



School of Engineering and Science

## Smart Systems

Graduate Program

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# 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 post-doctoral 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, and Databases and Web Information Technology*.

## **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 as well as their own projects. 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 Courses	$3 \cdot 9 = 27$	27	27
1	EECS Seminar	2	29	29
2	3 Graduate Seminars	$3 \cdot 9 = 27$	27	56
2	EECS Seminar	2	29	58
3	2 Graduate Courses	$2 \cdot 9 = 18$	18	76
3	EECS Seminar	2	20	78
3	Master Thesis Proposal	12	32	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 courses in all research areas of the graduate program. They introduce the topics and cover pertinent results and methods of the respective field. These courses 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.

The Spring semesters (usually semesters 2 and 4) are dedicated to research seminars, which are attended by M.Sc. and Ph.D. students. These seminars drill down on particular topics of interest in the research areas and introduce the students to the state of the art. Each student will work out and present an assigned topic from research papers (M.Sc. students) or from original research on the topic (Ph.D. students).

In their first semester Masters students will need to acquire 27 credits from the core Smart Systems curriculum detailed in Figure 1. 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. Furthermore, the student needs to acquire 2 credits from attending the EECS seminar. Altogether a minimum of 29 credits must be accomplished.

In the second semester, Master students will take part in three of the research seminars, carrying out guided research projects there. This yields the required 27 credits from this category, to

which 2 credits from the mandatory participation in the EECS seminar are added.

In the third semester, the student takes additional courses from the Smart Systems core curriculum to supplement the knowledge gained in the first two semesters. The student must reach 18 credits from these courses. In parallel to the core Smart Systems courses, 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 towards the eventual thesis topic. A research proposal with a passing grade gives 12 credits. Additional 2 credits are obtained by attending the EECS seminar.

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).

In the four semesters, the student is required to obtain 6 credits participating to the EECS seminar, the colloquium series for Electrical Engineering and Computer Science at Jacobs University. This will give the student an overview over current research topics and the work of the Smart Systems faculty and enable him/her to choose a research topic. Participation in the EECS seminar is awarded with two credits per semester.

#	Credits	Type	Title
300431	2	Seminar	EECS Seminar I
300432	2	Seminar	EECS Seminar II
300531	2	Seminar	EECS Seminar III
300541	2	Seminar	EECS Seminar IV
320501	12	Thesis	Master/Doctorate Thesis Proposal
3205xx	12	Thesis	Master/Doctorate Thesis

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:
  - 45 credits from Smart Systems courses. Undergraduate courses or courses from other graduate programs can be taken upon approval of the program coordinator
  - 27 credits from Smart Systems seminars
  - 12 credits from the master thesis proposal
  - 30 credits from the master thesis

- 6 credits from participation in the EECS seminar
- 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 courses and seminars 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). 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 courses modules that are offered on a regular basis in the program.

These courses (and accompanying labs) 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, 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.



#	Credits	Type	Title	Responsible
320411	5	Course	Information Architectures	P. Baumann
320622	4	Lab	Information Architectures Lab	P. Baumann
320421	5	Course	Advanced Robotics	A. Birk
3204yy	4	Lab	Advanced Robotics Lab	A. Birk
320541	5	Course	Computational Semantics of Nat. Lang.	M. Kohlhase
320591	4	Lab	Computational Semantics of NL Lab	M. Kohlhase
320451	9	Course	Advanced Machine Learning	H. Jaeger
320471	5	Lecture	Advanced Networking	J. Schönwälder
320401	4	Lab	Advanced Networking Lab	J. Schönwälder
320491	9	Course	Advanced Graphics	L. Linsen
320511	9	Course	Semantic Web Engineering	P. Baumann
320521	5	Course	Autonomous Systems	A. Birk
320611	4	Lab	Autonomous Systems Lab	A. Birk
320441	5	Course	Computational Logic	M. Kohlhase
320612	4	Lab	Computational Logic Lab	M. Kohlhase
320551	9	Course	Algorithmical Modelling	H. Jaeger
320571	5	Lecture	Advanced Distributed Systems	J. Schönwälder
320602	4	Lab	Advanced Distributed Systems Lab	J. Schönwälder
320581	9	Course	Advanced Visualization	L. Linsen

Figure 3: The courses 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,
- 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

#	Credits	Type	Title	Responsible
320422/320522	9	Seminar	Networks and Distributed Systems A/B	A. Birk
320432/320532	9	Seminar	Semantic Web and Knowledge Representation A/B	M. Kohlhase
320442/320542	9	Seminar	Machine Learning A/B	H. Jaeger
320452/320552	9	Seminar	Web Information Systems A/B	P. Baumann
320472/320572	9	Seminar	Topics in Algorithms A/B	A. Birk
320482/320582	9	Seminar	Topics in Robotics A/B	A. Birk
320492	9	Seminar	Topics in Graphics	L. Linsen
320562	9	Seminar	Topics in Visualization	L. Linsen

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

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

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 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:* 9  
*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:* 4  
*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.

### **3204yy – Advanced Robotics Lab**

*Short Name:* AdvRobLab  
*Type:* Lab  
*Semester:* 1st or 3rd  
*Credit Points:* 4  
*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:* 4  
*Prerequisites:* [320211](#), [320331](#)  
*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:* 9  
*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.

## 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 extent 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:* 4  
*Prerequisites:* [320301](#)  
*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:* 9  
*Prerequisites:* [320322](#)  
*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.

## 320511 – Semantic Web Engineering

*Short Name:* SemWebEng  
*Type:* Lecture  
*Semester:* 1st or 3rd  
*Credit Points:* 9  
*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](http://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 Grid and geo services.

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 or, alternatively, have a sound knowledge base to specialize towards a scientific career in the field.

## **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:* 4  
*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:* 9  
*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:* 4  
*Prerequisites:* [320211](#), [320331](#)  
*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:* 9  
*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.

### **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:* 4  
*Prerequisites:* [320312](#)  
*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:* 9  
*Prerequisites:* [320322](#)  
*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.

## 4.2 Graduate Seminars

The purpose of seminars, which are attended by Master and Ph.D. students, is to drill down on particular topics of interest in the research areas and introduce the students to the state of the art. Each student will work out and present an assigned topic from research papers (Master students) or from original research on the topic (Ph.D. students).

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:* 9  
*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 and to complete a (guided) research project.

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

*Short Name:* SemKnowWeb  
*Type:* Seminar  
*Semester:* 2nd  
*Credit Points:* 9  
*Prerequisites:* 320441 or 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 and complete a (guided) research project.

### **320442/320542 – Machine Learning A/B**

*Short Name:* SemML  
*Type:* Seminar  
*Semester:* 2nd  
*Credit Points:* 9  
*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.

### **320452/320552 – Web Information Systems A/B**

*Short Name:* SemWebInfSys  
*Type:* Seminar  
*Semester:* 2nd  
*Credit Points:* 9  
*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).

### **320472/320572 – Topics in Algorithms A/B**

*Short Name:* SemAlg  
*Type:* Seminar  
*Semester:* 2nd  
*Credit Points:* 9  
*Prerequisites:*  
*Corequisites:* None

**Course contents** In the algorithms seminar students will have to study and present one or more assigned papers, and to develop a related project. Preference will be given to applied rather than theoretical topics, from areas like computational geometry, motion planning, and computational robotics.

### **320482/320582 – Topics in Robotics A/B**

*Short Name:* SemTopRob  
*Type:* Seminar  
*Semester:* 2nd  
*Credit Points:* 9  
*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, to make at least one presentation based on the reading material, and to engage in a small project.

### **320492 – Topics in Graphics**

*Short Name:* SemGrafX  
*Type:* Seminar  
*Semester:* 2nd  
*Credit Points:* 9  
*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.

## 320562 – Topics in Visualization

*Short Name:* SemViz  
*Type:* Seminar  
*Semester:* 2nd  
*Credit Points:* 9  
*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.

### 4.3 EECS Seminar

The EECS seminar is a lecture series on Electrical Engineering and Computer Science. Lectures are given by faculty from the interdisciplinary research area “*Information and Communication Science and Technologies*”, their research collaborators from all over the world, and by selected graduate students from the “Smart Systems” and Electrical Engineering graduate programs. This colloquium gives students a unique opportunity to gain an insight into current research topics, and establish discussion contacts with external researchers.

### **300431 – EECS Seminar I**

*Short Name:* EECSSem  
*Type:* Seminar  
*Semester:* 1st  
*Credit Points:* None  
*Prerequisites:* None  
*Corequisites:* None

**Course contents** This is the Fall series of the EECS seminar.

### **300432 – EECS Seminar II**

*Short Name:* EECSSem  
*Type:* Seminar  
*Semester:* 2nd  
*Credit Points:* None  
*Prerequisites:* None  
*Corequisites:* None

**Course contents** This is the Spring series of the EECS seminar.

### **300531 – EECS Seminar III**

*Short Name:* EECSSem  
*Type:* Seminar  
*Semester:* 3rd  
*Credit Points:* None  
*Prerequisites:* None  
*Corequisites:* None

**Course contents** This is the Fall series of the EECS seminar.

### **300541 – EECS Seminar IV**

*Short Name:* EECSSem  
*Type:* Seminar  
*Semester:* 4th  
*Credit Points:* None  
*Prerequisites:* None  
*Corequisites:* None



**Course contents** This is the Spring series of the EECS seminar.

## 4.4 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:* 12

*Prerequisites:* None

*Corequisites:* None

**Course contents** The work out of a master/doctorate thesis proposal is done by graduate students after successfully finishing their first year of studies. The preparation of the proposal is carried out in collaboration with the according academic supervisor. The 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,
- 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.

### 3205xx – Master Thesis

*Short Name:* MThProp

*Type:*

*Semester:* 4th

*Credit Points:* 12

*Prerequisites:* 320501

*Corequisites:* None

**Course contents** 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).

