sem.	Title	Activity
1	Ph.D. project definition	development of a thesis proposal; public defense of thesis proposal at end of semester
2	Ph.D. project research	e.g., experiment design, detailed implementation specification
3	Ph.D. project research	e.g., running experiments, implementation phase
4	Ph.D. project research	evaluation and refinement phase; written progress assessment by the thesis committee at end of semester
5	Ph.D. project research	thesis preparation, publications
6	Ph.D. thesis and defense	write-up of the Ph.D. thesis; public defense

Figure 5: The structure of the Ph.D. program

on the presentations, any publications by the students, and available research results. This report will also contain suggestions about prioritizing the remaining research, and expected results.

The last semester is devoted to writing up the thesis document (target size 80–150 pages). At the end of the program, the findings are presented to the graduate program and the university in a public Ph.D. thesis defense. The thesis committee judges the presentation in the thesis defense together with the content and form of the thesis to determine whether to accept or reject the thesis. The Ph.D. thesis is not graded with respect to the Jacobs University grading system but may be awarded with an honour's predicate.

Ph.D. students are encouraged but not required to enlist in courses offered in the Smart Systems or related programs that can deepen and expand the perspective of the own chosen area of research.

Teaching experience is part of graduate education. All graduate students are encouraged to work in undergraduate courses as teaching assistants (TAs). This involves among other activities giving tutorials, grading exercise sheets, and supervising lab or undergraduate project work. According to their experience, Ph.D. students may also work out exercise sheets or define undergraduate projects and offer seminars. TA work is paid according to the general Jacobs University policies.

4 Course Descriptions

The following sections contain more detailed descriptions of the graduate courses and graduate seminars offered in the Smart Systems program.

The course descriptions below specify prerequisites both internal to the program as well as in terms of Jacobs University undergraduate courses. The meaning of the latter is that master's students that have obtained their bachelor's degree at other universities should have passed courses whose content is equivalent to the respective Jacobs University courses. Their content of the Jacobs University courses listed as prerequisite is specified in the undergraduate handbooks, which can be obtained from Jacobs' web site at `http://www.jacobs-university.de/`.

Students need to talk to the instructor of record and obtain a prerequisite waiver to be able to register for the course in case they miss any prerequisites.

4.1 Graduate Courses

320411 – Information Architectures

Short Name: InfArch
Type: Lecture
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: 320302
Corequisites: None

Course contents The title of this course can, and should, be understood in a twofold way. On the conceptual level, mastering the rapidly growing volume and complexity of information in industry, science, and society requires improved modelling and design methodologies. On the implementation level, existing storage, retrieval, and delivery techniques have to be revisited and new ones have to be designed in order to meet the challenges formulated conceptually. While these issues largely fall into the fields of databases, information retrieval, and Internet technology, the questions arising clearly transcend these fields and call for interdisciplinary research on more efficient and effective methods.

The course, therefore, starts with an overview of existing knowledge in the core fields and then covers selected themes in more depth. Among the candidate themes are non-standard applications such as spatio-temporal databases and sensor networks, distributed databases, XML databases, multimedia databases, streams, raster databases, storage structures, and query optimization.

Goal is to make students familiar with the state of the art in Web-enabled information systems so that they will be successful database/Internet professionals in IT industry and also have a sound knowledge base to specialize towards a scientific career in the field.

Students will be required to complete a (guided) research project concluding with a report and an oral presentation.

320622 – Information Architectures Lab

Short Name: InfArchLab
Type: Lab
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: 320411

Course contents This lab course is to be taken together with the Information Architectures course. It provides hands-on experiences with state-of-the-art array database technology including work on scientific applications embedded in international collaborations.

320421 – Advanced Robotics

Short Name: AdvRob
Type: Lecture
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: None

Course contents Robotics is a broad field ranging from low-level mechatronics and signal processing over autonomous capabilities to high-level cooperation protocols of intelligent agents. The advanced robotics course reflects this wide range and covers the engineering as well as the scientific side of robotics. The course links core scientific topics with a hands-on training with the equipment of the robotics group in the related lab course.

320601 – Advanced Robotics Lab

Short Name: AdvRobLab
Type: Lab
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: 320421

Course contents This lab course is to be taken together with the Advanced Robotics course. It provides hands-on experiences with the robotics equipment of the Jacobs Robotics group including advanced mobile robots equipped with state of the art sensors.

320441 – Computational Logic

Short Name: CompLog
Type: Lecture
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: 320211, 320331
Corequisites: None

Course contents In this course we will cover the basics of computational logic. We will introduce the syntax and semantics of first-order logic, and discuss calculi, soundness, completeness on this system. We will cover machine-oriented inference calculi like analytic tableaux, and resolution and apply them to theorem proving and logic programming applications.

We will discuss the non-deductive reasoning modes of abduction and induction and briefly introduce computational methods for mechanizing them. Finally, we will give an introduction to knowledge representation and description logics, leading to an introduction of "semantic web" techniques.

320612 – Computational Logic Lab

Short Name: CompLogLab
Type: Lab
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: 320441

Course contents This lab course is to be taken together with the Computational Logic course and provides hands-on programming exercises where selected topics of the course will be implemented in the programming language PROLOG.

320451 – Advanced Machine Learning

Short Name: AdvML
Type: Lecture
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: 120102 or 120112
Corequisites: None

Course contents The course offers an introduction into a variety of modern machine learning techniques. Because the field is fed from many disciplines (statistics, artificial intelligence, electrical engineering, mathematical modelling and logics, information theory) and is very diverse and quickly evolving, a comprehensive overview cannot be attempted. Instead, the student is first given an intuitive introduction to the basic concepts and challenges of machine learning (that is, to the "curse of dimensionality" and the "dilemma of bias vs. variance"). Then, in the main part of the course, two to four areas of modern machine learning from the following list are treated in some depth, where the choice is made by the students: (i) linear classifiers and feedforward neural networks, (ii) statistical learning theory and support vector machines, (iii) Hidden Markov models and Observable Operator Models, (iv) recurrent neural networks, (v) clustering algorithms and self-organizing feature maps, (vii) adaptive filters, – and possibly others. A self-contained set of lecture notes will be available.

320641 – Advanced Machine Learning Lab

Short Name: AdvMLLab
Type: Lab
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: 320451

Course contents This lab course is to be taken together with the Advanced Machine Learning course and provides hands-on exercises of selected topics of the course.

320471 – Advanced Networking

Short Name: AdvNet
Type: Lecture
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: 320301
Corequisites: None

Course contents This course covers advanced networking concepts such as multimedia communication and content distribution. The course will cover voice over IP, related signaling and transport protocols, quality of service approaches (integrated and differentiated services), and multicast group communications. Some attention will be given to reliability and security aspects. Finally, the course will cover to some extend link-layer technologies such as MPLS and pure optical networks.

This course assumes that students are familiar with the content of undergraduate data networking courses.

320401 – Advanced Networking Lab

Short Name: AdvNetLab
Type: Lab
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: 320471

Course contents This lab course is to be taken together with the Advanced Networking course and provides hands-on programming exercises where selected algorithms and mechanisms introduced in the Advanced Networking course will be implemented.

320491 – Advanced Graphics

Short Name: AdvGrafx
Type: Course
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: None

Course contents Computer graphics deals with the digital synthesis and manipulation of visual content, typically embedded in a three-dimensional scene. Prominent tasks in computer graphics are geometry processing, rendering, and animation. Geometry processing is concerned with object representations such as surfaces and their modeling, rendering is concerned with simulating light transport to get physically-based photorealistic images of 3D scenes or applying a certain style to create non-photorealistic images, and animation is concerned with descriptions for objects that move or deform over time. Methods that tackle these three tasks are being taught.

The course deepens, broadens, and enhances the knowledge in 3D computer graphics obtained from the undergraduate course on ”Graphics and Visualization” in terms of graphics methods.

320632 – Advanced Graphics Lab

Short Name: AdvGrafxLab
Type: Lab
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: 320491

Course contents This lab course is to be taken together with the Advanced Graphics course and provides hands-on exercises of selected topics of the course.

320511 – Semantic Web Engineering

Short Name: SemWebEng
Type: Lecture
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: working knowledge of Java and XML
Corequisites: None

Course contents "The Semantic Web is an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation" (Tim Berners-Lee et al). Following the explosive initial growth of the Web, we are faced now with a vast universe of more or less organized information resources.

Databases play a crucial role in this universe. Beyond the billion of static Web pages indexed by search engines, there is a "Deep Web" of database contents that is not indexed due to its dynamically generated responses. It is estimated that the Deep Web exceeds the commonly defined World-Wide Web by a factor of 500 in data volume (source: www.completeplanet.com).

The course is subdivided into four parts. In the first two parts, Web Services and the Semantic Web are introduced by inspecting the pertaining standards. The third part is dedicated to selected database concepts and techniques which contribute to the quest of efficiently adding more semantics to the Web. In the case studies finally investigated we put emphasis on data intensive scientific applications, in particular for the earth sciences.

Goal is to make students familiar with the state of the art in Web-enabled information systems so that they have a sound knowledge base to specialize towards a scientific career in the field or to become successful database/Internet professionals in IT industry.

320631 – Semantic Web Engineering Lab

Short Name: SemWebEngLab
Type: Lab
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: 320511

Course contents This lab course is to be taken together with the Semantic Web Engineering course and provides hands-on exercises of selected topics of the course.

320521 – Autonomous Systems

Short Name: AutSys
Type: Lecture
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: None

Course contents There is an increasing interest and need to generate artificial systems that can carry out complex missions in unstructured environments without permanent human supervision. Intelligent mobile robots are often used as prototype or even defining example of according autonomous systems. But in a more general notion, an autonomous system can be seen as a combination of a computational core, sensors and motors, a finite store for energy, and a suited control allowing, roughly speaking, for flexible stand-alone operation that can deal with situations the designers may not have foreseen when constructing and programming the system. The investigation of autonomous systems is driven from two different perspectives. First, it is driven by the engineering aspects of generating application oriented devices like household, care-giving or security and rescue systems. Second, artificial autonomous systems offer new ways to investigate and constructively understand natural cognition.

320611 – Autonomous Systems Lab

Short Name: AutSysLab
Type: Lab
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: 320521

Course contents This lab course is to be taken together with the Autonomous Systems course. It provides hands-on experiences, a.o., with the robotics equipment of the Jacobs Robotics group.

320541 – Computational Semantics of Natural Language

Short Name: CompSem
Type: Lecture
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: 320211, 320331
Corequisites: None

Course contents In this course we will cover the logical and linguistic foundation of syntactical and semantic modeling of natural language in computational linguistics (the study of natural languages from a computational perspective). We will proceed by the "method of fragments", where fragments of natural language are studied on a syntactic level (grammar and lexicon), the semantic level (transforming syntactic structures into logical forms), and a pragmatic level (inferring material that is not explicitly realized linguistically).

We will build up a sequence of fragments of increasing coverage (covering selected salient features of language) and discuss the linguistic and logical phenomena involved in detail.

The course will be accompanied by a hands-on programming lab, where the topics of the course will be implemented in the programming language PROLOG.

320591 – Computational Semantics of Natural Language Lab

Short Name: CompSemLab
Type: Lab
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: 320541

Course contents This lab course is to be taken together with the Computational Semantics of Natural Language course and provides hands-on programming exercises where selected topics of the course will be implemented in the programming language PROLOG.

320551 – Algorithmical and Statistical Modelling

Short Name: AlgMod
Type: Lecture
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: 120102 or 120112
Corequisites: None

Course contents Today's complex information processing systems often rest on a formal model of their target domain. Examples: (i) representing an estimate of a robot's position in the presence of noisy sensing, (ii) representing a human expert's vague knowledge about his domain of expertise, and answering queries from it, (iii) modelling a nationwide power distribution system for purposes of fault detection and optimal control. In this course, a choice of formal methods will be presented that enable a computer scientist to extract essential characteristics from a real-world system and construct a formal model that is accessible to an algorithmic treatment within information processing systems. Real-world modelling is an inherently probabilistic task: there is never enough data available to completely know the real system's state or laws – the gap must be filled by ingenious guessing, that is, statistics. Therefore, the emphasis in this course lies on statistical modelling and other methods that allow one to cope with uncertainty. A choice from the following techniques will be covered: (i) sampling methods and representations of probability distributions, (ii) Bayesian networks and graphical models, with exact, Monte Carlo, and/or variational inference techniques, (iii) input-output models used in agent modelling and control (POMDP's, input-output-OOMs), (iv) fuzzy logic. A self-sustained set of lecture notes will be provided.

320572 – Algorithmical and Statistical Modelling Lab

Short Name: AlgModLab
Type: Lab
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: 320551

Course contents This lab course is to be taken together with the Algorithmical and Statistical Modelling course and provides hands-on exercises of selected topics of the course.

320571 – Advanced Distributed Systems

Short Name: AdvDS
Type: Lecture
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: 320312
Corequisites: None

Course contents This course covers new approaches to create and manage robust and secure distributed systems. Some topics covered are:

- Peer-to-peer architectures and distributed lookup functions
- Operation and management of distributed systems (policies, virtualization, event correlation and root cause analysis, redundancy and failover techniques)
- Security aspects (authentication, privacy, key creation and distribution protocols, firewalls, access control models, trust in distributed systems)
- Self-organizing and autonomic distributed systems

This course assumes that students are familiar with fundamental distributed systems concepts usually covered in undergraduate courses on distributed systems. The course will be accompanied by a hands-on programming lab where selected topics of the course will be implemented and tested.

320602 – Advanced Distributed Systems Lab

Short Name: AdvDSLab
Type: Lab
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: 320571

Course contents This lab course is to be taken together with the Advanced Distributed Systems course and provides hands-on programming exercises where selected algorithms and mechanisms introduced in the Advanced Distributed Systems course will be implemented.

320581 – Advanced Visualization

Short Name: AdvViz
Type: Course
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: None

Course contents Scientific visualization deals with the visualization of data with a natural spatial interpretation such as computer-generated data from numerical simulations (physics, chemistry) or measured data using scanning or sensor techniques (medicine, life sciences, geosciences). Volume visualization methods such as segmentation, surface extraction, and direct volume rendering for structured and unstructured gridded as well as scattered data are being taught. These include techniques for scalar field, vector field, and tensor field visualization.

Information visualization deals with the visualization of abstract data with no spatial interpretation such as graph- or network-based data (life sciences, social sciences, computer networks) or multi-dimensional data (economics, databases). Methods that tackle these visualization problems are being taught.

The course deepens, broadens, and enhances the knowledge in visualization obtained from the undergraduate course on ”Graphics and Visualization” in terms of visualization methods.

320621 – Advanced Visualization Lab

Short Name: AdvVisLab
Type: Lab
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: 320581

Course contents This lab course is to be taken together with the Advanced Visualization course and provides hands-on exercises of selected topics of the course.

320651 – Advanced Automation and Control

Short Name: AdvAC
Type: Course
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: None

Course contents Automation and control are pervasively enabling technologies which are found in almost any modern technical system, in particular in processing, production and transportation systems. Process automation and robots are key components in modern factories.

This course provides an introduction to control systems from a computer science perspective. Application of feedback analysis and design ranges from mechanical, thermal, and electrical to fluid systems, including classical control theory in the frequency and time domains.

Besides coverings methods for system modeling and simulation, the course covers digital control and microprocessor systems, industrial robots and advanced mechatronic technology for product design.

The course deepens, broadens, and enhances the knowledge from the undergraduate course on ”Robotics”.

320661 – Advanced Automation and Control Lab

Short Name: AdvACLab
Type: Lab
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: 320xxx

Course contents This lab course is to be taken together with the Advanced Automation and Control course and provides hands-on exercises of selected topics of the course.

320671 – Machine Vision

Short Name: AdvMV
Type: Course
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: None

Course contents This course discusses introduces and discusses recent computer vision algorithms. Most of these algortihms developed are proven theoretically sound, presumably with a specific application in mind, but its practical applications and the detailed steps, methodology, and trade-off analysis required to achieve its real-time performance are never fully explored. This course focuses on applications of computer vision methods.

The real-time aspect is critical in many real-world devices or products such as mobile phones, digital still/video/cell-phone cameras, portable media players, personal digital assistants, high-definition television, video surveillance systems, industrial visual inspection systems, medical imaging devices, vision-assisted intelligent robots, spectral imaging systems, and many other embedded image or video processing systems.

320681 – Machine Vision Lab

Short Name: AdvMVLab
Type: Lab
Semester: 1st or 3rd
Credit Points: 5
Prerequisites: None
Corequisites: 320671

Course contents This lab course is to be taken together with the Machine Vision course and provides hands-on exercises of selected topics of the course.

4.2 Graduate Seminars

The purpose of seminars and projects is to drill down on particular topics of interest in the research areas and introduce the students to the state of the art. In the projects, each student will work out and present an assigned topic from research papers or from original research on the topic.

The topics of the seminars will vary over time in response to changing interests of the Smart Systems faculty and the expanding research frontier; the descriptions below should be read as examples of what might be covered and not as fixed seminar syllabi. For administrative reasons, the seminars have two course numbers that alternate year by year.

320422/320522 – Networks and Distributed Systems A/B

Short Name: SemNetDisSys
Type: Seminar
Semester: 2nd
Credit Points: 5
Prerequisites: 320471 or 320571
Corequisites: None

Course contents This seminar covers selected topics related to networks and distributed systems. Special attention will be given to topics related to self-organization and security and trust management aspects of distributed systems. Students will be required to give an oral presentation.

320424/320524 – Networks and Distributed Systems Project A/B

Short Name: ProjNetDisSys
Type: Project
Semester: 2nd
Credit Points: 10
Prerequisites: None
Corequisites: 320422 or 320522

Course contents This project course is to be taken together with the Networks and Distributed Systems seminar. Students will be required to complete a (guided) research project.

320432/320532 – Semantic Web and Knowledge Representation A/B

Short Name: SemKnowWeb
Type: Seminar
Semester: 2nd
Credit Points: 5
Prerequisites: 320441
Corequisites: None

Course contents This seminar will cover selected topics in computational logic, logic-based artificial intelligence and the semantic web technologies. Our special interest will be in inference processes and knowledge representation. Students will be required to give an oral presentation.

320434/320534 – Semantic Web and Knowledge Representation Project A/B

Short Name: ProjSemKnowWeb
Type: Project
Semester: 2nd
Credit Points: 10
Prerequisites: None
Corequisites: 320432 or 320532

Course contents This project course is to be taken together with the Semantic Web and Knowledge Representation seminar. Students will be required to complete a (guided) research project.

320442/320542 – Machine Learning A/B

Short Name:	SemML
Type:	Seminar
Semester:	2nd
Credit Points:	5
Prerequisites:	None
Corequisites:	None

Course contents The machine learning seminars will concentrate each on one theme connected to the ongoing research of Prof. Jaeger, who will choose the topic he finds most fascinating at the time when the seminar takes place. The topics might be only indirectly related to machine learning proper. At the time of writing, the following themes would qualify and can serve as examples: (i) motor control with neural networks, (ii) biological motor control, (iii) optimal decision making under uncertainty, (iv) learning algorithms for stochastic systems, (v) nonlinear system modelling: industrial applications, (vi) analyzing brain signals, (vii) the challenge of complexity: what mathematics still can't capture.

320444/320544 – Machine Learning Project A/B

Short Name:	ProjML
Type:	Project
Semester:	2nd
Credit Points:	10
Prerequisites:	None
Corequisites:	320442 or 320542

Course contents This project course is to be taken together with the Machine Learning seminar. Students will be required to complete a (guided) research project.

320452/320552 – Web Information Systems A/B

Short Name:	SemWebInfSys
Type:	Seminar
Semester:	2nd
Credit Points:	5
Prerequisites:	320302
Corequisites:	None

Course contents This seminar addresses trends and issues in database and Web technology, focusing on the field of raster databases. Choice of topics will be streamlined with ongoing research in the field, leading students to the forefront of technology. Among the areas likely to be investigated are: study of applications in geo sciences, life science, and supercomputing / Grid computing; conceptual modelling issues; query and storage optimization techniques; benchmarking raster databases.

Goal is to lead students to the frontiers of technology and confront them with active research by stimulating active discussion gradually involving them into ongoing research (e.g., in project collaborations).

320454/320554 – Web Information Systems Project A/B

Short Name: Projwebinfsys
Type: Project
Semester: 2nd
Credit Points: 10
Prerequisites: None
Corequisites: 320452 or 320552

Course contents This project course is to be taken together with the Web Information Systems seminar. Students will be required to complete a (guided) research project.

320482/320582 – Topics in Robotics A/B

Short Name: SemTopRob
Type: Seminar
Semester: 2nd
Credit Points: 5
Prerequisites: None
Corequisites: None

Course contents The seminar covers a selected area of robotics in a significant depth. The area differs each year and is typically based on a newly emerging, highly promising sub-field of robotics. The seminar uses a reader of selected literature from this area, which is distributed at the beginning of the course. Each participant is required to read in the order of two to three related journal articles and a Ph.D. thesis, and to make at least one presentation based on the reading material.

320484/320584 – Topics in Robotics Project A/B

Short Name: ProjTopRob
Type: Project
Semester: 2nd
Credit Points: 10
Prerequisites: None
Corequisites: 320422 or 320522

Course contents This project course is to be taken together with the Topics in Robotics seminar. Students will be required to complete a (guided) research project.

320492 – Topics in Graphics

Short Name: SemGrafx
Type: Seminar
Semester: 2nd
Credit Points: 5
Prerequisites: 320491
Corequisites: None

Course contents The seminar covers selected topics of 3D computer graphics. Computer graphics deals with the digital synthesis and manipulation of visual content, typically embedded in a three-dimensional scene. Prominent tasks in computer graphics are geometry processing, rendering, and animation. Geometry processing is concerned with object representations such as surfaces and their modeling, rendering is concerned with simulating light transport to get physically-based photorealistic images of 3D scenes or applying a certain style to create non-photorealistic images, and animation is concerned with descriptions for objects that move or deform over time. The content includes state-of-the-art and newly emerging approaches to geometry processing, rendering and animation.

320494 – Topics in Graphics Project

Short Name: ProjGrafx
Type: Project
Semester: 2nd
Credit Points: 10
Prerequisites: None
Corequisites: 320492

Course contents This project course is to be taken together with the Topics in Graphics seminar. Students will be required to complete a (guided) research project.

320562 – Topics in Visualization

Short Name: SemViz
Type: Seminar
Semester: 2nd
Credit Points: 5
Prerequisites: 320581
Corequisites: None

Course contents The seminar covers selected topics of visualization. Scientific visualization deals with the visualization of data with a natural spatial interpretation such as computer-generated data from numerical simulations (physics, chemistry) or measured data using scanning or sensor techniques (medicine, life sciences, geosciences). Volume visualization methods such as segmentation, surface extraction, and direct volume rendering for structured and unstructured gridded as well as scattered data are being taught. These include techniques for scalar field, vector field, and tensor field visualization. Information visualization deals with the visualization of abstract data with no spatial interpretation such as graph- or network-based data (life sciences, social sciences, computer networks) or multi-dimensional data (economics, databases). Methods that tackle these visualization problems are being taught. The content includes state-of-the-art and newly emerging approaches to scientific and information visualization.

320564 – Topics in Visualization Project

Short Name: ProjViz
Type: Project
Semester: 2nd
Credit Points: 10
Prerequisites: None
Corequisites: 320562

Course contents This project course is to be taken together with the Topics in Visualization seminar. Students will be required to complete a (guided) research project.

320592 – Topics in Automation

Short Name: SemAuto
Type: Seminar
Semester: 2nd
Credit Points: 5
Prerequisites: None
Corequisites: None

Course contents The seminar covers a selected area of automation in a signifcant depth. The area differs each year and is typically based on current developments in the field. The seminar uses a reader of selected literature from world class journal and conference papers, which is distributed at the beginning of the course. Each participant is required to make at least two presentations based on the reading material.

320594 – Topics in Automation Project

Short Name: ProjAuto
Type: Project
Semester: 2nd
Credit Points: 10
Prerequisites: None
Corequisites: 302592

Course contents This project course is to be taken together with the Topics in Automation seminar. Students will be required to complete a (guided) research project.

320672 – Topics in Machine Vision

Short Name: SemVision
Type: Seminar
Semester: 2nd
Credit Points: 5
Prerequisites: None
Corequisites: None

Course contents The seminar covers selected topics of machine vision research, and development. The seminar focuses on applications and engineering aspects of image-related computing. The following aspects of machine vision applications are of interest: algorithms, architectures, VLSI implementations, AI techniques and expert systems for machine vision, front-end sensing, multidimensional and multisensor machine vision, real-time techniques, image databases, virtual reality and visualization.

Each participant is required to make at least two presentations based on the reading material.

320674 – Topics in Machine Vision

Short Name: ProjVision
Type: Project
Semester: 2nd
Credit Points: 10
Prerequisites: None
Corequisites: 320672

Course contents This project course is to be taken together with the Topics in Machine Vision seminar. Students will be required to complete a (guided) research project.

4.3 Master Thesis

In their third semester students elaborate a Master Thesis proposal, based on which they prepare their Master Thesis during the fourth semester.

320501 – Master Thesis Proposal

Short Name: MThProp
Type:
Semester: 3rd
Credit Points: 20
Prerequisites: None
Corequisites: None

Course contents The work out of a master/doctorate thesis proposal is done by graduate students after sucessfully finishing their first year of studies. The preparation of the proposal is carries out in collaboration with the according academic supervisor. The proposal (target size 20 pages) must

- demonstrate that the student masters the professional terminology in the research domain and has the requisite background knowledge,
- identify and motivate a relevant and feasible research question,
- connect the question to the state of the art by a focussed and illustrative literature overview,
- lay out a design for planned experiments, theoretical investigations or implementations, including a schedule,
- and describe criteria for evaluating the eventual success of the project.